April 2018
Rock Island Hydroelectric Project FERC License No. 943

ANCHOR QEA

Annual Report Calendar Year 2017 Activities Under the Anadromous Fish Agreement and Habitat Conservation Plan

Prepared for Federal Energy Regulatory Commission

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TABLE OF CONTENTS

1 Introduction 1

2 Progress Toward Meeting No Net Impact 2

2.1 Project Survival and Dam Operations 7

2.1.1 Status of Phase Designations for Current Plan Species 7

2.1.2 Assessment of Project Survival 9

2.1.3 Project Operations and Improvements 11

2.2 Hatchery Compensation 16

2.2.1 Hatchery Production Summary 17

2.2.2 Hatchery Planning and Implementation 18

2.2.3 Maintenance and Improvements 28

2.3 Tributary Committees and Plan Species Accounts 28

2.3.1 Regional Coordination 29

2.3.2 Fiscal Management of Plan Species Accounts 30

2.3.3 General Salmon Habitat Program 31

2.3.4 Small Projects Program 33

2.3.5 Tributary Assessment Program 34

3 Habitat Conservation Plan Administration 36

3.1 Mid-Columbia Habitat Conservation Plan Forums 36

3.2 Habitat Conservation Plan Related Reports and Miscellaneous Documents Published in Calendar Year 2017 36

TABLES

Table 1 Rock Island Habitat Conservation Plan No Net Impact Progress for Plan Species (2017) 3

Table 2 Summary of 2017 Decisions for Rock Island Habitat Conservation Plan 3

Table 3 Phase Designations for Rock Island Habitat Conservation Plan Under Conditions of 10% Spill 7

Table 4 Habitat Conservation Plan Juvenile, Adult, and Combined Survival Rates at Rock Island and Rocky Reach 10

Table 5 2017 Production Level Objectives and Smolt Releases for Rock Island Habitat Conservation Plan Hatchery Programs 17

Table 6 General Salmon Habitat Program Projects Reviewed by the Habitat Conservation Plan Tributary Committees in 2017 32

Table 7 Projects Reviewed by the Habitat Conservation Plan Tributary Committees under the Small Projects Program in 2017 33

APPENDICES

Appendix A Habitat Conservation Plan Coordinating Committees 2017 Meeting Minutes and Conference Call Minutes

Appendix B Habitat Conservation Plan Hatchery Committees 2017 Meeting Minutes and Conference Call Minutes

Appendix C Habitat Conservation Plan Tributary Committees 2017 Meeting Minutes

Appendix D List of Rock Island Habitat Conservation Plan Committees Members

Appendix E Statements of Agreement for Habitat Conservation Plan Coordinating Committees

Appendix F Statements of Agreement for Habitat Conservation Plan Hatchery Committees

Appendix G 2016 Rock Island Dam Smolt Monitoring Program and Gas Bubble Trauma Evaluation Final Report

Appendix H 2016 Northern Pikeminnow Predator Control Program Rocky Reach and Rock Island Hydroelectric Projects Final Summary Report

Appendix I Rock Island Dam Smolt Monitoring and Gas Bubble Trauma Evaluation Plan 2017

Appendix J 2017 Wenatchee Steelhead Release Plan (Brood Year 2016)

Appendix K 2017 Fish Spill Plan Rock Island and Rocky Reach Dams

Appendix L 2017 Rock Island and Rocky Reach HCP Action Plan

Appendix M Draft Upper Columbia River 2017 BY Salmon and 2018 BY Steelhead Hatchery Program Management Plan and Associated Protocols for Broodstock Collection, Rearing/Release, and Management of Adult Returns

Appendix N Chelan County PUD Hatchery Monitoring and Evaluation Implementation Plan 2018

Appendix O Chelan PUD Rocky Reach and Rock Island HCPs Final 2017 Fish Spill Report

Appendix P Monitoring and Evaluation Plan for PUD Hatchery Programs – 2017 Update

Appendix Q Monitoring and Evaluation of the Chelan and Grant County PUDs Hatchery Programs: 2016 Annual Report

Appendix R Rock Island Hydro Project Habitat Conservation Plan 2017 Annual Financial Report, Plan Species Account

ABBREVIATIONS

BiOp	Biological Opinion
BY	brood year
CCFEG	Cascade Columbia Fisheries Enhancement Group
CCNRD	Chelan County Natural Resources Department
CCT	Colville Confederated Tribes
CDLT	Chelan-Douglas Land Trust
cfs	cubic feet per second
Chelan PUD	Public Utility District No. 1 of Chelan County
ESA	Endangered Species Act
FERC	Federal Energy Regulatory Commission
GSHP	General Salmon Habitat Program
HCP	Habitat Conservation Plan
HETT	Hatchery Evaluation Technical Team
HxH	hatchery-by-hatchery
HxW	hatchery-by-wild
kcfs	thousand cubic feet per second
M&E	monitoring and evaluation
MSRF	Methow Salmon Recovery Foundation
NMFS	National Marine Fisheries Service
NNI	No Net Impact
OLAFT	off-ladder adult fish trap
ONA	Okanagan Nation Alliance
pHOS	Percent Hatchery-Origin Spawners
PIT	passive integrated transponder
Plan Species	species addressed in the HCP
PNI	Proportionate Natural Influence
PRCC	Priest Rapids Coordinating Committee
RI	Rock Island Plan Species Account
RIJSF	Rock Island Dam Juvenile Sampling Facility
RM	river mile
RR	Rocky Reach Plan Species Account
RRS	relative reproductive success
SOA	statement of agreement
SRFB	Salmon Recovery Funding Board
TMDL	Total Maximum Daily Load
TU-WWP	Trout Unlimited – Washington Water Project

UCR	Upper Columbia River
UCSRB	Upper Columbia Salmon Recovery Board
USDA	U.S. Department of Agriculture
USFWS	U.S. Fish and Wildlife Service
W	Wells Plan Species Account
WxW	wild-by-wild
YN	Yakama Nation

1 Introduction

On June 21, 2004, the Federal Energy Regulatory Commission (FERC) approved an Anadromous Fish Agreement and Habitat Conservation Plan (HCP) for the Rock Island Hydroelectric Project (Rock Island – FERC License No. 943) on the Columbia River in Washington State, operated by Public Utility District No. 1 of Chelan County (Chelan PUD). The HCP provides a comprehensive and long-term adaptive management plan for meeting a No Net Impact (NNI) goal for species addressed in the plan (Plan Species) and their habitats. This document fulfills Article 413(a) of the FERC Project license issued on January 1, 1989[1], and Section 4.8 of the HCP, which requires annual reporting of progress toward achieving the NNI goal. Responsibilities toward achieving the NNI goal are described in Section 3 of the HCP and in a 10-year Comprehensive Report assessing overall status of NNI, as well as successive 10-year intervals, in common understandings based upon completed studies, including those conducted as research and development for NNI progress or those not considered valid due to extenuating circumstances (Section 5.2.3 of the HCP).

The signatories of the Mid-Columbia HCPs (HCPs of the Wells, Rocky Reach, and Rock Island hydroelectric projects) meet as combined Coordinating Committees, Hatchery Committees, and Tributary Committees to expedite the process of overseeing and guiding HCP implementation. Minutes from the 2017 monthly meetings are compiled in Appendix A (HCP Coordinating Committees), Appendix B (HCP Hatchery Committees), and Appendix C (HCP Tributary Committees). The HCP Policy Committees provide a forum for resolution of disputes that are either elevated to or arise in the HCP Coordinating Committees and remain unresolved. The HCP Policy Committees did not meet in 2017 because no issues were discussed requiring dispute resolution. Therefore, there are no HCP Policy Committees meeting minutes to append to this annual report. Appendix D lists members of the Rock Island HCP Committees. The Rock Island HCP Coordinating Committee oversaw the preparation of this 14th Annual Report, which covers the period from January 1 to December 31, 2017. (The 1st through 13th Annual Reports covered the periods January 1 to December 31, 2004, through 2016, respectively.)

[1] 46 FERC, paragraph 61,033 (1989)

2 Progress Toward Meeting No Net Impact

The Rock Island HCP requires preparation of an Annual Report that describes progress toward achieving the performance standard of NNI for each Plan Species. The NNI standard consists of two components: 1) 91% combined adult and juvenile project survival, as achieved by project improvement measures implemented within the geographic area of the project; and 2) up to 9% compensation for unavoidable project mortality provided through hatchery and tributary programs, with up to 7% compensation provided through hatchery programs and 2% through tributary programs (Section 3.1 of the HCP).

In 2017, Chelan PUD has met or exceeded all requirements for NNI under the Rock Island HCP for spring migrant HCP Plan Species (spring Chinook salmon [*Oncorhynchus tshawytscha*], steelhead [*O. mykiss*], and sockeye salmon [*O. nerka*]). Since 2010, and including 2017, project survival standards have been exceeded for steelhead, yearling Chinook salmon, and sockeye salmon; all of which are currently designated Phase III (Standards Achieved). As of 2017, coho salmon (*O. kisutch*) are also now classified as Phase III (Standards Achieved) under the Rock Island HCP (see Section 2.1.1). Discussions about hatchery compensation needed to meet Chelan PUD's NNI mitigation requirement for coho salmon began within the HCP Hatchery Committees in 2017, and is expected to be finalized in 2018 (see Section 2.2.2.15). For subyearling summer/fall Chinook salmon (a summer migrant and non-Endangered Species Act [ESA]-listed Plan Species), considerable life-history variability and limited technology constrain the ability to estimate project survival (see Section 2.1.1). As a result, subyearling summer Chinook salmon are designated as Phase III (Additional Juvenile Studies[2]) and will continue to be compensated through the Tributary Conservation and Hatchery Compensation Plans at levels consistent with the HCP. As established in Section 3.1 of the HCP, the inability to estimate survival due to limitations of technology shall not be construed as a success or a failure to achieve NNI.

Recalculated NNI production levels for all Plan Species were agreed upon in 2011 within the HCP Hatchery Committees, and implementation began with the 2014 release year and will continue for the next 10 years (release years 2014 through 2023). Chelan PUD funded the Tributary Conservation Plan at the level established in the HCP ($485,200 in 1998 dollars) and will continue to do so for the duration of the HCP (see Section 2.3; Table 1 [below]).

[2] The current phase designation will be re-evaluated in 2019.

Table 1
Rock Island Habitat Conservation Plan No Net Impact Progress for Plan Species (2017)

HCP Plan Species (ESA Status)	Survival Standard Met	Hatchery Compensation Provided	Tributary Conservation Plan Funded	NNI
Spring Chinook Salmon Yearlings (ESA-listed)	Yes – Combined Adult and Juvenile	Yes	Yes	Yes
Steelhead (ESA-listed)	Yes – Combined Adult and Juvenile	Yes	Yes	Yes
Sockeye Salmon (Not Listed)	Yes – Combined Adult and Juvenile	Yes	Yes	Yes
Summer/Fall Chinook Salmon (Not Listed)	Phase III (Additional Studies)	Yes	Yes	Yes – NNI compensation provided, but additional studies required
Coho Salmon (Not Listed)	Phase III (Standards Achieved)	Yes	Yes	Yes

Throughout 2017, the HCP Coordinating, Hatchery, and Tributary Committees reached agreement on numerous issues during meetings in support of achieving the NNI goals, all of which were documented in the meeting minutes or were described in stand-alone statements of agreement (SOAs). These agreements, along with approvals for funding of habitat projects by the Rock Island HCP Tributary Committee, are summarized in Table 2 and discussed in the remainder of this report.

Table 2
Summary of 2017 Decisions for Rock Island Habitat Conservation Plan

Date	Agreement	HCP Committee	Reference
January 24, 2017	Agreed to a 10-day review period (initiated when the revised SOA is distributed) and a vote via email on the revised draft SOA titled, Acknowledgement of Rock Island Powerhouse 1 Units B1-B4 Consultation	Coordinating	Appendix A
January 24, 2017	Agreed Chelan PUD does not need to provide an annual fish passage plan for HCP Coordinating Committees review (the plan will be removed from the annual Rock Island and Rocky Reach HCP Action Plan)	Coordinating	Appendix A

Date	Agreement	HCP Committee	Reference
January 27, 2017	Approved a Douglas PUD, Chelan PUD, and WDFW request for gametes from four female and four male Twisp River hatchery-origin steelhead that WDFW will collect at the Twisp Weir in 2017 for use in pilot studies on egg-to-fry survival, as follows: Douglas PUD, Chelan PUD, WDFW, USFWS, the YN, and the CCT approved on January 18; and NMFS approved via email on January 27, 2017	Hatchery	Appendix B
February 3, 2017	Approved via email the Chelan PUD SOA titled, Acknowledgement of Rock Island Powerhouse 1 Units B1-B4 Consultation, as follows: Chelan PUD approved on January 24; the CCT approved on January 25; NMFS and USFWS approved on January 26; WDFW approved on February 1; and the YN approved on February 3, 2017	Coordinating	Appendix A and Appendix E
February 15, 2017	Approved the hatchery portion of the 2017 Rock Island and Rocky Reach HCP Action Plan	Hatchery	Appendix B
February 22, 2017	Approved the 2016 Rock Island Smolt Monitoring Program and Gas Bubble Trauma Report, after no disapprovals were received prior to the 30-day review deadline on February 22, 2017	Coordinating	Appendix A and Appendix G
February 22, 2017	Approved the 2016 Rock Island and Rocky Reach Pikeminnow Control Program Summary Report, after no disapprovals were received prior to the 30-day review deadline on February 22, 2017	Coordinating	Appendix A and Appendix H
February 22, 2017	Approved the 2017 Rock Island Bypass Monitoring Plan, after no disapprovals were received prior to the 30-day review deadline on February 22, 2017	Coordinating	Appendix A and Appendix I
March 9, 2017	Approved a time extension request from Trout Unlimited on the Methow Valley Irrigation District Instream Flow Improvement Project, to extend the period of their contract from September 30, 2016 to November 30, 2017	Tributary	Appendix C
March 9, 2017	Approved a budget amendment request from Trout Unlimited on the Beaver Fever: Restoring Ecosystem Function Project, to move $1,997.00 from "Administration/Overhead" to "Salaries and Benefits," $2,294.94 from "Administration/Overhead" to "Professional Services," and $7,028.75 from "Administration/Overhead" to "Project Materials"	Tributary	Appendix C
March 9, 2017	Approved the tributary portion of the 2017 Rock Island and Rocky Reach HCP Action Plan	Tributary	Appendix C
March 13, 2017	Approved the Chelan PUD SOA titled, M&E Reporting Schedule for the Douglas PUD, Grant PUD, and Chelan PUD Hatchery Programs	Hatchery	Appendix B and Appendix F
March 13, 2017	Agreed Chelan PUD and USFWS may perform maturation sampling on 300 Chiwawa spring Chinook salmon	Hatchery	Appendix B

Date	Agreement	HCP Committee	Reference
March 16, 2017	Approved the 2016 Rock Island HCP Annual Report after no disapprovals were received prior to the 30-day review deadline on March 16, 2017	Coordinating	Appendix A
March 16, 2017	Approved the Chelan PUD 2017 Steelhead Release Plan, as follows: Chelan PUD approved on March 13; and USFWS, WDFW, NMFS, the YN, and the CCT approved via email on March 16, 2017	Hatchery	Appendix B and Appendix J
March 24, 2017	Approved the 2017 Rock Island and Rocky Reach Fish Spill Plan, as revised, after no disapprovals were received prior to the 30-day review deadline on March 24, 2017	Coordinating	Appendix A and Appendix K
March 28, 2017	Approved adding Catherine Willard (Chelan PUD) to the HCP Coordinating Committees email distribution list	Coordinating	Appendix A
March 28, 2017	Agreed to vote via email on the Revised Draft 2017 Rock Island and Rocky Reach HCP Action Plan	Coordinating	Appendix A
March 30, 2017	Approved the Rock Island and Rocky Reach Coho Phase Designation SOA, as revised *(Note: Carmen Andonaegui provided WDFW approval of the SOA via email on March 30, 2017)*	Coordinating	Appendix A and Appendix E
April 5, 2017	Approved via email the 2017 Rock Island and Rocky Reach HCP Action Plan, as revised, as follows: Chelan PUD and USFWS approved on March 30; NMFS approved on April 4; and WDFW, the CCT, and the YN approved on April 5, 2017	Coordinating	Appendix A and Appendix L
April 7, 2017	Approved via email the 2017 Broodstock Collection Protocols	Hatchery	Appendix B and Appendix M
April 13, 2017	Approved a time extension request from CCFEG on the White River Floodplain Connection (RM 3.4) Project, to extend the period of the contract from September 30 to December 30, 2017	Tributary	Appendix C
April 13, 2017	Approved a request for funding from CCFEG on the Debry Creek Fish Passage – Collins Project, contributing $65,000 to the project	Tributary	Appendix C
April 19, 2017	Agreed via email to add Alf Haukenes (WDFW Hatchery/Wildlife Interactions Unit leader) to select HCP Hatchery Committees email distribution lists, per a request by Mike Tonseth (WDFW HCP Hatchery Committees Representative), as follows: WDFW, Douglas PUD, NMFS, and USFWS approved on April 17; Chelan PUD and the YN approved on April 18; and the CCT approved on April 19, 2017	Coordinating	Appendix A
April 19, 2017	Approved the Outplanting Adults Plan for Spring Chinook Salmon in the Chewuch River	Hatchery	Appendix B

Date	Agreement	HCP Committee	Reference
June 8, 2017	Approved a budget amendment request from CCFEG on the Permitting Nutrient Enhancement in the Chiwawa River Basin Project, to move $1,028 from "Professional Services" and "Indirect/Admin/Overhead" to "Sponsor Salaries and Benefits"	Tributary	Appendix C
June 8, 2017	Approved via email a time extension request from Trout Unlimited on the Barkley Irrigation Project, to extend the project from May 31, 2017 to December 31, 2018	Tributary	Appendix C
June 27, 2017	Agreed to add Chad Jackson (WDFW) and Mike Tonseth (WDFW) to the HCP Coordinating Committees email distribution lists and provide them both with access to the HCP Coordinating Committees extranet site because Jackson will potentially become the WDFW HCP Coordinating Committees Representative and Tonseth will likely be a new WDFW HCP Coordinating Committees Alternate *(Note: on August 14, 2017, Jackson became the representative and Patrick Verhey remained the alternate; however, Tonseth remained on the email lists and retained extranet access, per a request from WDFW)*	Coordinating	Appendix A
July 13, 2017	Approved a budget amendment request from CCFEG on the White River Floodplain Connection (RM 3.4) Project, to move all available funds in "Excavation and Heavy Equipment" ($5,000) and "Project Materials and Equipment" ($500) to "Salaries and Benefits," "Overhead and Administration," and "Permit Fees"	Tributary	Appendix C
July 13, 2017	Approved a time extension request from CCFEG on the Permitting Nutrient Enhancement in the Chiwawa, to extend the period of the contract from June 30, 2017 to June 30, 2018	Tributary	Appendix C
July 13, 2017	Approved a Small Projects Program application from Chelan County Natural Resources Department titled, Poison Canyon Restoration	Tributary	Appendix C
August 18, 2017	Approved the Chelan PUD 2018 Hatchery M&E Implementation Plan, as follows: Chelan PUD, WDFW, USFWS, the YN, and NMFS approved on August 16; and the CCT approved on August 18, 2017	Hatchery	Appendix B and Appendix N
October 24, 2017	Approved the 2017 Rock Island and Rocky Reach Fish Spill Program Report, with the CCT abstaining	Coordinating	Appendix A and Appendix O
November 15, 2017	Approved the M&E Plan for PUD Hatchery Programs (2017 Update)	Hatchery	Appendix B and Appendix P
November 15, 2017	Approved the Final Chelan PUD SOA, Regarding District's Coho Obligation, as followed: CCT approved on November 14, and Chelan PUD, WDFW, USFWS, the YN, and NMFS approved on November 15, 2017.	Hatchery	Appendix B and Appendix F

The following sections summarize the achievements, actions, and activities taken in 2017 specific to project survival and dam operations, hatchery compensation, and funding of tributary habitat protection and restoration projects.

2.1 Project Survival and Dam Operations

2.1.1 Status of Phase Designations for Current Plan Species

A major feature of the Rock Island HCP is what is termed a "phased implementation plan" to achieve the survival standards. This approach includes three phases (Phase I, II, and III), and consists of conducting survival studies over multiple years and evaluating the achievement of survival standards, which is needed to proceed to the next phase. Progress through each phase has been described at length in previous HCP Annual Reports submitted to FERC.

Section 5.2 of the Rock Island HCP states that a combined adult and juvenile project survival of 91% shall be achieved and maintained. In October 2006, following 3 years of valid juvenile survival studies and completion of 3 years of adult passage survival estimates, the Rock Island Project proceeded to Phase III (Standards Achieved), meaning the Rock Island Project had achieved a combined adult and juvenile survival of 91%. This standard is in place for steelhead, spring Chinook salmon, and sockeye salmon.

Section 5.3.3 of the Rock Island HCP allows for reduced spill if survival standards for juvenile migration have been exceeded and an additional 1 to 3 years of testing confirm achievement of the survival standards under the new spill operations. Beginning in 2007 and continuing through 2010, Chelan PUD tested juvenile survival at Rock Island Dam under a 10% spill condition during the spring juvenile migration period. The current phase designations for all Rock Island Plan Species under conditions of 10% spill are summarized in Table 3.

Table 3
Phase Designations for Rock Island Habitat Conservation Plan Under Conditions of 10% Spill

Plan Species	Project Survival (%)	Phase Designation	SOA Date
Okanogan and Wenatchee Rivers Sockeye Salmon	91.75[1]	Phase III (Standards Achieved)	January 25, 2013
UCR Steelhead	96.08[1]	Phase III (Standards Achieved)	January 25, 2013
UCR Yearling Chinook Salmon	93.65[1]	Phase III (Standards Achieved)	January 25, 2013
UCR Subyearling Summer/ Fall Chinook Salmon	To Be Determined	Phase III (Additional Juvenile Studies)	September 29, 2016
Coho Salmon	93.98[2]	Phase III (Standards Achieved)	March 30, 2017

Note:
1. Combined adult and juvenile project survival achieved (standard is 91%)
2. Juvenile project survival achieved (see below)

In 2013, information was reviewed on the status of tag technology and life-history attributes of subyearling summer Chinook salmon in the Mid-Columbia. Based on this information and review, the Rock Island HCP Coordinating Committee agreed that empirical estimates of juvenile project survival were not feasible. As a result, on June 25, 2013, the Rock Island HCP Coordinating Committee approved an SOA maintaining subyearling summer Chinook salmon in Phase III (Additional Juvenile Studies) for 3 years (through June 2016). In June 2016, the Rock Island HCP Coordinating Committee re-evaluated the ability to conduct survival studies on subyearling Chinook salmon. Once again, available data indicated conducting survival studies on subyearling Chinook salmon is not feasible at this time. On September 29, 2016, the Rock Island HCP Coordinating Committee approved an SOA maintaining subyearling summer Chinook salmon in Phase III (Additional Juvenile Studies) for another 3 years (through September 2019) and stipulating that it will continue to evaluate or monitor study design, tag technology, and life-history information to better understand future survival study feasibility by 2019.

In 2016, coho salmon were classified as Phase III (Standards Achieved – Interim Value), and were due to be re-evaluated in 2017. In September 2016, Chelan PUD began discussing estimates of juvenile coho salmon survival through the Rock Island and Rocky Reach projects with the Rock Island HCP Coordinating Committee. In January 2017, Chelan PUD presented results from an analysis conducted by Drs. John Skalski and Richard Townsend (Columbia Basin Research), based on passive integrated transponder (PIT)-tag data from 2010 to 2016, which indicated that projected coho salmon survival through the Rock Island Project is 93.98% with a standard error of 0.0233, and through the Rocky Reach Project is 92.94% with a standard error of 0.0081. Chelan PUD drafted an SOA indicating these data demonstrate that yearling Chinook salmon are a good surrogate for juvenile coho salmon, with 93% survival at both Rock Island and Rocky Reach projects. The draft SOA designated juvenile coho salmon as being in Phase III (Standard Achieved) at both the Rock Island and Rocky Reach projects. Concern was expressed about combining survival through the Rock Island and Rocky Reach projects and setting a precedent for accepting lower standards than is stated in the HCPs[3] (the projected survival for coho salmon through the Rock Island Project was slightly less than 93%). The Rock Island and Rocky Reach HCP Coordinating Committees discussed how Drs. Skalski's and Townsend's initial analysis used only 2 years of acoustic and PIT-tag data (2010 and 2011) for the Rocky Reach Project that resulted in an average survival of 95.15% for the 2-year period, which meant that a survival level of only 88.71% would be needed during the third year of study to achieve Phase III (Standards Achieved). Chelan PUD chose not to accept these data in the interest of using all data available for a more robust dataset. Governing documents were reviewed, including past SOAs containing variability in the data and based on less years of data, where the HCP Coordinating Committees were satisfied with making a decision based on the available data. After 3 months of discussion, the Rock

[3] Section 5.2.2 of the Rocky Reach HCP states, "If Juvenile Project Survival for each Plan Species is measured to be greater than or equal to 93%, then the District will proceed to Phase III (Standard Achieved)."

Island and Rocky Reach HCP Coordinating Committees agreed there is a high level of confidence that the projected coho salmon survival through the Rocky Reach Project is sufficient to meet or exceed the standard. On March 30, 2017, the Rock Island and Rocky Reach HCP Coordinating Committees approved the Rock Island and Rocky Reach Coho Phase Designation SOA, as revised (Appendix E), designating juvenile coho salmon in Phase III (Standard Achieved) at both Rock Island and Rocky Reach projects. The Rock Island and Rocky Reach HCP Coordinating Committees notified their respective HCP Hatchery Committees of approval of this SOA, to initiate moving forward with hatchery compensation planning (see Section 2.2.2.15).

2.1.2 Assessment of Project Survival

The Rock Island HCP requires that Chelan PUD shall work toward a 91% combined adult and juvenile project survival at Rock Island Dam, which is achieved by project-improvement measures implemented within the geographic area of the project. Progress toward this objective is described in the following section.

2.1.2.1 Adult Passage Monitoring

When the Rock Island HCP was signed in 2002, it was acknowledged there was no scientifically rigorous method for the Rock Island HCP Coordinating Committee to assess adult project passage survival for Plan Species. Existing methods did not differentiate between mortality caused by the project and other sources of mortality (e.g., delayed mortality from injuries resulting from passage at downstream projects, injuries sustained by marine mammals, or harvest activities). Section 5.2 of the Rock Island HCP states, that given the inability to differentiate between the sources of adult mortality, initial compliance with the combined adult and juvenile survival standard would be based on the measurement of 93% juvenile project survival or 95% juvenile dam passage survival and an adult survival estimate of 98 to 100%.

Beginning in December 2012, Chelan PUD was able to evaluate adult passage survival through the Rock Island Project (dam and reservoir) for spring Chinook salmon, steelhead, and sockeye salmon, even though unknown harvest mortality remained in the survival estimates for steelhead and sockeye salmon. PIT-tag detections from the PIT Tag Information System database were used to evaluate adult fish migrating upstream in 2010, 2011, and 2012 to estimate project conversion rates. For spring Chinook salmon and steelhead, adults destined for the Methow and Okanogan river systems were used for the survival evaluation. For sockeye salmon, adults originating from the Wenatchee and Okanogan river systems were evaluated. The 3-year arithmetic mean survival rates at Rock Island Project for adult spring Chinook salmon, steelhead, and sockeye salmon were 99.89%, 99.31%, and 98.37%, respectively (Table 4.) Chelan PUD will re-evaluate adult passage survival at Rock Island in 10-year intervals, as required per the HCP.

Juvenile, adult, and combined (juvenile and adult) survival rates at the Rock Island and Rocky Reach projects are presented in Table 4. Adult conversion rates were calculated from adult passage data for the years 2010 through 2012.[4]

Table 4
Habitat Conservation Plan Juvenile, Adult, and Combined Survival Rates at Rock Island and Rocky Reach

Project	Species	Juvenile Survival	Adult Survival	Combined[5]
Rock Island	Steelhead	96.75%	99.31%[2]	96.08%
	Spring Chinook Salmon	93.75%[1]	99.89%[3]	93.65%
	Sockeye Salmon	93.27%	98.37%[2]	91.75%
Rocky Reach	Steelhead	95.79%	98.93%[2]	94.77%
	Spring Chinook Salmon	92.37%[1]	99.90%[3]	92.28%
	Sockeye Salmon	93.59%	98.92%[4]	92.58%

Notes:
1. Includes spring-migrating yearling Chinook salmon.
2. Estimate does not account for fish losses due to recreational harvest in any years.
3. No recreational harvest occurred.
4. Estimate adjusted for fish losses from recreational harvest in 2010 and 2011, but not for harvest losses in 2012.
5. Combined survival is the product of juvenile and adult survival estimates (e.g., 98% × 93% = 91%).

The HCP combined adult and juvenile project survival standard is 91%. The HCP combined adult and juvenile project survival estimates apply to fish actively migrating through the Rock Island and Rocky Reach projects in the mainstem Columbia River and do not include mortality occurring in other locations (i.e., they do not include ocean or tributary mortality).

2.1.2.2 Valid Study Flow Duration Curve Update

Section 13.24 of the Rock Island HCP requires that as part of the 2013 comprehensive review, and every 10 years thereafter, the Rock Island Coordinating Committee shall update the spring and summer period Flow Duration Curves used to define valid survival studies. The updated Flow Duration Curves must reflect "Representative Flow Conditions," meaning river flows between the 10th and 90th percentiles on the Flow Duration Curve, as calculated from the Grand Coulee Dam daily average outflow. In 2013, efforts began to update the Flow Duration Curve. The HCP Coordinating Committees agreed to develop the updated Flow Duration Curve with the historical 1929 to 1978 and 1983 to 2001 datasets used previously, to which the new 2002 to 2012 dataset was added. For comparison, Flow Duration Curves were also constructed using only the 1983 to 2012 dataset. The HCP Coordinating Committees also agreed to revise the definition of the

[4] Buchanan R. A. and J. R. Skalski, 2012. *Estimation of the Adult Salmon and Steelhead Conversion Rates through Rock Island and Rocky Reach Projects, 2010-2012*. Prepared for Public Utility District No. 1 of Chelan County. December 2012.

summer period to comprise June 1 through August 15, compared to the former July 1 through August 15 period. Updated Flow Duration Curves were expected to become final in early 2014; however, in February 2014, a fracture discovered in Wanapum Dam postponed a number of efforts, including updating the curves, until time allows. The final updated Flow Duration Curves are projected to be completed in 2018.

2.1.2.3 2017 Survival Studies

No yearling or subyearling Chinook salmon survival studies were conducted in 2017 at the Rock Island Project.

There are no planned Rock Island juvenile salmonid project survival studies for 2018. However, in 2017, the Rock Island HCP Coordinating Committee continued briefly discussing the upcoming HCP 10-year check-in survival study for Rock Island Dam in 2020, in terms of completing ongoing improvements and maintenance (see Section 2.1.3.2).

2.1.3 Project Operations and Improvements

This section summarizes project operations and progress toward maintaining the juvenile project survival standards at Rock Island Dam in 2017. Actions in 2017 were guided by the 2017 Rocky Reach and Rock Island HCP Action Plans (Appendix L), as approved by the Rocky Reach and Rock Island HCP Coordinating Committees on April 5, 2017 (Appendix A).

2.1.3.1 Operations

2.1.3.1.1 Juvenile Bypass System and Fish Spill Operations

At Rock Island Dam, juvenile fish spill operations are guided by two documents. The Rock Island and Rocky Reach HCP Coordinating Committees approved the 2017 Rock Island Bypass Monitoring Plan (Appendix I) and the 2017 Rocky Reach and Rock Island Fish Spill Plan (Appendix K) on February 22 and March 24, 2017, respectively, after no disapprovals were received prior to the 30-day review deadlines. The Rock Island bypass system operated from April 1 through August 31, 2017, which covered the normal bypass operating period for the outmigration of juvenile salmon and steelhead at Rock Island Dam.

Spring fish spill at Rock Island Dam for yearling Chinook salmon, steelhead, and sockeye salmon began on April 16, 2017, at 0001 hours and continued uninterrupted for 40 days through 2400 hours on May 25, 2017. The target spill level for the duration of the spring spill period in 2017, was 10% of the estimated daily average river flow, as specified and approved in the Rock Island Fish Spill Plan (Appendix K). Actual spill for this 40-day period averaged 35.22% of the total river flow, and comprised 9.69% fish spill and an additional 25.53% unavoidable hydraulic spill. The Columbia River average flow through Rock Island Dam during the spill period was 227,790 cubic feet per second (cfs), and the daily average spill was 80,222 cfs. Following completion of spring spill on May 25, 2017, spill at Rock Island Dam was provided for 99.8% of the steelhead outmigration, 97.0% of the sockeye salmon outmigration, and 98.4% of the yearling Chinook salmon outmigration passing Rock Island Dam.

Summer fish spill at Rock Island Dam for subyearling Chinook salmon began at 20% of daily average flow on May 26, 2017, at 0001 hours, immediately following completion of spring spill at 10%. Spill continued uninterrupted for 85 days at a spill target of 20% of the estimated daily average river flow. Spill ended on August 18, 2017, at 2400 hours. Actual spill for the 85-day period averaged 29.47% of the total river flow, and comprised 19.89% fish spill and an additional 9.58% unavoidable hydraulic spill. The Columbia River average flow rate past Rock Island Dam during the spill period was 162,085 cfs, and the daily average spill rate was 47,774 cfs. Following completion of the bypass operations on August 31, 2017, it was estimated that summer spill at Rock Island Dam was provided for 97.5% of the subyearling Chinook salmon outmigration passing Rock Island Dam.

Complete Rock Island Dam 2017 fish spill operations results are summarized in the 2017 Rocky Reach and Rock Island Fish Spill Report (Appendix O), which was approved by the Rocky Reach and Rock Island HCP Coordinating Committees, with the Colville Confederated Tribes (CCT) abstaining, on October 24, 2017.

2.1.3.1.2 Juvenile Sampling Facility

Each year, Chelan PUD operates the Rock Island Dam Juvenile Sampling Facility (RIJSF) from April 1 to August 31. The RIJSF is used to examine outmigrating juvenile salmonids for species composition and fish condition, including gas bubble trauma. Data collected provide information for in-season management decisions regarding juvenile anadromous fish passage.

The 2016 Rock Island Smolt Monitoring Program and Gas Bubble Trauma Report (Appendix G), which summarizes activities at the RIJSF in 2016, was approved by the Rock Island HCP Coordinating Committees after no disapprovals were received prior to the 30-day review deadline on February 22, 2017. A complete report summarizing 2017 activities at the RIJSF is expected in 2018.

2.1.3.1.3 Pikeminnow Predator Control

Chelan PUD has implemented a northern pikeminnow (*Ptychocheilus oregonensis*) predator-control program in the Rock Island Project since 1995. Since 1996, Chelan PUD has contracted annually with the U.S. Department of Agriculture (USDA) to carry out this program. Chelan PUD also provides funding for the annual Pikeminnow Derby sponsored by the East Wenatchee Rotary Club.

Complete results from the 2016 removal effort were summarized in the 2016 Rock Island HCP Annual Report, and are described in the 2016 Rock Island and Rocky Reach Pikeminnow Control Program Summary Report (Appendix H), which was approved by the Rock Island and Rocky Reach HCP

Coordinating Committees after no disapprovals were received prior to the 30-day review deadline on February 22, 2017.

In 2017, Chelan PUD continued implementing the northern pikeminnow removal program with Columbia Research long-line angling during the pre-migration period to target large pikeminnow that stage in deep reservoir areas and are difficult to capture with other gear types. The 2017 USDA hook-and-line angling program commenced during the peak of the juvenile salmonid migration. The total combined harvest of pikeminnow in 2017 from Rocky Reach and Rock Island reservoirs was 91,147 fish. Harvest numbers from the various control efforts in 2017 were as follows: USDA hook-and-line angling – 62,387 fish; Columbia Research long-line angling – 24,981 fish; East Wenatchee Rotary Club Pikeminnow Derby – 2,628 fish; and removal by Chelan PUD Fish and Wildlife personnel – 1,151 fish. A report summarizing results of the 2017 removal effort is expected sometime in early 2018.

2.1.3.1.4 Rock Island Dam Powerhouse 1 Turbine Units B1 to B4

In October 2015, Rock Island Dam Powerhouse 1 Turbine Units B1, B2, B3, and B4, were removed from service due to cracks discovered in the turbine unit blades (see Section 2.1.3.2). The unit capacity of Units B1 to B4 is 6.75 thousand cubic feet per second (kcfs) each (27 kcfs total). With Units B1 to B4 out of service, generation at Rock Island Dam is reduced from the usual 216 kcfs to 189 kcfs. Maintenance is planned for the units with a target completion date of April 2020. In 2017, a finite analysis identified several more parts in need of repair (see Section 2.1.3.2); however, because the failing parts were caught early enough, the repairs should not impact the maintenance schedule for Turbine Units B1 to B4.

2.1.3.1.5 Pacific Lamprey Passage at Tumwater Dam

In March 2016, the U.S. Fish and Wildlife Service (USFWS) raised a question regarding how to properly address Pacific lamprey passage at Tumwater Dam as it relates to HCP Plan Species broodstock collection. Per the Rock Island and Rocky Reach HCPs, the HCP Hatchery Committees have oversight regarding trapping for broodstock, and the HCP Coordinating Committees have oversight regarding fish passage. After internal discussion, Chelan PUD agreed this same demarcation applies to Pacific lamprey at Tumwater Dam when either collection of broodstock or adult passage of HCP Plan Species is of concern. Therefore, any future discussions of Pacific lamprey passage at Tumwater Dam will likely be presented to the HCP Coordinating and Hatchery Committees, because the issue involves activities overseen by both committees.

In 2017, Chelan PUD voluntarily drafted an engineering feasibility report to determine how lamprey passage could be improved at Tumwater Fishway, should the need arise. Progress updates on the status of the feasibility report were provided to the HCP Coordinating Committees and HCP Hatchery Committees.

2.1.3.1.6 Federal Columbia River Power System National Environmental Policy Act Scoping Process

In January 2017, Chelan PUD notified the HCP Coordinating Committees that the District planned to submit comments on the Federal Columbia River Power System National Environmental Policy Act Scoping Process documents. Comments were regarding maintaining the integrity of the HCPs and acknowledging the PUDs have certain protections under the HCPs. The comments focused on: 1) analyzing the potential effects of predation, specifically in the estuary; 2) acknowledging scientific uncertainties associated with Upper Columbia River (UCR) spring-run Chinook salmon; and 3) climate change (as it relates to how to replace clean renewable energy sources if hydroelectric dams are removed). The comments were submitted to the U.S. Army Corps of Engineers on February 7, 2017.

2.1.3.1.7 Rock Island Dam Powerhouse 2 Rehabilitation

In October 2017, Chelan PUD notified the HCP Coordinating Committees that the Board of Commissioners is beginning to engage in planning for the rehabilitation of Powerhouse 2 at Rock Island Dam. An economic analysis recommended a rehabilitation, versus a full overhaul, to extend the lifespan of the system by an additional 40 years. In-depth analyses will be regularly conducted throughout the duration of the rehabilitation, parts will be refurbished and sandblasted to ensure they are structurally sound, and machine tolerances will be returned to their original specifications. The turbine runners will stay the same, and there will be no changes to the name plate discharge or horsepower ratings of the turbine units. Rehabilitation is tentatively scheduled to begin by the third quarter of 2021 (following the HCP 10-year check-in survival study for Rock Island Dam that will conducted in 2020), and all eight turbine units are scheduled to be complete by the first quarter of 2029 (before the HCP 10-year check-in survival study for Rock Island Dam in 2030). This rehabilitation is not expected to affect the relicensing of Rock Island Dam in 2028.

2.1.3.1.8 Spill Gate Change

On May 18, 2017, Rock Island Dam lost the capability of operating automated spill gate 7, resulting in a total of three spill gates being out of service during the spill and fish migration season (spill gates 7, 17, and 25). Due to the record-high river flow past Rock Island Dam and snowpack estimates that at the time were exceeding 100% in basins above Rock Island Dam, Rock Island Dam engineers converted two notch gates back to full gate operation to address concerns about overall spillway capacity and dam safety. Chelan PUD internally discussed at length which notch gates to convert back to full gate operation and decided to convert notched spill gates 18 and 26. This was based on the following: 1) conversion of these gates to full gate operation was not expected to have negative impacts to juvenile fish passage; 2) gates 18 and 26 are located away from the left powerhouse entrance of the right bank adult fish ladder and would have no impact on adult fish passage; and 3) both of these gates are shallow spill gates so additional total dissolved gas from the gate conversions would be negligible. This conversion was temporary until July 21, 2017, when gates 18 and 26 were converted back to their notched gate configuration (see Section 2.1.3.2).

2.1.3.1.9 Application for Non-Capacity Amendment

In 2017, Chelan PUD filed with FERC an Application for Non-Capacity Amendment to modify the former Olds Bridge recreation site in the existing Recreation Plan. Prior to filing with FERC, Chelan PUD must conduct stakeholder consultation to ensure the proposed amendment is consistent with current Rock Island Project operations and implementing existing license management plans. As requested, the Rock Island HCP Coordinating Committee representatives submitted edits and comments, or an indication of no comments, on the application by the review deadline.

2.1.3.2 Improvements and Maintenance

Facility improvements and maintenance at the Rock Island Project in 2017 that had the potential to affect Plan Species are described in this section.

2.1.3.2.1 Rock Island Dam Powerhouse 1 Turbine Units B1 to B4

In October 2015, surface cracks were discovered on the turbine unit blades of Rock Island Dam Powerhouse 1 Unit B2. Based on surveys conducted, the cracks were attributed to corrosion fatigue. Units B1, B2, B3, and B4 are all similar, and initial analyses of the turbine blades on Units B1, B3, and B4 showed the same signs of metal fatigue that were identified on Unit B2; therefore, all four units were removed from service (see Section 2.1.3.1). In July 2016, following several months of blade repairs and continued cracking, Chelan PUD presented to the Rock Island HCP Coordinating Committee maintenance plans for Units B1 to B4. These plans were designed to optimize flow, increase unit efficiency, and benefit fish passage survival. In February 2017, to demonstrate clear support for the rehabilitation, the Rock Island HCP Coordinating Committee approved the SOA, "Acknowledgement of Rock Island Powerhouse 1 Units B1-B4 Consultation" (Appendix A and E). In August 2017, results from a finite metal analysis identified additional parts in need of repair, including: 1) rotor poles; 2) generator shaft; and 3) wicket gate body and stems. These repairs should not impact the target completion date of April 2020, which is in time for Chelan PUD to conduct the HCP 10-year check-in survival study for Rock Island Dam (see Section 2.1.2.3).

2.1.3.2.2 2016/2017 Rock Island Dam Adult Fish Ladder Winter Maintenance

The middle ladder at Rock Island Dam was taken offline for annual winter maintenance on December 6, 2016, and returned to service on January 6, 2017. Activities beyond general maintenance included: 1) replacing lower valves (gear stems wore out); 2) conducting grating inspection; and 3) evaluating concrete integrity.

The left ladder at Rock Island Dam was taken offline for annual winter maintenance on December 21, 2016, and returned to service on February 27, 2017. Activities beyond general maintenance included maintenance on the gates and valves.

The right ladder at Rock Island Dam was taken offline for annual winter maintenance on January 9, 2017, and returned to service on February 2, 2017. Activities conducted included general maintenance.

2.1.3.2.3 Automated Spill Gates 7, 17, and 25

In May 2017, Chelan PUD notified the HCP Coordinating Committees that three spill gates were currently out of service (spill gates 7, 17, and 25; see Section 2.1.3.1). An explanation of the equipment failures and timeline for repairing the gates is as follows:

- Spill Gate 7 – one of the suspension cables on spill gate 7 became unattached, damaging the gate and guiderails, and jamming the gate in place.
- Spill Gate 17 – during operation, the gear shaft twisted in half in the gear box, damaging the gate and gear box, and jamming the gate in place.
- Spill Gate 25 – after the spill gate 17 failure, mechanics observed the same cracks in the gear shaft on spill gate 25 and removed the gate from service.

Spill gate 7 will require that divers be deployed to complete the repairs and spill gates 17 and 25 need new gear boxes. The spill gates are targeted to be back in service by spring 2018.

2.1.3.2.4 2017/2018 Rock Island Dam Adult Fish Ladder Winter Maintenance

The right and left ladders at Rock Island Dam were taken offline for annual winter maintenance on December 4 and December 18, 2017, respectfully. The middle ladder at Rock Island Dam will be taken offline for annual winter maintenance when the right and left fish ladders are returned to service. All fishways at Rock Island Dam should be back to service by mid-February 2018.

2.2 Hatchery Compensation

Section 8.1 of the Rock Island HCP describes a Hatchery Compensation Plan with two primary objectives: 1) to provide compensation for Plan Species; and 2) to implement specific elements of the hatchery program consistent with the overall objectives of rebuilding natural populations and achieving NNI. In 2017, Chelan PUD continued providing funding and capacity for hatchery production consistent with meeting NNI. Recalculated hatchery production values required to meet NNI through 2023 were approved by the Rock Island HCP Hatchery Committee on December 14, 2011, and represented in *Chelan PUD's No Net Impact and Inundation Obligations for Release Years 2014-2023*. Hatchery compensation for the Rock Island Project in 2017 included the release of 2,525,168 juvenile salmonids (combined Rock Island and Rocky Reach hatchery compensation; Table 5).

To improve coordination, a representative from Grant PUD is invited to the monthly HCP Hatchery Committees meetings. The Grant PUD representative and the Priest Rapids Coordinating Committee (PRCC) Hatchery Sub-Committee facilitator also receive meeting announcements, final agendas, and meeting minutes. Furthermore, in June 2015, the HCP Hatchery Committees agreed to convene joint sessions of the HCP Hatchery Committees and PRCC Hatchery Sub-Committee when discussing agenda items applicable to and requiring participation from both committees. This practice benefits the HCP Hatchery Committees through increased coordination and sharing of expertise. The Grant PUD representative has no voting authority under the HCPs; however, because these joint discussions influence similar and sometimes overlapping hatchery programs, those discussions are documented and included here, accordingly. The HCP Hatchery Committees and PRCC Hatchery Sub-Committee continued holding joint sections of meetings in 2017 when agenda items pertain to both sets of committees. This coordination and joint process is planned to continue in 2018.

2.2.1 Hatchery Production Summary

Table 5 summarizes and compares HCP hatchery production objectives and actual 2017 smolt releases.

Table 5
2017 Production Level Objectives and Smolt Releases for Rock Island Habitat Conservation Plan Hatchery Programs

Species[a]	Program	Final Rearing Site	Rock Island Production Level Objectives (2014 to 2023)[b]	Total Releases for Rock Island in 2017 (Number of Fish)
Spring Chinook Salmon	Chiwawa (Wenatchee)	Chiwawa	144,026	163,411 smolts
Summer/Fall Chinook Salmon	Wenatchee	Dryden Pond	318,000	334,133 smolts
Steelhead	Wenatchee	Chiwawa Hatchery[c]	247,300[d]	251,692 smolts
Sockeye Salmon	Okanogan	kł cp̓əlk̓ stim̓ Hatchery	591,050[e] (34% of kł cp̓əlk̓ stim̓ Hatchery production)	1,526,600 fry
Spring Chinook Salmon	Okanogan	Chief Joseph Hatchery	115,000 (12.81% of Chief Joseph Hatchery production)	121,159 smolts
Summer Chinook Salmon	Okanogan	Chief Joseph Hatchery /Omak Pond	94,570 (13.51% of Chief Joseph Hatchery production	54,395 subyearlings
Summer Chinook Salmon	Okanogan	Similkameen	166,569 (12.81% of Chief Joseph Hatchery production)	73,778 yearlings

Notes:

a. Coho salmon mitigation met by the funding agreement with the YN.
b. As specified in the Rocky Reach and Rock Island HCP Hatchery Committees SOA Chelan PUD Hatchery Compensation, Release Years 2014 to 2023, approved December 14, 2011.
c. Includes releases from Blackbird Island Pond.
d. Steelhead production at Chiwawa Acclimation Facility includes Rock Island and Rocky Reach obligations.
e. Combined with the Rocky Reach HCP, the Okanogan sockeye salmon production requirement totals 591,050 smolts (production is allocated between the two HCPs); the table includes the number of fry released. By agreement of the HCP Hatchery Committees, this production requirement is satisfied for Okanogan sockeye salmon by funding of the Okanagan Skaha Lake sockeye salmon reintroduction program until otherwise determined by the HCP Hatchery Committees.

2.2.2 Hatchery Planning and Implementation

This section details the actions taken in 2017 that are relevant to planning for hatchery operations supporting the HCP.

2.2.2.1 2017 Broodstock Collection Protocols

In March 2017, the HCP Hatchery Committees began their review of the draft 2017 Broodstock Collection Protocols for Chinook salmon and steelhead. The revised draft protocols were approved, via email, as follows: Washington Department of Fish and Wildlife (WDFW), Chelan PUD, Douglas PUD, National Marine Fisheries Service (NMFS), USFWS, the CCT, and the Yakama Nation (YN) approved on April 7, 2017. The 2017 Broodstock Collection Protocols (Appendix M) were distributed to the HCP Hatchery Committees on April 14, 2017, and implemented at program hatcheries throughout 2017. In-season revisions were made as needed in coordination with the HCP Hatchery Committees. As in previous years, the 2017 Broodstock Collection Protocols were intended to guide the collection of salmon and steelhead broodstock in the Methow River, Wenatchee River, and Columbia River basins. The protocols are consistent with previously defined program objectives such as program operational intent (i.e., conservation and/or harvest augmentation) and mitigation production levels (i.e., HCPs), and they comply with ESA permit provisions.

2.2.2.1.1 Chiwawa Spring Chinook Salmon Broodstock Collection

In August 2017, WDFW presented provisional data to the HCP Hatchery Committees regarding Wenatchee spring Chinook salmon broodstock collection. The program collected enough broodstock to meet production obligations, but was four females short of its natural-origin target due to three factors: 1) adult natural-origin fish were limited and hard to acquire; 2) the collection weir was not operational as early in the season as intended because of high flows; and 3) mechanical issues took the weir out of operation for 1 week at a critical point, and the weir was lowered towards the end of the collection season to avoid impinging fish.

2.2.2.1.2 Brood Year 2017 Wenatchee Steelhead Release Plan

In March 2017, Chelan PUD and WDFW presented to the HCP Hatchery Committees a Draft 2017 Wenatchee Steelhead Release Plan and also presented preliminary results from the 2016 Wenatchee steelhead release (Appendix B). Chelan PUD summarized preliminary results for survival to McNary Dam for screened versus non-screened fish, brood origin, and release locations, and the HCP Hatchery Committees discussed the results. Release strategy objectives for 2017 were the same as in 2016 and included evaluating best management practices for hatchery releases to optimize homing fidelity, minimize residualism, maximize out-migration survival, and minimize negative ecological interactions. The plan initially implemented a paired release design by vessel type, brood origin, and release sites, and also a detailed monitoring and evaluation (M&E) plan. In 2017, the plan stipulates performing screened (volitional) releases, plus more intensive length-weight sampling and

PIT-tagging a group of non-moving fish to assess behavior. The 2017 Wenatchee Steelhead Release Plan (Appendix J) was approved by the Rock Island and Rocky Reach HCP Hatchery Committees on March 16, 2017, and was implemented in April and May 2017.

2.2.2.2 Hatchery Monitoring and Evaluation Plan Implementation

2.2.2.2.1 Hatchery Monitoring and Evaluation Plan – 2017 Update

Since 2013, Chelan PUD hatchery M&E programs have been operated in accordance with the *Monitoring and Evaluation Plan for PUD Programs 2013 Update*. The plan was updated in 2017, titled *Monitoring and Evaluation Plan for PUD Hatchery Programs – 2017 Update (Appendix P)*, as described below.

In May 2017, Chelan PUD and the HCP Hatchery Committees began reviewing the objectives in the *Monitoring and Evaluation Plan for PUD Hatchery Programs – 2013 Update* in order to update the plan in 2017. The review began with Table 1, which includes program objectives, indicators, and goals for conservation hatchery programs including productivity and monitoring indicators. Regarding the second objective, "determine if the proportion of hatchery fish affects freshwater productivity," the HCP Hatchery Committees noted improvements to methodologies for estimating freshwater productivity are underway, and the objective should be revisited once more accurate estimates for Methow Basin data are available. Regarding the fourth objective, "determine if the program has affected genetic diversity and population structure," the HCP Hatchery Committees reviewed further information from WDFW about genetic monitoring, as discussed in Section 2.2.2.3 though no substantial edits were made in 2017 to genetic monitoring objectives due to pending updates.

Chelan PUD and the HCP Hatchery Committees frequently discussed brood year (BY) stray rates, specifically Question 6.1.1 of the M&E Plan, in 2017. Discussions centered around the initial selection of the 5% maximum threshold for BY stray rates, how empirical information should factor into thresholds, recent scientific literature on the topic, the purpose of the thresholds, hatchery versus wild strays, and potential changes to the thresholds. Further discussions included setting a quantitative versus qualitative threshold, removing the threshold altogether, and how the metric is related to other metrics with which it is evaluated. Section 4.4 and Question 6.1.1 of the plan were revised and reviewed, and currently the section and question focus on determining what the BY stray rate is, and putting the rate into context with respect to other stray rates, and management concerns.

In addition to stray rates, Chelan PUD and the HCP Hatchery Committees revised language for statistical analyses associated with Objective 5, added fish-per-pound targets and release numbers to Appendix 5, updated Table 3, revised non-target taxa of concern language in Section 7.2, and added to Section 8 (Adaptive Management). To complete analyses specified in Section 8, the HCP Hatchery Committees determined they need to identify major program changes in fish culture or M&E for each program and began drafting program timelines as described below. Tracy Hillman, Chair of the

Rock Island, Rocky Reach, and Wells HCP Hatchery Committees, also finalized Appendix 1, Carrying Capacity, as described in Section 2.2.2.4. Lastly, edits were made throughout the document for clarification and ease of cross-referencing appendices. The HCP Hatchery Committees approved the final plan, *Monitoring and Evaluation Plan for PUD Hatchery Programs – 2017 Update,* in November 2017 (Appendix P).

2.2.2.2.2 Hatchery Monitoring and Evaluation Implementation Plan

The Chelan *County* PUD Hatchery *Monitoring and Evaluation Implementation* Plan, is prepared annually to describe the M&E activities for the next calendar year. The Rock Island and Rocky Reach HCP Hatchery Committees approved the Chelan PUD 2018 Hatchery M&E Implementation Plan (Appendix N) on August 18, 2017, following a 30-day HCP Hatchery Committees review period.

2.2.2.2.3 Genetic Analyses for Habitat Conservation Plan Program Species

The M&E Plan specifies genetic analyses, which should occur at 10-year intervals in order to examine the potential for changes in genetic diversity of natural populations as a result of hatchery programs. In 2016, the HCP Hatchery Committees recognized the need to reconsider the genetic sampling intervals and scheduling for HCP program species.

WDFW worked on this task throughout 2016 and 2017. They conducted a literature review and made a list of relevant reports. They developed a draft timeline for sample collection, analyses, and reporting to meet all monitoring objectives, and they investigated potential analyses with geneticists to inform updated sampling intervals. This material was shared with the HCP Hatchery Committees in January 2017, then revised and shared again in April 2017. The timeline includes analysis needs, the projected year of the analysis, and the requirements for M&E reporting. The HCP Hatchery Committees discussed whether analysis intervals should be based on listing status or other factors, and whether to synchronize analysis years for the same species across basins, or by each basin. A power analysis was proposed as a way to determine how large of a genetic change could be detected in a population and how rapid it may occur (which would inform the analysis interval). The HCP Hatchery Committees also recognized that a baseline genetic period for each program needs to be determined, because hatchery programs change over time, especially in regard to broodstock. It was determined that the WDFW genetics lab should work on a power analysis to determine recommended analysis frequency, and the HCP Hatchery Committees should determine baseline periods for each program.

2.2.2.2.4 Timelines for Habitat Conservation Plan Programs

To complete analyses specified in Section 8 of the M&E Plan, Chelan PUD and the HCP Hatchery Committees determined they need to identify major program changes in fish culture or M&E for each program, and began drafting program timelines in October 2017. The timelines will be used to determine breaks for statistical analysis and will help complete the 5-year statistical and 10-year comprehensive reports.

Tracy Hillman drafted the timeline for spring Chinook salmon, which the HCP Hatchery Committees reviewed in October 2017. Timelines for steelhead, summer Chinook salmon, sockeye, and Entiat programs are also being drafted and will be discussed in 2018.

2.2.2.2.5 Expanded Sampling at the Off-Ladder Adult Fish Trap

In February 2017, WDFW introduced the idea of expanding sampling at the off-ladder adult fish trap (OLAFT) at Priest Rapids Dam as an approach for monitoring spring Chinook salmon. The HCP Hatchery Committees discussed how sampling could inform unbiased estimates for prespawn mortality, and provide data for managing Percent Hatchery Origin Spawners (pHOS) and Proportionate Natural Influence (PNI) objectives. Sampling at Wells and Tumwater dams for spring Chinook salmon could be decreased if a sampling scheme for the OLAFT is developed. WDFW indicated they would develop an overview of the expanded sampling strategy. Because the strategy has not been developed yet, expanded sampling at the OLAFT will likely be discussed in 2018, but not implemented in 2018.

2.2.2.2.6 Hatchery Monitoring and Evaluation Plan Reporting

In September 2017, the Chelan PUD 2016 Hatchery M&E Plan Report, titled *Monitoring and Evaluation of the Chelan and Grant County PUDs Hatchery Programs 2016 Annual Report,* which documented M&E activities in 2016 (Appendix Q) was finalized following a 30-day HCP Hatchery Committees review period. In addition, Chelan PUD began working with the HCP Hatchery Committees in 2016 to develop a long-term scheduling plan to logically orchestrate HCP requirements and M&E reporting, including annual and 5-year interval reports, and the 10-year Program Review (Rock Island HCP: Section 8.7).

From January to March 2017, Chelan PUD and the HCP Hatchery Committees discussed the purpose and contents of the annual, 5-year, and 10-year reports and drafted a schedule. The 10-year Program Review is an HCP requirement, the 5-year Statistical Report is an M&E Plan requirement, and the M&E Plan is a requirement of permitting, so Chelan PUD coordinated with Douglas PUD and Grant PUD to develop reporting timelines, and a Rock Island and Rocky Reach HCP Hatchery Committees SOA describing the background and purpose of the timeline. The *Final M&E Reporting Schedule for the PUD Hatchery Programs,* finalized in March 2017, describes the content and function of each report and development and due dates through 2052 (Appendix F). The Rock Island and Rocky Reach HCP Hatchery Committees approved the SOA, M&E Reporting Schedule for the Chelan PUD, Douglas PUD, and Grant PUD Hatchery Programs, in March 2017 (Appendix F).

2.2.2.3 Hatchery Monitoring and Evaluation Plan Appendices

In January 2015, while discussing where to append the memorandum clarifying standardized methods for Hatchery M&E Plan Objective 8.3, Fecundity at Size, the HCP Hatchery Committees recognized that the Hatchery M&E Plan Appendices had not yet been finalized. In March 2015, the

HCP Hatchery Committees agreed to reconvene the Hatchery Evaluation Technical Team (HETT) to finalize the appendices. The HETT first reconvened in April 2015, and discussed a plan for completing the appendices, which are living documents, subject to change as more data become available. Appendices were split up among HETT members to complete by varying dates, and work continued in 2016 to finalize the Hatchery M&E Plan Appendices. HETT members distributed drafts of Appendices 2, 4, 5, and 6 in February and March 2016. In March 2016, the HCP Hatchery Committees discussed how carrying capacity estimates should be calculated for Appendix 1 and provided feedback to Tracy Hillman on material that should be included in Appendix 1. Hillman presented carrying capacity estimates for Chiwawa River spring Chinook salmon to the HCP Hatchery Committees in April 2016, and the HCP Hatchery Committees suggested Hillman focus on methodology for calculating carry capacity estimates when drafting Appendix 1, with some populations included as examples. In May 2016, Appendix 3 was distributed for review. In June 2016, the HCP Hatchery Committees discussed and revised draft Appendices 2 through 6. The HCP Hatchery Committees approved Appendices 2 (Hatchery Replacement Rate Targets), 4 (Spatial Distribution of Spawners), and 6 (Rearing Targets) in June 2016. Appendix 6 was later revised, and a final revised version was approved in August 2016. Appendix 3, PNI and pHOS Targets and Sliding Scales, was revised and later approved in August 2016. Appendix 5, Stray Rate Objectives, was further revised and discussed in August, September, and October 2016. In October 2016, the HCP Hatchery Committees discussed that material in Appendix 5 is redundant with the Hatchery M&E Plan, and decided to delete Appendix 5. Appendices 2, 3, 4, and 6 were renumbered and appended to the Hatchery M&E Plan in 2017. In October 2017, Hillman presented Appendix 1, Estimation of Carrying Capacity, to the HCP Hatchery Committees, which included an example of how carrying capacity is estimated for spring Chinook salmon in the Chiwawa River watershed and the entire Wenatchee River Basin. The HCP Hatchery Committees concluded their review of the Hatchery M&E Plan Appendices when Appendix 1 was finalized along with the *Monitoring and Evaluation Plan for PUD Hatchery Programs – 2017 Update* in November 2017.

2.2.2.4 Okanogan Sockeye Salmon Mitigation

In 2017, Chelan PUD provided a twelfth year of funding for a portion of the Okanagan Nation Alliance (ONA)'s 12-year Skaha Lake Sockeye Salmon Reintroduction Program (the current hatchery production obligation for Okanogan sockeye salmon mitigation is a combined 591,050 smolts for Rocky Reach and Rock Island HCPs). Chelan PUD funding contributed to the construction of the new kł cp̓əlk̓ stim̓ Sockeye Salmon Hatchery in Penticton, British Columbia, which was completed in September 2014; currently Chelan PUD funding contributes to operation and maintenance of the hatchery and to the M&E program. In June 2015, the hatchery held its first official fish release of roughly 1.7 million fry, mostly in Shingle Creek, and some in Okanagan Lake as part of a ceremonial ONA release. The hatchery was designed to support up to an 8-million-egg program; however, the plumbing system initially installed supports a production capacity of 5 million eggs. The egg-take goal of 5 million eggs was achieved for the first time in 2016. In spring 2017, the hatchery released roughly 4,449,000 fry (Chelan PUD's proportion was 1,526,600) into Skaha Lake.

2.2.2.5 Hatchery and Genetic Management Plans

Efforts continue to complete the consultation process, including coordination in prior years among Chelan PUD, NMFS, USFWS, the YN, WDFW, the CCT, and Grant and Douglas PUDs.

2.2.2.5.1 Chiwawa Spring Chinook Salmon

On July 3, 2013, NMFS issued a new Permit No. 18121 jointly to WDFW, Chelan PUD, and the YN (as an authorized agent of Chelan PUD) for operation of the Chiwawa spring Chinook salmon hatchery program. An amended permit was issued on May 29, 2015. This program was still awaiting consultation by the USFWS which was completed in 2017.

2.2.2.5.2 Wenatchee Steelhead

On June 30, 2014, after more than 4 years of consultation, the initial draft Wenatchee Steelhead Biological Opinion (BiOp) was completed by NMFS. The BiOp was revised several times in 2014 and 2015, and a final BiOp was issued on July 20, 2016. Section 7(a)(2) consultation with USFWS was completed in 2017 and the Section 10 (a)(1)(A) permit (NMFS No. 18583) was issued on December 31, 2017.

2.2.2.5.3 Wenatchee Summer Chinook Salmon

In May 2013, NMFS requested that Chelan PUD and other Permit No. 1347 permit holders submit letter applications for extension of Permit No. 1347. NMFS indicated that an extension of the existing Permit No. 1347 was feasible. Chelan PUD submitted an extension request letter on August 27, 2013. Subsequently, on September 20, 2013, Chelan PUD received a letter from NMFS indicating that the existing ESA permits would be extended until new consultations are completed and new permits issued. In 2014, NMFS indicated that, due to higher priority permitting of programs rearing ESA-listed species, permitting of summer and fall Chinook salmon programs would not be addressed until spring 2015. In 2015, permitting of summer and fall Chinook salmon programs was postponed again because parties agreed that these programs are the lowest priority for completing consultation.

In May 2017, NMFS indicated they were drafting the proposed action for the batch of unlisted Chinook salmon programs in the UCR (Wenatchee summer Chinook, Chelan Falls summer Chinook, Wells summer Chinook, Priest Rapids fall Chinook, Methow summer Chinook, and Ringold upriver bright fall Chinook) and would be coordinating with parties to gain needed information. In June 2017, the HCP Hatchery Committees discussed possible consultation pathways for the unlisted programs. In September 2017, NMFS indicated that the BiOp for the Columbia River unlisted summer Chinook salmon programs was being drafted. The applicants officially initiated consultation with request letters in November 2017, and NMFS responded with letters of sufficiency to the applicants on

November 25, 2017. The draft BiOp was available for the applicants and HCP Hatchery Committees to review in November to December 2017. The BiOp was finalized on December 25, 2017, and Section 10 permits are expected to be issued in 2018.

2.2.2.5.4 Biological Opinion for Chiwawa Spring Chinook Salmon, Wenatchee Steelhead, and Wenatchee Summer Chinook Salmon Programs

On November 28, 2012, NMFS requested formal consultation with USFWS under Section 7(a)(2) of the ESA on the proposed permitting of the following five hatchery programs that operate in the Wenatchee subbasin: Chiwawa River spring Chinook salmon, Nason Creek spring Chinook salmon, White River spring Chinook salmon, Wenatchee River summer steelhead, and Wenatchee River summer Chinook salmon. A partial draft BiOp was distributed by USFWS on December 23, 2014. Another draft was submitted for review on September 8, 2016. A completed BiOp was issued by USFWS on November 27, 2017.

2.2.2.6 Wenatchee Steelhead Relative Reproductive Success Study

The Rock Island HCP, Section 8.5.3, requires that Chelan PUD fund and implement a steelhead relative reproductive success (RRS) study. The Wenatchee Steelhead RRS Study began in 2008 and incorporated data from each subsequent BY, to 2011. The study objective was to measure the RRS of hatchery-origin steelhead in the natural environment and determine the degree to which any differences in reproductive success between hatchery- and natural-origin steelhead can be explained by measurable biological characteristics.

In September 2015, WDFW and NMFS presented to the HCP Hatchery Committees the results of the Wenatchee Steelhead RRS Study. In summary, many differences in life-history traits were detected between hatchery and natural fish; however, there were no apparent differences in spawn timing. Additionally, spawning distribution was similar. Hatchery-by-hatchery (HxH) broodstock male and female fish had the lowest RRS. Hatchery-by-wild (HxW) broodstock male and female fish had a RRS between those of HxH broodstock and wild-by-wild (WxW) broodstock. WxW male and female fish had almost indistinguishable RRS from wild fish, though the RRS had greater variance between years. Size and season also contributed to variation in RRS among individuals. A final report documenting the study results will be distributed in 2018.

2.2.2.7 Dryden Overwintering Feasibility Study/Wenatchee River Total Maximum Daily Load

In 2011, Chelan PUD agreed to assess the feasibility of modifying the Dryden Acclimation Facility to accommodate overwinter rearing, as memorialized in the SOA titled *Chelan PUD Hatchery Compensation, Release Years 2014-2023*, approved by the Rocky Reach and Rock Island HCP Hatchery Committees on December 14, 2011. Concurrent with this effort, Chelan PUD is evaluating ways to meet the Washington State Department of Ecology's addendum to the Wenatchee Total

Maximum Daily Load (TMDL) establishing modified phosphorus targets for discharge into the Wenatchee River, effective in 2019.

In July 2012, Chelan PUD committed to conduct specific actions toward assessing the feasibility of converting the Dryden Acclimation Facility to an overwinter facility in conjunction with determining how best to meet TMDL requirements for phosphorous discharge by 2018. Based on the proposed schedule for implementing these actions, Chelan PUD expected to have all the information needed to make a decision by 2015.

In March 2015, the HCP Hatchery Committees agreed for Chelan PUD to continue their Wenatchee and Chelan Falls Summer Chinook Size Target Study for 1 additional year in order to obtain additional data to better inform a long-term decision. This study was intended to contribute information about the performance of hatchery fish released at a smaller size, which may help Chelan PUD meet the phosphorus TMDL targets at the facility (described below). Adding an additional year of testing, however, postponed making a final decision for another year.

In January 2016, Chelan PUD presented the results of their feasibility analysis to the HCP Hatchery Committees and concluded that the most effective and risk-minimizing approach to meeting phosphorous discharge limits is to rear Wenatchee summer Chinook salmon to a smaller size (anticipated to be 18 fish per pound). This would be accomplished by constructing a new, chilled, partial-water reuse system at Eastbank Fish Hatchery using circular ponds as a successfully demonstrated rearing practice, prior to transfer to the Dryden Acclimation Pond for final spring acclimation. Chelan PUD proposed to proceed with a feasibility study for design of a chilled, partial-water reuse aquaculture system at Eastbank Fish Hatchery for Wenatchee summer Chinook salmon, to enable Chelan PUD to meet phosphorus discharge limits under the Wenatchee River TMDL for dissolved oxygen and pH levels. On February 17, 2016, the Rock Island and Rocky Reach HCP Hatchery Committees approved the Improvement Feasibility at Eastbank Hatchery for Wenatchee summer Chinook salmon SOA. The next steps in the feasibility study, should the improvements be warranted, may include a complete design and construction in 2018, and first fish ponded in summer 2019.

2.2.2.7.1 Dryden Water Quality Monitoring

In 2017, Chelan PUD implemented the sixth year of water quality monitoring at the Dryden Acclimation Facility to help inform the ongoing evaluation of the feasibility for meeting phosphorus TMDL requirements. Water quality monitoring at the Dryden Acclimation Facility will continue in 2018.

2.2.2.7.2 Summer Chinook Salmon Size Target Study

In 2015, Chelan PUD conducted the second and final year of the Wenatchee and Chelan Falls Summer Chinook Size Targets Study with the National Oceanic and Atmospheric Administration's Northwest Fisheries Science Center to help inform the feasibility of converting the Dryden Acclimation Facility to an overwinter facility in conjunction with determining how best to meet TMDL requirements. During the first year of this study (BY 2012), there were challenges reaching the specific size targets. During the second year of this study (BY 2013), size targets were generally met, and preliminary results showed differences as a result of rearing vessel and/or release size in juvenile performance for Wenatchee summer Chinook salmon and no difference in juvenile performance between the four size-at-release targets. In 2015, the HCP Hatchery Committees agreed for Chelan PUD to conduct a third year of the study (BY 2014) to attempt to replicate success from the BY 2013 study. Results from the BY 2014 study will be available in 2018.

2.2.2.8 Supplemental Radio-Tagging of Summer Steelhead

In November 2015, the HCP Hatchery Committees received a proposal from WDFW and the University of Idaho to PIT-tag and radio-tag summer steelhead collected at Tumwater Dam and the Twisp Weir. WDFW and University of Idaho were trying to tag up to 500 summer steelhead at Priest Rapids Dam; however, due to lower than expected return rates in 2015, only 400 summer steelhead were tagged. There were 100 tags left, and WDFW and University of Idaho suggested tagging at Tumwater Dam and the Twisp Weir could provide additional information on parameters such as estimating stray rates and estimating overwinter survival, among other things. The HCP Hatchery Committees approved the proposal, which was also conducted during the spring of 2016 and 2017.

2.2.2.9 Releasing PIT-Tagged Pacific Lamprey in the Tumwater Dam Fishway

In April 2016, YN presented a Scope of Work (SOW) to the HCP Hatchery Committees titled *SOW for Releasing Adult Pacific Lamprey within Tumwater Dam Fish Ladder*. The YN agreed to monitor Pacific lamprey passage through the ladder throughout Plan Species broodstock collection, and report back to the Hatchery Committees should any effects be identified. PIT-tagged Pacific lamprey were released in the Tumwater fishway in 2016.

Pacific lamprey were released into several locations in the Wenatchee River again in 2017. In 2017, 14 Pacific lamprey were counted at the Tumwater Dam observation window during non-trapping periods indicating complete ascension of the Tumwater fishway. Additionally, one Pacific lamprey was observed ascending the denil to the trap hopper while trapping was actively occurring.

2.2.2.10 Steelhead Gamete Request

In January 2017, Chelan PUD, Douglas PUD, and the HCP Hatchery Committees discussed Douglas PUD's planned pilot study for estimating steelhead egg-to-fry survival in the Twisp River in 2017 (Attachment B). Douglas PUD requested gametes from three female and three male Twisp hatchery-origin steelhead, surplus to broodstock and escapement needs, that WDFW would collect at the Twisp Weir in spring 2017 for use in the egg-to-fry survival study. WDFW and Chelan PUD indicated interest in also using gametes from surplus steelhead, and the request was modified to four female and four male steelhead to accommodate the Chelan PUD egg to emergence study to be conducted in the Chelan River. The HCP Hatchery Committees approved the request. In February 2017, however, Douglas PUD indicated intent to perform an egg-to-fry survival study with spring Chinook salmon instead of steelhead in 2017. The purpose of this study is to get better estimates of spring Chinook salmon egg-to-fry survival than previously attained in other studies. Douglas PUD communicated that they would still work with Chelan PUD to acquire the surplus steelhead gametes needed from the Twisp River for the Chelan PUD study, and would provide an update to the HCP Hatchery Committees when the spring Chinook salmon study plan is developed.

2.2.2.11 Maturation Sampling for Chiwawa Spring Chinook Salmon

In March 2017, Chelan PUD proposed performing maturation sampling on 300 spring Chinook salmon from the 2017 release group for the third year in a row, in partnership with the USFWS and WDFW. The Rock Island HCP Hatchery Committee agreed to this request on March 13, 2017.

2.2.2.12 Coho Salmon Recalculation Agreements

In March 2017, the Rocky Reach and Rock Island HCP Coordinating Committees approved the Designation of Juvenile Coho Salmon in Phase III (Standard Achieved) at the Rock Island and Rocky Reach Projects SOA (Appendix E), as described in Section 2.1.1. Approval of this SOA initiated the hatchery compensation planning process, because survival estimates inform mitigation calculations. Chelan PUD and YN worked together to calculate mitigation numbers based on methods used during the 2013 NNI Recalculation for other species.

In May 2017, Chelan PUD reviewed the 2013 NNI Recalculation approach for determining mitigation. In August 2017, Chelan PUD presented a draft SOA for review, regarding District's Coho Obligation (Appendix B). The mitigation proposed in the SOA included a 7% compensation rate at both Rocky Reach and Rock Island as agreed to by the Rocky Reach and Rock Island HCP Coordinating Committees for BYs 2017 to 2021. The SOA is an agreement about the methodology used to calculate hatchery compensation levels, and is an agreement that Chelan PUD will meet its obligation through funding and/or facility use to support a coho salmon reintroduction project. While reviewing the draft SOA, CCT requested more time to coordinate revisions with YN, and due to ongoing coordination, the SOA was separated into two SOAs, with the first one focusing on just the methodology for meeting Chelan PUD's coho salmon obligation without the funding arrangement discussed. The Rocky Reach and Rock Island HCP Hatchery Committees approved the SOA Regarding District's Coho Obligation on November 15, 2017 (Appendix F). A second SOA regarding the funding arrangement is expected in early 2018.

2.2.2.13 Lifecycle Modeling for Wenatchee Spring Chinook Salmon

In September 2017, the HCP Hatchery Committees invited Jeff Jorgensen (Ocean Associates, Inc.) to discuss his work on lifecycle modeling for Wenatchee spring Chinook salmon (Appendix B). Jorgensen leads a lifecycle modeling team whose work is mostly directed to inform biological opinions and recovery planning. The Wenatchee lifecycle model is a population dynamics model that addresses how the population changes relative to natural factors or demographic rates, and has its roots in a matrix-type model. Jorgensen described how to run the model and use its modules, and the model's different scenarios and outputs. There are different scenarios for evaluating hatchery management in which the HCP Hatchery Committees expressed interest. Broodstock collection levels, smolt releases, and domestication are all factors that can change, affecting the number of hatchery-origin spawners in the wild, for example. Future collaborations between the HCP Hatchery Committees and Jorgensen may involve running certain hatchery module scenarios in the Wenatchee Basin.

2.2.2.14 Brood Year 2016 Nason Creek Spring Chinook Salmon Surplus

In September 2017, the HCP Hatchery Committees discussed a surplus identified in the Chelan PUD and Grant PUD Hatchery Programs M&E Progress Report – August 2017 (Appendix B). There was an over-production of both WxW and HxH spring Chinook salmon for the Nason Creek brood. As a result, a surplus of 41,263 HxH spring Chinook salmon were released into Banks Lake. WDFW indicated that capacity issues at the hatchery influenced the decision to release the fish, and an overage outside of the 110% acceptable limit was not expected based on estimates of fish on hand during the eyed-egg stage and during tagging. The HCP Hatchery Committees discussed policy for moving and tagging fish outside of what is described in broodstock collection protocols, and expressed concerns about marking WxW fish with adipose-clips and coded-wire tags. The HCP Hatchery Committees discussed adding as many management options and caveats in the broodstock collection protocols as feasible each year to reduce in-season decision-making.

2.2.3 Maintenance and Improvements

2.2.3.1 Chelan Fish Hatchery Rehabilitation Design

In 2015, a rehabilitation feasibility study began for the Chelan Fish Hatchery Building, which is more than 60 years old. Rehabilitation is planned for the existing hatchery building, including the offices, incubation, early rearing, and ancillary functions. No program changes are proposed at this time. The feasibility study continued in 2016 and will be finalized in 2018.

2.3 Tributary Committees and Plan Species Accounts

As outlined in the Rock Island HCP, the signatory parties each designated one member to serve on the Tributary Committee. The Rock Island, Rocky Reach, and Wells HCP Tributary Committees meet on a regularly scheduled basis as a collective group to enhance coordination and minimize meeting dates and schedules. Subject items requiring decisions are voted on in accordance with the terms outlined in the specific HCPs. During 2017, the Rock Island HCP Tributary Committee met on six occasions and held one conference call.

An initial task of the HCP Tributary Committees in 2017 was to review and update their operating procedures that provide a mechanism for decision making. These were initially developed in 2005 and were included in that year's annual report (Anchor 2005)[5]. The HCP Tributary Committees also developed Policies and Procedures for soliciting, reviewing, and approving project proposals (Anchor 2005). The Policies and Procedures provide formal guidance to project sponsors on submission of proposals for projects to protect and restore habitat of Plan Species within the geographic scope of the HCP. The HCP Tributary Committees established two complementary funding programs, the General Salmon Habitat Program (GSHP) and the Small Projects Program.

In 2017, the HCP Tributary Committees reviewed their Policy and Procedures document and agreed to add the following language to the beginning of Section 6.3 (Timelines and Extensions):

> Project Sponsors must have a signed contract with the Committees within one (1) year from the date when the Committees approved the project. In the event the Project Sponsor does not have a signed contract because of a lack of additional funds (cost share), a lack of landowner support, or any other reason, the Committees may cancel funding for the project. After the one-year period, the Project Sponsor may need to resubmit a new proposal seeking funding for a canceled project.

They also reviewed their Operating Procedures and agreed to remove the following statement from Section IX (Plan Species Account):

> The Committees will provide financial reports to the District no less than on a quarterly basis.

The Committees provide annual reports and believe there is no need to provide quarterly reports.

2.3.1 Regional Coordination

Similar to the HCP Hatchery Committees and to improve coordination, a representative from Grant PUD and the facilitator of the PRCC Habitat Sub-Committee were invited to the HCP Tributary Committees monthly meetings. In addition, these representatives received meeting announcements, draft agendas, and meeting minutes. This benefits the HCP Tributary Committees through increased coordination and the sharing of expertise. The Grant PUD representative and PRCC Habitat Sub-Committee facilitator have no voting authority.

The HCP Tributary Committees also coordinate with the Upper Columbia Salmon Recovery Board (UCSRB). Coordination is typically between the chairperson of the HCP Tributary Committees and the

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[5] Anchor Environmental, L.L.C. 2005. *Annual Report, Calendar Year 2005, of Activities under the Anadromous Fish Agreement and Habitat Conservation Plan.* Rock Island Hydroelectric Project, FERC license no. 943. Prepared for FERC by Anchor Environmental L.L.C. and Public Utility District No. 1 of Chelan County.

Executive Director or the Natural Resource Program Manager of the UCSRB. In addition, some members of the HCP Tributary Committees typically attend UCSRB meetings to foster coordination in developing and selecting projects for funding. Some members of the HCP Tributary Committees are also members of the UCSRB's Regional Technical Team, which increases coordination in selecting projects for funding. Many of the Policies and Procedures of the Salmon Recovery Funding Board (SRFB) and HCP Tributary Committees are complementary, and annual funding rounds by these funding entities have been coordinated during the last several years.

In addition to coordinating with the SRFB process and the PRCC Habitat Sub-Committee, the Rock Island HCP Tributary Committee coordinates funding of GSHP proposals with Bonneville Power Administration and the U.S. Bureau of Reclamation. The purpose of this coordination, according to Section 2 of the Tributary Fund Policies and Procedures for Funding Projects, is to collaborate with regional, local, state, tribal, and national organizations that fund salmon habitat projects. The efforts resulted in identification of possible cost-shares for suitable habitat restoration projects.

2.3.2 Fiscal Management of Plan Species Accounts

The HCP Tributary Committees set up methods for the long-term management of the Plan Species accounts for each HCP. The Rock Island HCP Tributary Committee appointed the accounting firm Clifton Larson Allen to perform the necessary tasks for fiscal management of the Rock Island Plan Species Account. These tasks include the following: 1) develop a long-term approach to maintain the funds and to carry out tax calculations and reporting; 2) conduct the daily management of activities (such as processing of invoices); and 3) provide technical expertise on financial matters to the committees. The beginning balance of the Rock Island Plan Species Account on January 1, 2017, was $5,897,144.62. Chelan PUD's annual Rock Island contribution was $737,452.00. Interest received during 2017 was $31,692.34. Funds disbursed for projects in 2017 totaled $100,663.45. In addition, $3,545.04 was paid to Clifton Larson Allen and Chelan PUD for account administration, $1,000.00 was paid to the UCSRB for sponsorship in the 2018 Upper Columbia Science Conference, and $50.90 was paid in bank fees. The ending balance on December 31, 2017, was $6,561,029.57. The 2017 Annual Financial Report for this Plan Species Account is provided in Appendix R.

The Rock Island HCP Tributary Committee delegated signatory authority to the Chairperson for processing of payments for invoices approved by the Committee, with the HCP Coordinating Committees Chairperson serving as the alternate. Chelan PUD recognizes the uniqueness of the Rock Island HCP Tributary Committee decision-making process and delegation of signatory authority to the Chairperson, and the Chelan PUD subsequently has provided funding necessary to assign reasonable liability insurance to the Tributary Chairperson.

2.3.3 General Salmon Habitat Program

The HCP Tributary Committees established the GSHP as the principle mechanism for funding projects. The goal of the program is to fund projects for the protection and restoration of Plan Species habitat. An important aspect of this program is to assist project sponsors in developing practical and effective applications for relatively large projects. Many habitat projects are increasingly complex in nature and require extensive design, permitting, and public participation to be feasible. Often, a reach-level project involves many authorities and addresses more than one habitat factor. Because of this trend, the GSHP was designed to fund relatively long-term projects. There is no maximum financial request in the GSHP; the minimum request is $100,000, although the HCP Tributary Committees may approve lesser amounts during a phased project.

In 2014 the HCP Tributary Committees announced that they would accept GSHP applications at any time during the year. They also announced that they would continue to accept SRFB applications for projects where Plan Species Account Funds are included as cost-shares in SRFB Proposals.

In an effort to coordinate with ongoing funding and implementation programs within the region, the HCP Tributary Committees used the previously established technical framework and review process for this geographic area and worked with the other funding programs to identify cost-sharing procedures (see Section 2.3.1).

2.3.3.1 2016 General Salmon Habitat Projects

The SRFB announced its 2017 funding cycle in March, with draft proposals due on April 14, 2017, and final proposals due on June 30, 2017. The HCP Tributary Committees received and reviewed nine draft proposals. The HCP Tributary Committees identified four projects that they believed warranted full proposals and dismissed five projects because they were inconsistent with the intent of the Tributary Fund, did not have strong technical merit, or had low benefits per cost.

In July, the HCP Tributary Committees received four full SRFB proposals to the GSHP. All were cost-shares with the SRFB or other funding entities. The HCP Tributary Committees approved funding for three projects. In addition, the HCP Tributary Committees received one full proposal to the GSHP that was outside the SRFB process. The Rock Island Tributary Committee approved funding for that project. Table 6 identifies the projects, sponsors, total cost of each project, amount requested from Tributary Funds, and, if funded, which Plan Species Account supported the project.

Table 6
General Salmon Habitat Program Projects Reviewed by the Habitat Conservation Plan Tributary Committees in 2017

Project Name	Sponsor	Total Cost	Request from Tributary Committee	Plan Species Account
Salmon Recovery Funding Board Applications				
M2 WDFW Flow Connection Project	MSRF	$78,828	$11,824	W: $11,824
M2 Mid-Sugar Acquisition Project	MSRF	$291,268	$43,690	W: $43,690
Piscine Passage Design (Brush and Minnow Creeks)	CCFEG	$162,500	$52,500	Not funded
Methow Basin Barrier and Diversion Assessment	CCFEG	$206,650	$40,000	W: $40,000
General Salmon Habitat Program Applications				
Derby Creek Fish Passage – Collins Project	CCFEG	$155,000	$65,000	RI: $65,000

In 2017, the Rock Island HCP Tributary Committee agreed to fund the following GSHP project:

- **Derby Creek Fish Passage – Collins Project for the amount of $65,000 (with cost share the total cost of the project was $155,000) –** This project will remove the lowermost fish passage barrier culvert (river mile [RM] 0.3) on Derby Creek, a tributary to the Wenatchee River. Removal of the lowermost barrier will open about 10 miles of habitat for steelhead spawning and rearing.

2.3.3.2 Modifications to General Salmon Habitat Program Contracts

In 2017, the Rock Island HCP Tributary Committee received the following requests from sponsors asking for modifications to GSHP projects funded by the Committee:

- In April, Trout Unlimited – Washington Water Project (TU-WWP) asked the Rock Island HCP Tributary Committee for a time extension on the *Methow Valley Irrigation District Instream Flow Improvement Project* from September 30, 2016 to November 30, 2017. The extra time is needed to complete tasks associated with the project. The Rock Island HCP Tributary Committee approved the time extension.
- In April, TU-WWP asked the Rock Island HCP Tributary Committee for a budget amendment on the *Beaver Fever: Restoring Ecosystem Function Project*. TU-WWP asked the Committee to move $1,997.00 from “Administration/Overhead” to “Salaries and Benefits,” $2,294.94 from “Administration/Overhead” to “Professional Services,” and $7,028.75 from “Administration/Overhead” to “Project Materials.” The Rock Island HCP Tributary Committee approved the budget amendment.
- In May, TU-WWP asked the Rock Island HCP Tributary Committee for a time extension on the *Barkley Irrigation Project* from May 31, 2017 to December 31, 2018. Extra time was needed

because of a delay in construction. The Rock Island HCP Tributary Committee approved the time extension.

- In July, TU-WWP asked the Rock Island HCP Tributary Committee for a budget amendment on the *Beaver Fever: Restoring Ecosystem Function Project*. TU-WWP asked the Committee if they could use $10,000 under Construction and Permitting to purchase a hydraulic post driver. The driver would be used to install beaver dam analogues. This would eliminate the need to rent the equipment and could be used on other projects. The Rock Island HCP Tributary Committee denied the request, because equipment purchased with Plan Species Account Funds becomes the property of the Committee and the Committee is not set up to deal with equipment storage, maintenance, management, and liability, and they do not want to be in a position of lending expensive equipment to project sponsors.

2.3.4 Small Projects Program

The Small Projects Program has an application and review process that increases the likelihood of participation by private stakeholders that typically do not have the resources or expertise to go through an extensive application process. The HCP Tributary Committees encourage small-scale projects by community groups, in cooperation with landowners, to support Plan Species recovery on private property. Project sponsors may apply for funding at any time, and in most cases, will receive a funding decision within three months. The maximum contract allowed under the Small Projects Program is $100,000.

2.3.4.1 2016 Small Projects

In 2017, the HCP Tributary Committees received four requests for funding under the Small Projects Program. Table 7 identifies the project, sponsor, total cost of the project, amount requested from Tributary Funds, and which Plan Species Account supported the projects.

Table 7
Projects Reviewed by the Habitat Conservation Plan Tributary Committees under the Small Projects Program in 2017

Project Name	Sponsor	Total Cost	Request from Tributary Committee	Plan Species Account
Poison Canyon Restoration Project	CCNRD	$37,918	$21,600	RI: $21,600
Cottonwood Bridge Removal Project	CDLT	$95,000	$21,000	RR: $21,000
Frazer Creek – Lazy K Property Appraisal	MSRF	$1,421.40	$1,421.40	Not funded
Upper Beaver Creek – Anderson Property Appraisal	MSRF	$1,421.40	$1,421.40	Not funded

In 2017, the Rock Island HCP Tributary Committee agreed to fund the following Small Project:

- **Poison Canyon Restoration Project for the amount of $21,600 (with cost share the total cost of the project was $37,918) –** This project will install 20 wood jams using on-site wood and hand tools to aggrade incised reaches within Poison Canyon, a tributary to Sand Creek, which is a tributary to Mission Creek. Aggrading the channel should improve instream flows and water quality in Mission Creek.

2.3.4.2 Modifications to Small Project Contracts

In 2017, the Rock Island HCP Tributary Committee received the following requests from sponsors asking for modifications to Small Projects funded by the Committee.

- In April, Cascade Columbia Fisheries Enhancement Group (CCFEG) asked the Rock Island HCP Tributary Committee for a time extension on the *White River Floodplain Connection (RM 3.4) Project*. CCFEG asked the Committee to extend the period of the contract from September 30, 2017 to December 30, 2017. The Rock Island HCP Tributary Committee approved the time extension.
- In June, CCFEG asked the Rock Island HCP Tributary Committee for a budget amendment on the *Permitting Nutrient Enhancement in the Chiwawa River Basin Project*. CCFEG asked the Committee to move $1,028 from "Professional Services" and "Indirect/Admin/Overhead" to "Sponsor Salaries and Benefits." The total budget amount did not change because of this amendment. The Rock Island HCP Tributary Committee approved the budget amendment.
- In June, CCFEG asked the Rock Island HCP Tributary Committee for a budget amendment on the *White River Floodplain Connection (RM 3.4) Project*. CCFEG asked the Committee to take all the available funds in "Excavation and Heavy Equipment" ($5,000) and "Project Materials and Equipment" ($500) and move those into "Salaries and Benefits," "Overhead and Administration," and "Permit Fees." The total budget amount did not change because of this amendment. The Rock Island HCP Tributary Committee approved the budget amendment.
- In July, CCFEG asked the Rock Island HCP Tributary Committee for a time extension on the *Permitting Nutrient Enhancement in the Chiwawa River Basin Project*. Because of ongoing discussions with the U.S. Forest Service, USFWS, and Washington State Department of Ecology, CCFEG asked to extend the period of the contract from June 30, 2017 to June 30, 2018. The Rock Island HCP Tributary Committee approved the time extension.

2.3.5 Tributary Assessment Program

The Rock Island HCP established the Tributary Assessment Program (separate from the Rock Island Plan Species Account) intended to fund monitoring and evaluation of the relative performance of projects funded by the initial contribution to the Plan Species Account. The Tributary Assessment program comprised a fixed contribution of $200,000, not subject to inflation adjustment. To date, Chelan PUD has not spent any of the original $200,000.00 total for the Rock Island HCP Tributary Assessment Program.

3 Habitat Conservation Plan Administration

This section lists events of note that occurred in 2017 related to the administration of the HCPs and provides a list of reports published in 2017 that relate to the HCPs.

3.1 Mid-Columbia Habitat Conservation Plan Forums

In 2005 and 2006, Mid-Columbia Forums were held as a means of communicating and coordinating with the non-signatories and other interested parties regarding the implementation of the HCPs. Non-signatory parties at the time of the 2006 meeting included the Confederated Tribes of the Umatilla Indian Reservation and American Rivers. As in 2006 through 2016, these parties were invited by letter in 2017 to participate in a meeting with members of the HCP Coordinating, Hatchery, and Tributary Committees, in conformity with the 2005 FERC Order on Rehearing 109 FERC 61208 and in accordance with the offer to non-signatory parties of non-voting membership in HCP Hatchery and Tributary Committees processes. The non-signatory parties again indicated no interest in attending a meeting with the HCP Committees in 2017.

3.2 Habitat Conservation Plan Related Reports and Miscellaneous Documents Published in Calendar Year 2017

The following is a list of reports released in 2017 that are related to the implementation of the Rock Island HCP:

- Anchor QEA and Chelan PUD (Public Utility District No. 1 of Chelan County), 2017. Annual Report Calendar Year 2016 of Activities Under the Anadromous Fish Agreement and Habitat Conservation Plan Rock Island Hydroelectric Project FERC License No. 943. Prepared for FERC. April 2017.
- Chelan PUD, 2017. Chelan PUD Rocky Reach and Rock Island HCPs Final 2017 Fish Spill Report. September 2017.
- Chelan PUD, 2017. Final 2017 Rocky Reach and Rock Island HCP Action Plans. April 2017.
- Hillman, T., M. Miller, M. Johnson, C. Moran, J. Williams, M. Tonseth, C. Willard, S. Hopkins, B. Ishida, C. Kamphaus, T. Pearsons, and P. Graf, 2017. *Monitoring and Evaluation of the Chelan and Grant County PUDs Hatchery Programs: 2016 Annual Report*. Report to the HCP and PRCC Hatchery Committees. September 15, 2017.
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Appendix A
Habitat Conservation Plan Coordinating Committees 2017 Meeting Minutes and Conference Call Minutes

FINAL

720 Olive Way, Suite 1900
Seattle, Washington 98101
206.287.9130

ANCHOR QEA

Memorandum

To: Wells, Rocky Reach, and Rock Island HCPs Coordinating Committees

Date: February 28, 2017

From: John Ferguson, HCP Coordinating Committees Chairman

cc: Kristi Geris

Re: Final Minutes of the January 24, 2017, HCP Coordinating Committees Meeting

The Wells, Rocky Reach, and Rock Island Hydroelectric Projects Habitat Conservation Plans (HCPs) Coordinating Committees met at the Grant PUD Office in Wenatchee, Washington, on Tuesday January 24, 2017, from 10:00 a.m. to 12:45 p.m. Attendees are listed in Attachment A to these meeting minutes.

Action Item Summary

- Alene Underwood (Chelan PUD Fish and Wildlife Program Manager) will provide Chelan PUD's comments on the Federal Columbia River Power System (FCRPS) National Environmental Policy Act (NEPA) Scoping Process to Kristi Geris for distribution to the Coordinating Committees (Item II-B).
- Lance Keller will revise the draft Statement of Agreement (SOA), "Acknowledgement of Rock Island Powerhouse 1 Units B1-B4 Consultation," as discussed, and will provide the revised draft SOA to Kristi Geris for distribution to the Coordinating Committees (Item II-C). *(Note: the revised draft SOA was distributed following the meeting on January 24, 2017, and is available for a 10-day review with vote via email due to Keller by Friday, February 3, 2017.)*
- Lance Keller will revise the Draft 2017 Rock Island and Rocky Reach HCP Action Plan, as discussed, and will provide the revised draft plan to Kristi Geris for distribution to the Coordinating Committees (Item II-D). *(Note: the revised draft plan was distributed following the meeting on January 24, 2017, and is available for review with edits and comments due to Keller by Wednesday, February 22, 2017.)*
- Lance Keller will provide fish rescue numbers from the 2016/2017 Rock Island and Rocky Reach dams adult fish ladder maintenance periods to Kristi Geris for distribution to the Coordinating Committees (Item II-E). *(Note: Keller provided fish rescue numbers [Attachment B] to Geris on February 16, 2017, which Geris distributed to the Coordinating Committees on February 17, 2017.)*
- Lance Keller will notify the Rocky Reach HCP Coordinating Committee when the Rocky Reach Dam adult fish ladder is brought back online from the 2016/2017 Rocky Reach Dam adult fish ladder maintenance period (Item II-E). *(Note: Keller provided notification that the Rocky Reach Dam adult fishway was returned to service on February 14, 2017, which was distributed to the Coordinating Committees by Kristi Geris that same day.)*

- Tom Kahler will provide fish passage count data for winter months at Wells Dam for review regarding timing of winter maintenance at Wells Dam to Kristi Geris for distribution to the Coordinating Committees (Item III-A).
- Tom Kahler will notify the Wells HCP Coordinating Committee when the Wells Dam west fishway is brought back online from the 2016/2017 Wells Dam fishway maintenance period (Item III-A). *(Note: Kahler provided this notification to Kristi Geris on February 21, 2017, which Geris distributed to the Coordinating Committees that same day.)*
- Tracy Hillman (HCP Tributary Committees Chairman) will provide U.S. Fish and Wildlife Service's (USFWS's) presentation on the Silver Side-Channel Rehabilitation Project to Kristi Geris for distribution to the Coordinating Committees (Item IV-A). *(Note: the presentation was posted to the Coordinating Committees HCP Extranet Site [file was too large to email], and the Coordinating Committees were notified by Geris following the meeting on January 24, 2017.)*
- John Ferguson will follow up with Michelle Rub (National Marine Fisheries Service [NMFS]) regarding possibly presenting an update on her presentation, "Estimation of Survival and Run Timing of Adult Spring/Summer Chinook from the Columbia River Estuary to Bonneville Dam," to the Coordinating Committees during a future meeting (Item V-E).
- **The Coordinating Committees meeting on February 28, 2017, will be held in-person at the Grant PUD office in Wenatchee, Washington (Item V-E).**

Decision Summary

- Rock Island HCP Coordinating Committee representatives approved the SOA, "Acknowledgement of Rock Island Powerhouse 1 Units B1-B4 Consultation," via email as follows: Chelan PUD approved on January 24, 2017; the Colville Confederated Tribes (CCT) approved on January 25, 2017; NMFS and USFWS approved on January 26, 2017; Washington Department of Fish and Wildlife (WDFW) approved on February 1, 2017; and the Yakama Nation (YN) approved on February 3, 2017 (Item II-C).
- Wells HCP Coordinating Committee representatives approved the 2017 Wells Dam Gas Abatement Plan and Bypass Operating Plan (GAP and BOP), as revised, via email as follows: Douglas PUD approved on February 7, 2017; NMFS approved on February 8, 2017; USFWS approved on February 10, 2017; and WDFW, CCT, and the YN approved on February 14, 2017 (Item III-B).

Agreements

- Rock Island HCP Coordinating Committee representatives present agreed to a 10-day review period (initiated when the revised SOA is distributed) and a vote via email on the revised draft SOA, "Acknowledgement of Rock Island Powerhouse 1 Units B1-B4 Consultation," (Item II-C).

- Rock Island and Rocky Reach HCP Coordinating Committees representatives present agreed Chelan PUD does not need to provide an annual fish passage plan for Coordinating Committees review. The plan will be removed from the annual Rock Island and Rocky Reach HCP Action Plan (Item II-D).

Review Items

- Kristi Geris sent an email to the Coordinating Committees on December 15, 2016, notifying them the Draft 2015 Douglas PUD Pikeminnow Program Annual Report is available for a 60-day review period, with edits and comments due to Tom Kahler by Monday, February 13, 2017.
- Kristi Geris sent an email to the Coordinating Committees on January 5, 2017, notifying them the Draft 2017 Wells Dam GAP and BOP is available for a 30-day review period, with edits and comments due to Tom Kahler by Monday, February 6, 2017 (Item III-B). *(Note: USFWS provided comments on the draft plan on February 2, 2017, which Douglas PUD incorporated into the plan, and a Revised Draft 2017 Wells Dam GAP and BOP was distributed to the Coordinating Committees by Geris on February 7, 2017, with a vote via email due by Tuesday, February 14, 2017; see Decision Summary.)*
- Kristi Geris sent an email to the Coordinating Committees on January 23, 2017, notifying them that six Chelan PUD documents are available for a 30-day review, including: the Draft 2016 Rock Island Smolt Monitoring Program and Gas Bubble Trauma (SMP and GBT) Report; the Draft 2016 Rocky Reach Juvenile Fish Bypass System (RRJFBS) Report; the Draft 2016 Rock Island and Rocky Reach Pikeminnow Control Program Summary Report; the Draft 2017 Rock Island Bypass Monitoring Plan; the Draft 2017 Rock Island and Rocky Reach HCP Action Plan; and the Draft 2017 Rocky Reach Juvenile Sampling Facility (RRJSF) Protocol. Edits and comments on these documents are due to Lance Keller by Wednesday, February 22, 2017 (Item II-D). *(Note: a Revised Draft 2017 Rock Island and Rocky Reach HCP Action Plan was distributed for review on January 24, 2017. The Draft 2017 RRJFBS Operations Plan was distributed for a 30-day review period on February 17, 2017 [comments due Monday, March 20, 2017], replacing the Draft 2017 RRJSF Protocol, which was mistakenly distributed instead of the RRJFBS Operations Plan.)*
- Kristi Geris sent an email to the Coordinating Committees on January 24, 2017, notifying them the revised draft SOA, "Acknowledgement of Rock Island Powerhouse 1 Units B1-B4 Consultation," is available for a 10-day review with votes via email due to Lance Keller by Friday, February 3, 2017 (Item II-C).
- Kristi Geris sent an email to the Coordinating Committees on February 8, 2017, notifying them the Draft 2016 Wells HCP Annual Report is available for a 30-day review with edits and comments due to Geris by Friday, March 10, 2017 (Item V-D).

- Kristi Geris sent an email to the Coordinating Committees on February 16, 2017, notifying them the Draft 2016 Rock Island and Rocky Reach HCP Annual Reports are available for a 30-day review with edits and comments due to Geris by Monday, March 20, 2017 (Item V-D).
- Kristi Geris sent an email to the Coordinating Committees on February 22, 2017, notifying them the Draft 2017 Rock Island and Rocky Reach Fish Spill Plan is available for a 30-day review with edits and comments due to Lance Keller by Friday, March 24, 2017.
- Kristi Geris sent an email to the Coordinating Committees on February 23, 2017, notifying them the Draft 2017 Wells HCP Action Plan is available for review. Douglas PUD will request approval of the plan during the Coordinating Committees meeting on March 28, 2017 (Item III-C).

Finalized Documents

- The final SOA, "Acknowledgement of Rock Island Powerhouse 1 Units B1-B4 Consultation," was distributed to the Coordinating Committees by Kristi Geris on February 13, 2017 (Item II-C).
- The Final 2017 Wells Dam GAP and BOP was filed with FERC on February 27, 2017, and was distributed to the Coordinating Committees by Kristi Geris that same day (Item III-B).

I. Welcome

A. Review Agenda (John Ferguson)

John Ferguson welcomed the Coordinating Committees and reviewed the agenda. Ferguson asked for any additions or changes to the agenda, and the following revisions were requested:

- Lance Keller and Alene Underwood added a notification of Chelan PUD's intent to comment on the FCRPS NEPA Scoping Process.
- Ferguson added two updates under HCP Administration: 1) Coordinating Committees email distribution; and 2) Draft 2017 HCP Annual Reports.

B. Meeting Minutes Approval (John Ferguson)

The Coordinating Committees reviewed the revised draft November 15, 2016, meeting minutes. Kristi Geris noted that the Draft 2017 Wells Dam GAP and BOP and Douglas PUD's Draft 2015 Douglas PUD Pikeminnow Program Annual Report were added under the review items. She said those documents are available for review, with edits and comments due to Tom Kahler by February 6 and February 13, 2017, respectively. Geris also said the Final Wells Post-Season Bypass Report and Passage-Dates Analysis was added under the finalized documents. She said the report was finalized following a 60-day review period, which ended on December 5, 2016, and was distributed to the Coordinating Committees on December 28, 2016. She said, as noted in the email, the edits discussed and requested by the Coordinating Committees were incorporated into the final passage-dates analysis, and the post-season bypass report was updated accordingly. Geris said all other comments and revisions received from members of the Committees were incorporated into the revised minutes. Coordinating Committees members present approved the November 15, 2016, meeting minutes, as revised. The CCT abstained, because a CCT representative was not present during the November 15, 2016, meeting.

C. Last Meeting Action Items (John Ferguson)

Action items from the Coordinating Committees meeting on November 15, 2016, and follow-up discussions, were as follows. *(Note: italicized text corresponds to agenda items from the meeting on November 15, 2016):*

- *Lance Keller will confirm the appropriate title for Alene Underwood (Chelan PUD), for the administrative record, regarding her participation in the Coordinating Committees meeting on October 25, 2016 (Item I-B).*
  Keller confirmed Underwood's title, Chelan PUD Fish and Wildlife Program Manager, on November 18, 2016.
- *Bob Rose will provide a list of Yakama Nation (YN) concerns regarding datasets used for estimating coho salmon survival, which will be used in future discussions of the Rock Island and Rocky Reach Coho Salmon Phase Designation, prior to the Coordinating Committees meeting on December 13, 2016 (Item III-A).*
  This will be discussed during today's meeting.
- *Chelan PUD and the YN will convene to discuss concerns regarding datasets used for estimating coho salmon survival, prior to the Coordinating Committees meeting on December 13, 2016 (Item III-A).*
  Chelan PUD and the YN plan to meet after the meeting today.
- *Rock Island and Rocky Reach Coho Salmon Phase Designation will be discussed during the Coordinating Committees meeting on December 13, 2016 (Item III-A).*
  This will be discussed during today's meeting.
- *Chelan PUD will provide a Rock Island Powerhouse 1 Maintenance Update during the Coordinating Committees meeting on December 13, 2016, including discussing the Draft Federal Energy Regulatory Commission (FERC) Notification Letter for Rock Island B1-B4 Maintenance (Item III-B).*
  This will be discussed during today's meeting.
- *John Ferguson will coordinate with Denny Rohr (Priest Rapids Coordinating Committee [PRCC] Facilitator) regarding scheduling a joint HCP/PRCC meeting soon to discuss estimating the survival of subyearling Chinook salmon passing Mid-Columbia dams (Item V-A).*

Ferguson recalled that the Coordinating Committees agreed to convene quarterly, joint HCP/PRCC sessions to continue discussions regarding subyearling Chinook salmon passage studies; however, the joint meetings have not occurred to date. Ferguson said he spoke with Rohr who indicated the PRCC still intends to convene joint HCP/PRCC sessions; however, the PRCC is discussing this topic and several other issues and is not ready for joint sessions at this time.

II. Chelan PUD

A. Rock Island and Rocky Reach Coho Salmon Phase Designation (Steve Hemstrom, Lance Keller, Alene Underwood, and Catherine Willard)

Steve Hemstrom recalled the SOA, "Regarding District's Coho Obligation" (approved by the Rock Island and Rocky Reach HCP Coordinating Committees on June 26, 2007), which designated coho salmon in the Rock Island and Rocky Reach reservoirs as in Phase III Additional Juvenile Studies. Hemstrom recalled the 2007 SOA assumed an interim juvenile dam-passage survival value of 93%, unless compelling evidence indicated otherwise, in which survival studies would be conducted. Hemstrom said in 2010, installation of the Rocky Reach Dam juvenile salmon bypass passive integrated transponder (PIT)-tag detector provided key infrastructure needed to estimate survival rates of PIT-tagged juvenile coho salmon, yearling spring Chinook salmon, and steelhead released in the Methow River basin. He said new data are now available, and Chelan PUD is reassessing coho salmon survival.

Hemstrom said Chelan PUD asked John Skalski (Skalski Statistical Services) and Rich Townsend (Columbia Basin Research) to complete an analysis of hydrosystem survival estimates for PIT-tagged juvenile coho salmon, yearling spring Chinook salmon, and steelhead released from the Methow River basin through two reaches: 1) from Rocky Reach Dam to McNary Dam; and 2) from McNary Dam to John Day Dam. Hemstrom said the most recent analysis also includes statistical analyses based on PIT tags detected at the corner collector located at Bonneville Dam, as well as an additional year of data for all analyses (distributed September 22, 2016). He said there are now PIT-tag data from 2010 to 2016, providing a robust dataset. He said these data indicate coho salmon and yearling spring Chinook salmon survive most similarly from Rocky Reach Dam to McNary Dam and McNary Dam to John Day Dam. He added that the difference in estimated survival between the two species is not statistically significant.

Casey Baldwin asked about the standard errors on the estimates. Hemstrom said the reach survival estimates based on PIT tags had standard errors of approximately 8% for coho and Chinook salmon, whereas the standard errors associated with the dam-passage survival estimates based on acoustic tags were less than 2.5% (which meets the HCP requirements for standard error). Hemstrom added that it is important to remember this analysis is using a comparison. John Ferguson asked if the passage timing is similar, and Catherine Willard (Chelan PUD HCP Hatchery Committees Alternate) said passage timing of coho and Chinook salmon occurs within approximately 1 or 2 weeks of each other. Hemstrom also noted that the analysis uses the harmonic mean for travel times. Ferguson asked when an updated report from Skalski and Townsend will be available for review, and Alene Underwood replied, likely within the next couple of weeks. Hemstrom added that Chelan PUD also plans to distribute an SOA for discussion at the next Coordinating Committees meeting on February 28, 2017.

Hemstrom said the ultimate goal is to estimate coho salmon survival through the Rock Island and Rocky Reach reservoirs based on comparisons of the species's hydrosystem survival. He explained this calculation as being in the form of the following ratio:

$$\frac{Coho\ \ salmon\ survival\ from\ Rocky\ Reach\ Dam\ to\ McNary\ Dam}{Yearling\ Chinook\ salmon\ survival\ from\ Rocky\ Reach\ Dam\ to\ McNary\ Dam} = Survival\ ratio$$

He added, for example, that if coho salmon were to survive twice as well as yearling Chinook salmon the survival ratio would be 2, and if half as well it would be 0.5. Ferguson asked about the range of calculated survival ratios among the years, and Hemstrom said they ranged from less than 1.0 to about 1.3 to 1.4. Hemstrom added that the average ratio is 1.0024 based on PIT-tag data. Baldwin noted that a mean and the standard error associated with the mean are important information to have when interpreting significance, and when the mean is converted to a ratio, the variance is lost. Hemstrom said a standard error on the ratio was calculated, as well and is in the report. He explained when the individual survival of two species is compared, both species include a standard error; therefore, variance is already captured in the individual survival. He added that the ratios would be used to adjust the available dam-passage survival estimates for each project and species, based on the more precise acoustic telemetry data. He also said the exact values are in the report and recalled that adjusting the dam-passage estimates by the ratios resulted in estimates of 92.94% and 93.98% survival for coho salmon passing Rocky Reach Dam and Rock Island Dam, respectively.

Baldwin asked about fish-size comparisons between hatchery and wild coho salmon (i.e., how well are hatchery coho salmon surrogates for wild coho salmon). Willard said, overall, the two are similar with little variation. She added that occasionally, hatchery coho salmon are released a little earlier than the wild coho salmon outmigration. Lance Keller agreed he does not recall a significant discrepancy. Underwood said hatchery coho salmon are typically released when fish size is about 14.8 to 20 fish per pound. Jim Craig noted that hatchery fish are often times larger than wild fish; however, data on wild coho salmon are not substantial enough to confirm such a comparison.

Hemstrom said analyzing the survival ratios of 7 years of PIT-tag data, including a range of river environments and water years, incorporates all available data into the analysis, providing the most robust dataset available to date. He said Chelan PUD would like to achieve Phase III (Standard Achieved) for juvenile coho salmon through this analysis. Underwood also reiterated that the 2007 SOA stipulates:

> *"Juvenile coho [salmon] survival studies will not be performed unless there is compelling[1] information that demonstrates hydro project operations have an impact of greater than 7% mortality on coho [salmon]."*

She said, additionally, a survival study does not seem feasible at this time, based on fish counts in the river and juvenile collector at Rocky Reach Dam. Hemstrom noted that upward of 1,000 acoustically-tagged fish would be needed to obtain a standard error of 2.5%. Underwood said Chelan PUD intends to request (Standard Achieved) for juvenile coho salmon for the life of the license. She said a re-evaluation will coincide with the 10-year check-in. Baldwin asked how re-evaluation works, and Keller read from the Rock Island and Rocky Reach HCPs:

> *"…the District shall re-evaluate survival under the applicable standard every 10 years. Representative species shall be picked by the Coordinating Committee. This re-evaluation will occur over one year and be included in the pertinent average for that particular species. If the survival standard is met, then Phase III (Standard Achieved) status will remain. If the survival standard is not met, then an additional year of testing will occur. If the survival standard remains unmet over three years of re-evaluation, then Phase II designation will take affect for the representative species, and the Coordinating Committee shall re-evaluate the survival of other Plan Species, as appropriate."—Rock Island HCP (page 12); Rocky Reach HCP (page 13)*

Ferguson asked about timing of the next 10-year check-in. Keller said the next check-in is scheduled for 2020 for the Rock Island HCP and 2021 for the Rocky Reach HCP.

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[1] "Compelling" evidence could relate to information collected as part of the hatchery monitoring and evaluation program. For example, smolt-to-adult survivals for coho [salmon] that are significantly lower than other species in the same geographical area may be compelling evidence that coho [salmon] are experiencing differential mortality rates at project passage. In all cases the evidence should be empirical and related to Project survival.

B. Chelan PUD Intent to Comment on FCRPS NEPA Scoping Process (Alene Underwood)

Alene Underwood notified the Coordinating Committees that Chelan PUD is preparing comments on the FCRPS NEPA Scoping Process documents, and plans to submit them by February 7, 2017. She said the comments are regarding maintaining the integrity of the HCPs and acknowledging the PUDs have certain protections under the HCPs. She said the comments focus on: 1) analyzing the potential effects of predation, specifically in the estuary; 2) acknowledging scientific uncertainties associated with Upper Columbia River spring-run Chinook salmon; and 3) climate change (as it relates to how to replace clean renewable energy sources if dams are removed). Underwood said she will provide Chelan PUD's comments on the FCRPS NEPA Scoping Process to Kristi Geris for distribution to the Coordinating Committees.

C. Rock Island Powerhouse 1 Maintenance Update (Lance Keller)

Lance Keller distributed hard copies of the draft SOA, "Acknowledgement of Rock Island Powerhouse 1 Units B1-B4 Consultation," which was distributed electronically to the Coordinating Committees by Kristi Geris on January 23, 2017. Keller recalled Rock Island Powerhouse 1 Units B1 to B4 were taken out of service for periodic maintenance, at which time staff noticed cracks in the turbine blades. He said, when cracks were discovered, the cracked areas were fixed, the blades were determined to be crack-free, and the units were put back into service. However, during follow-up inspections, staff discovered that additional cracks had formed. Keller said pieces of the blades were sent out for metallurgic analysis and results indicated the blades were at the end of their lifespan. He noted that these units are the original units installed at Rock Island Dam in 1933. He said Chelan PUD decided to perform maintenance on all four units. He said rehabilitation plans were reviewed at length with the Coordinating Committees, a draft notification letter to FERC about the proposed maintenance was provided to the Coordinating Committees for a 30-day review period, and no comments were received on the plans or letter. Keller said, because no comments were received, FERC has requested additional assurances the Rock Island HCP Coordinating Committee is indeed supportive of the proposed rehabilitation; therefore, Chelan PUD drafted this SOA.

Keller said Chelan PUD requested and received bids for the rehabilitation work in December 2016, including bids for repairing one unit at a time or two at a time. He said a company named Andritz Hydro (based in Austria, with a location in the United States) provided a bid for repairing three units all at once. Keller recalled the old maintenance schedule included the last unit returning to service in March 2020, which was an aggressive schedule that also had no room for slippage ahead of the 2020 10-year check-in scheduled for Rock Island Dam. He said, with the proposal from Andritz Hydro, the new schedule includes dewatering Unit B4 in June 2018, and Units B2 to B3 in July 2018 (three units at once). He said those units will be back online by the first quarter of 2019, and then Unit B1 will be dewatered and recommissioned by about November 2019. Keller said Chelan PUD held a Board of

Commissioners meeting on December 30, 2016, to accept the bid. Alene Underwood said Andritz Hydro will be handling the entire rehabilitation, and Chelan PUD is confident all units will be back to service in 2019.

Keller reiterated this SOA is simply a formal document FERC requested to demonstrate a clear paper trail that the Rock Island HCP Coordinating Committee supports this rehabilitation. Underwood said Chelan PUD hopes to keep this process moving and requested a vote take place today, via email, or during the next Coordinating Committees meeting on February 28, 2017. Keller also noted that he will revise the minor typos in the draft SOA and will provide a revised draft SOA to Geris for distribution to the Coordinating Committees.

Bob Rose asked if Chelan PUD knows, or rather anticipates, whether the proposed design changes will benefit fish. He recalled similar claims from Grant PUD during an overhaul of turbines at Priest Rapids Dam; however, the designs had errors. Rose asked if the language in the SOA background can be changed to reflect this uncertainty. Keller said Chelan PUD can state with a high level of confidence these design upgrades will benefit fish passage; however, he also agreed to modify the background language, as requested. Jim Craig requested a 10-day review and vote via email after the revised draft SOA is distributed.

Coordinating Committees representatives present agreed to a 10-day review period (initiated when the revised SOA is distributed) and vote via email on the revised draft SOA, "Acknowledgement of Rock Island Powerhouse 1 Units B1-B4 Consultation." *(Note: the revised draft SOA was distributed following the meeting on January 24, 2017, and is available for a 10-day review with vote via email due to Keller by Friday, February 3, 2017.)*

Rock Island HCP Coordinating Committee representatives approved the SOA, "Acknowledgement of Rock Island Powerhouse 1 Units B1-B4 Consultation," via email as follows: Chelan PUD approved on January 24, 2017; the CCT approved on January 25, 2017; NMFS and USFWS approved on January 26, 2017; WDFW approved on February 1, 2017; and the YN approved on February 3, 2017. The final SOA was distributed to the Coordinating Committees by Geris on February 13, 2017.

D. Draft 2017 Rock Island and Rocky Reach HCP Action Plan (Lance Keller)

Lance Keller distributed hard copies of the Draft 2017 Rock Island and Rocky Reach HCP Action Plan, which was distributed electronically to the Coordinating Committees by Kristi Geris on January 23, 2017. He said the draft plan was presented to the HCP Hatchery Committees during their meeting on January 18, 2017, and will be presented to the HCP Tributary Committees during their meeting on March 9, 2017. He said, once those committees approve their respective portions of the action plan, Chelan PUD will request Rock Island and Rocky Reach HCP Coordinating Committees approval of the entire plan.

Keller said the first four documents listed in the action plan (the Draft 2016 Rock Island SMP and GBT Report; the Draft 2016 RRJFBS Report; the Draft 2017 Rock Island Bypass Monitoring Plan; and the Draft 2017 RRJSF Protocol), as well as the Draft 2016 Rock Island and Rocky Reach Pikeminnow Control Program Summary Report, were distributed to the Coordinating Committees by Geris on January 23, 2017. These five documents and the draft action plan are available for a 30-day review, with edits and comments due to Keller by Wednesday, February 22, 2017. *(Note: the Draft 2017 RRJFBS Operations Plan was distributed for a 30-day review period on February 17, 2017 [comments due Friday, March 17, 2017], replacing the Draft 2017 RRJSF Protocol, which was mistakenly distributed instead of the RRJFBS Operations Plan.)*

Keller said the 2017 action plan is business as usual except for the coho salmon survival standards SOA. He said he also wanted to discuss the 2017 Rock Island and Rocky Reach Fish Passage Plan. He said this plan has been included in the Rock Island and Rocky Reach Action Plan for years; however, Chelan PUD has not distributed the plan to the Coordinating Committees since 2013, and he cannot recall why. He explained the fish passage plan document summarizes bypass operations, adult passage, and fish spill operations, all of which are already covered under other documents that the Coordinating Committees review. He said the fish passage plan is essentially a summary of other documents, and asked if the Coordinating Committees want to receive this plan in 2017. Rock Island and Rocky Reach HCP Coordinating Committees representatives present agreed Chelan PUD does not need to provide an annual fish passage plan for Coordinating Committees review. The plan will be removed from the annual Rock Island and Rocky Reach HCP Action Plan.

Keller also noted that pikeminnow trapping activities will be removed from the action plan and will be added again if the activities are actually planned. Keller said he will revise the Draft 2017 Rock Island and Rocky Reach HCP Action Plan, as discussed, and will provide the revised draft plan to Geris for distribution to the Coordinating Committees. *(Note: the revised draft plan was distributed following the meeting on January 24, 2017, and is available for review with edits and comments due to Keller by Wednesday, February 22, 2017.)*

E. Rock Island and Rocky Reach Adult Fish Ladder Maintenance Update (Lance Keller)

Lance Keller reviewed maintenance updates at Rock Island Dam and Rocky Reach Dam, as follows:

<u>Rock Island Dam</u>

Keller recalled that at Rock Island Dam, one ladder remains operational for fish passage at all times, and up to two ladders can be offline for maintenance.

Middle Ladder

Keller said the middle ladder at Rock Island Dam was taken offline for annual winter maintenance on December 6, 2016. He said a fish rescue was conducted, and he reviewed the numbers. He added that he will provide fish rescue numbers from the 2016/2017 Rock Island and Rocky Reach dams adult fish ladder maintenance period, to Kristi Geris for distribution to the Coordinating Committees. *(Note: Keller provided fish rescue numbers [Attachment B] to Geris on February 16, 2017, which Geris distributed to the Coordinating Committees on February 17, 2017.)*

Keller said extensive (beyond general) maintenance activities conducted included: 1) replaced lower valves (gear stems wore out); 2) conducted grating inspection; and 3) evaluated concrete integrity. Keller said the middle ladder was returned to service on January 6, 2017.

Left Ladder

Keller said the left ladder at Rock Island Dam was taken offline for annual winter maintenance on December 21, 2016. He said a fish rescue was conducted, and he reviewed the numbers (Attachment B). He said extensive maintenance activities conducted included maintenance on the gates and valves. He said Chelan PUD contracts a consultant to clean the windows in the fish ladders, which still needs to be done. Keller said the left ladder is expected to return to service by the first week in February 2017.

Right Ladder

Keller said the right ladder at Rock Island Dam was taken offline for annual winter maintenance on January 9, 2017. He said a fish rescue was conducted on January 9 and 13, 2017, and he reviewed the numbers (Attachment B). John Ferguson asked if Pacific lamprey slipped through the grating this year as they have done in the past. Keller said yes, that 93 of 100 Pacific lamprey rescued came from the auxiliary water system (AWS) side of the diffuser grating, and 7 of 100 were rescued from the fish ladder side of the grating. He said the diffuser grating has 1-inch spacing and recalled having past issues with bowed veins. He said, Chelan PUD now conducts a “ping” test each year to determine the veins’ integrity. He said veins that are bowing are repaired. He said, unfortunately, the grating cannot be replaced with smaller spaced grating as was done at Rocky Reach Dam because this would restrict flow too much. He further explained that the picket barrier is a wall several feet tall and wide, and reducing the spacing between the gratings will create hydraulic issues. He said this may still be something Chelan PUD further investigates in the future.

Keller said maintenance activities conducted on the right ladder were minimal, and the ladder is expected to return to service by the end of January 2017.

Rocky Reach Dam

Keller recalled that the Rocky Reach HCP Coordinating Committee agreed to Chelan PUD's request to begin the 2016/2017 Rocky Reach Dam adult fish ladder maintenance period 3 weeks early to allow more time to complete needed work on the AWS pumps. He said as agreed, the adult fish ladder at Rocky Reach Dam was taken offline for annual winter maintenance on December 12, 2016. He said a fish rescue was conducted in the upper ladder on December 12, 2016, while the lower ladder remained watered with entrances open. He said the lower ladder was then dewatered on December 23, 2016, and a fish rescue was conducted that same day.

Keller reviewed the fish rescue numbers (Attachment B), and noted that all mortalities were juveniles. He explained that when the upper ladder is dewatered, water can only get out through the orifice of the weir. He said, once the water reaches a certain level, a gate is dropped closing the orifice. He said, this year, when the gate was dropped, a carabiner prevented the gate from completely closing, and a few smaller fish exited through the orifice and slipped through the floor gratings. He said when the fish were discovered, they had already expired.

Keller also noted 169 adult Pacific lamprey were rescued. He recalled replacing the upper ladder 1-inch floor grating with 3/4-inch grating in the lower weir section of the adult ladder, and said the rescued Pacific lamprey did not descend until they reached the remaining 1-inch grating. He said Chelan PUD plans to replace this remaining 1-inch grating in the lower weir section of the adult ladder in 2017. He also noted the one rescued bull trout, which was found holding in the middle of the 169 adult Pacific lamprey.

Keller said all rescued fish were released in the Rocky Reach Dam forebay. Casey Baldwin asked why the Pacific lamprey were not released farther upstream to avoid potential fallback. Keller said the Pacific lamprey were released at the landing near the bypass, per usual. He said the river is fairly calm there and suitable habitat is nearby. Jim Craig agreed this is a safe release location for Pacific lamprey.

Keller recalled that Chelan PUD requested approval from the Rocky Reach HCP Coordinating Committee for an early outage of the ladder to rehabilitate the AWS pumps and, specifically, to refurbish the seal on one of the butterfly valves. He said, by the time Chelan PUD received the estimate from the contractor, there was not enough time to complete the repairs within the allotted maintenance work window. Keller apologized for the disorganization that resulted in not completing the intended repairs after the Rocky Reach HCP Coordinating Committee approved the extended outage. He said the fish ladder will be returned to service as soon as possible, which is expected by the week of February 20, 2017, and he added that he will notify the Rocky Reach HCP Coordinating Committee when this occurs. *(Note: Keller provided notification that the Rocky Reach Dam adult* *fishway was returned to service on February 14, 2017, which was distributed to the Coordinating Committees by Geris that same day.)*

Keller said, regarding rehabilitating the AWS pumps, Chelan PUD investigated replacing the butterfly valves rather than repairing them, which turned out to be more cost-effective. He said Chelan PUD now plans to purchase the parts for all three pumps and replace the valves in each pump at a rate of one pump per year starting in 2017 (i.e., the 2017/2018 winter maintenance period). He added that by having the new parts onsite, this prevents the need to ship the valves offsite and will not require an early winter maintenance outage.

III.Douglas PUD

A. Wells Dam Fishway Maintenance Update (Tom Kahler)

Tom Kahler reviewed maintenance updates at Wells Dam, as follows:

East Fishway

Kahler said the east fishway at Wells Dam was taken offline for annual winter maintenance on December 7, 2016. He said a fish rescue was conducted, and a fish-salvage memorandum for the east fishway (Attachment C) was distributed to the Coordinating Committees by Kristi Geris on December 8, 2016. Kahler said routine maintenance was conducted, as well as maintenance on the fish pump (which was already completed in the west fishway). He said the east fishway was returned to service on January 9, 2017.

West Fishway

Kahler said the west fishway at Wells Dam was taken offline for annual winter maintenance on January 16, 2017. He said the upper ladder was dewatered on January 16, 2017, and a fish rescue was conducted that same day. He said the dewatering process in the lower ladder began on January 17, 2017; however, the gate motor that operates the leaf gates of the fishway collection gallery froze, and staff had to manually crank the gates closed. He said dewatering of the collection gallery was completed on January 19, 2017, and a fish rescue was conducted that same day. He said a fish-salvage memorandum for the west fishway (Attachment D) was distributed to the Coordinating Committees by Geris on January 19, 2017. Kahler said the west fishway is expected to return to service by the end of January 2017, and he added that he will notify the Wells HCP Coordinating Committee when this occurs. *(Note: Kahler provided this notification to Geris on February 21, 2017, which Geris distributed to the Coordinating Committees that same day.)*

Winter Maintenance Timing

Kahler said the Wells HCP contains no specific requirement for timing of winter maintenance; however, Douglas PUD has historically targeted December 1 to February 28 for completing necessary work. Kahler said the Mechanic Foreman at Wells Dam inquired about starting annual winter maintenance earlier, possibly by mid-November, in an effort to complete work before the coldest part of winter and freezing temperatures, which complicate maintenance activities. Kahler said, with this earlier schedule, maintenance could be completed as early as the end of December.

Kahler said he reviewed count data at Wells Dam and discovered there is more steelhead movement in February than December. He said fish counts are recorded via video during the winter months (offseason), and when fish counters return, the count video is immediately reviewed. The Wells HCP Coordinating Committee agreed to consider this further, and Kahler said he will provide fish passage count data for winter months at Wells Dam, to Geris for distribution to the Coordinating Committees for review.

B. Draft 2017 Wells Dam Gas Abatement Plan and Bypass Operating Plan (Tom Kahler)

Tom Kahler said Kristi Geris sent an email to the Coordinating Committees on January 5, 2017, notifying them the Draft 2017 Wells Dam GAP and BOP was available for a 30-day review period, with edits and comments due to Kahler by Monday, February 6, 2017. Kahler explained that Douglas PUD's FERC license, issued in 2012, required combining the GAP and BOP into one document (the BOP is now an appendix in the GAP). He said, per the license, Douglas PUD must provide the Wells HCP Coordinating Committee the opportunity to consult on both plans, but only requires Wells HCP Coordinating Committee approval of the BOP. He said the full document (2017 Wells Dam GAP and BOP) must ultimately be approved by the Washington State Department of Ecology and the Aquatic Settlement Work Group, prior to submitting the final document to FERC by February 28, 2017. *(Note: USFWS provided comments on the draft plan on February 2, 2017, which Douglas PUD incorporated into the plan, and a Revised Draft 2017 Wells Dam GAP and BOP was distributed to the Coordinating Committees by Geris on February 7, 2017, with a vote via email due by Tuesday, February 14, 2017.)*

Wells HCP Coordinating Committee representatives approved the 2017 Wells Dam GAP and BOP via email as follows: Douglas PUD approved on February 7, 2017; NMFS approved on February 8, 2017; USFWS approved on February 10, 2017; and WDFW, CCT, and the YN approved on February 14, 2017. The Final 2017 Wells Dam GAP and BOP was filed with FERC on February 27, 2017, and was distributed to the Coordinating Committees by Geris that same day.

C. Draft 2017 Wells HCP Action Plan (Tom Kahler)

Tom Kahler said the Draft 2017 Wells HCP Action Plan is not yet ready for distribution.

Kristi Geris sent an email to the Coordinating Committees on February 23, 2017, notifying them the Draft 2017 Wells HCP Action Plan is available for review. Douglas PUD will request approval of the plan during the Coordinating Committees meeting on March 28, 2017.

IV. HCP Tributary and Hatchery Committees Update

A. HCP Tributary and Hatchery Committees Update (Tracy Hillman)

Tracy Hillman updated the Coordinating Committees on the following actions and discussions that occurred during the HCP Tributary Committees meeting on January 12, 2017:

- *ORRI Phase II Side Channel Reconnection Project*: The Okanagan Nation Alliance (ONA) recently contacted the HCP Tributary Committees requesting feedback on the Okanagan River Restoration Initiative (ORRI) Phase II Side Channel Reconnection Project. The project (implemented in 2013) reconnected a side channel to the mainstem Okanagan River, with the goal of maintaining side channel connectivity at all flows. Monitoring indicates there is a blockage issue, and river flow through the side channel is too low (to provide rearing habitat for native fish) during low flow conditions. ONA asked the HCP Tributary Committees to provide feedback about what can be done to preserve the reconnected channel as a permanent channel. The HCP Tributary Committees believed the channel could remain permanent by: 1) adding another riffle or expanding the existing riffle in the main channel; 2) excavating to design grade; 3) widening the approach channel; and 4) adding a high-flow return to the approach channel.
- *Beaver Fever Project Presentation*: Trout Unlimited and USFWS provided an update on the Beaver Fever: Restoring Ecosystem Function Project. The purpose of the project is to re-establish beavers and install beaver-dam analogs (BDAs) in tributaries of the Wenatchee and/or Entiat river basins. The Rock Island HCP Tributary Committee agreed to fund the installation of BDAs, but not the reintroduction of beavers. The sponsor used the Beaver Restoration Assessment Tool model and conducted site visits to help identify suitable locations for installing BDAs. So far, 10 different drainages have been evaluated, and potential areas have been identified for implementation. Trout Unlimited asked if BDAs should be concentrated within a single watershed or spread across several watersheds, and what information should be collected once the BDAs are installed. Trout Unlimited also asked whether they should explore partnerships with other entities (to help monitor the structures). The HCP Tributary Committees suggested focusing on one watershed (e.g., in Mission, Peshastin, or Roaring creeks). The HCP Tributary Committees would like to know the effects of

BDAs on water temperatures, stream flows, and salmonid abundance. The HCP Tributary Committees also suggested exploring additional relationships. Hillman recalled Jeff Korth discussing results from beaver reintroduction efforts in the Methow River Basin, specifically that there were difficulties getting beavers to colonize, resulting in not being able to collect certain data. Hillman said this is why the HCP Tributary Committees requested specific data to help inform actions in the future.

- *Nason Creek River Mile 4.6 Channel Reconnection Project*: In 2013, the Rock Island HCP Tributary Committee agreed to partially fund this project. The goal of this project is to provide high-flow refugia and rearing habitat for adult and juvenile salmonids in Nason Creek by reconnecting a 4.6-acre, high-flow channel to the mainstem near river mile 4.6. Because Chelan County was unable to secure a cost share, the proposal will be resubmitted. In 2013, the project cost was about $525,000, and the Rock Island HCP Tributary Committee agreed to fund $88,000 at that time. Chelan County met with the U.S. Forest Service (USFS), and USFS is unwilling to approve reconnecting the upper end of the side channel because water will be on both sides of the road, which will increase the likelihood of eroding the road prism. Chelan County spoke with the Washington State Department of Transportation (WSDOT), and WSDOT did not have the same concern; however, USFS indicated support for a downstream-only connection. The Rock Island HCP Tributary Committee said this is now a vastly different project, and requested that Chelan County resubmit a new proposal. The Rock Island HCP Tributary Committee recommended that Chelan County continue seeking approval from USFS to reconnect the upstream end. If USFS approves, funds from the Rock Island Plan Species Account can be used for the upstream connection. Hillman said he believes the sponsor will ask the Bonneville Power Administration to fund the downstream connection; however, Chelan County does not want to push the upstream connection with USFS at this time.
  Casey Baldwin said it seems the Rock Island HCP Tributary Committee put up 15% for the Salmon Recovery Funding Board (SRFB) to match, and he asked why the remainder did not get funded. Hillman explained that higher priority projects received the available SRFB funds in 2013.
- *Silver Side-Channel Rehabilitation Project Presentation*: A couple years ago, the Rocky Reach HCP Tributary Committee approved funding for the design of enhancement work implemented in the lower portion of the Silver Side Channel in the Methow River basin. The purpose of the project is to increase habitat quality and quantity for salmonids within the side channel and floodplain corridor. USFWS provided a lengthy presentation, including before and after photographs of the construction process, evidence of improved channel complexity, improved fish passage, and restored riparian and floodplain habitat, among other things. Hillman said he believes USFWS or WDFW will also conduct fish monitoring in the future. He said the presentation was quite interesting and suggested contacting Robes Parrish (USFWS)

about providing the presentation to the Coordinating Committees. Hillman said he will provide Parrish's presentation to Kristi Geris for distribution to the Coordinating Committees. *(Note: the presentation was posted to the Coordinating Committees HCP Extranet Site [file was too large to email], and the Coordinating Committees were notified by Geris following the meeting on January 24, 2017.)*

- *Meeting Schedule*: The HCP Tributary Committees will continue to meet on the second Thursday of each month.
- *Next Steps*: The next meeting of the HCP Tributary Committees will be on March 9, 2017.

Hillman updated the Coordinating Committees on the following actions and discussions that occurred during the HCP Hatchery Committees meeting on January 18, 2017:

- *Representative Changes and Distribution Lists*: Casey Baldwin is now the CCT HCP Hatchery Committees Alternate. Brett Farman has been designated the new NMFS HCP Hatchery Committees Representative, and Charlene Hurst has also been designated the new NMFS HCP Hatchery Committees Alternate.
- *DECISION: Twisp Hatchery-origin Steelhead Gametes*: Douglas PUD indicated that WDFW and Cramer Fish Sciences are proposing to conduct a steelhead egg-to-fry survival study in the Twisp River. The purpose of the study is to provide estimates of egg-to-fry survival within the Twisp River to support estimates of survival throughout the range of steelhead spawning, and also to examine survival across different habitat conditions. The proposed approach involves burying 100 fertilized eggs in substrate in 12 different locations within the Twisp River. To conduct the study, WDFW and Cramer Fish Sciences requested fertilized eggs from three female and three male Twisp River hatchery steelhead from the Methow Fish Hatchery. Hillman said the HCP Hatchery Committees approved this request, except for NMFS, who are still discussing the request internally. Hillman noted that this work has already been performed in other places, and the proposed study is just filling a data gap in the Methow River Basin. *(Note: NMFS approved the study proposal via email on January 27, 2017.)*
- *Twisp Steelhead Program Broodstock Issues*: WDFW expressed concern that operation of the Twisp River Steelhead Program may pose long-term genetic risks to the Twisp River steelhead population. Corrective actions discussed could potentially create programmatic issues with regard to Section 10 permitting and may create further genetic issues. WDFW suggested further discussing this topic with the Joint Fisheries Parties and during future HCP Hatchery Committees meetings.
- *Chelan Falls Broodstock Collection Canal Trap Pilot Study Results*: Chelan PUD implemented a pilot study to trap summer Chinook salmon in an effort to determine an easier method for collecting summer broodstock for the Chelan Falls program. The pilot study was conducted in 2016 and was successful in collecting 100 summer Chinook salmon, including 51 males and

49 females. Because the warm water temperatures of the Chelan River have the potential to affect gamete quality of fish collected at the Chelan Falls Canal Trap, Chelan PUD evaluated the potential effects of high water temperature on gamete quality compared to fish collected in other locations. Results indicated that fish collected at the Chelan Falls canal trap had a slightly higher eye-up rate compared to fish collected at the Eastbank Outfall and Entiat National Fish Hatchery (93% compared to 91%). Chelan PUD will repeat the study in 2017.

- *Draft 2017 Rock Island and Rocky Reach HCP Action Plan*: The Rock Island and Rocky Reach HCP Hatchery Committees will review the draft plan, provide comments, and likely approve the hatchery portion during the next HCP Hatchery Committees meeting on February 15, 2017. Douglas PUD will likely present the Draft 2017 Wells HCP Action Plan at that time.
- *Genetic Analysis for HCP Program Species:* The HCP Hatchery Committees continued discussing timing of genetic sampling for all stocks in the Mid-Columbia River Basin. The HCP Hatchery Committees are coordinating with WDFW to determine whether sampling needs to occur every 5 years or some other frequency. The HCP Hatchery Committees are awaiting feedback from a geneticist.
- *Monitoring and Evaluation (M&E) Report Scheduling*: The HCP Hatchery Committees are discussing timing of hatchery M&E reporting. The HCP Hatchery Committees are still proposing completing an annual report, with no changes. However, the HCP Hatchery Committees want to add a statistical report, generated every 5 years, to analyze all data using statistics identified in the Hatchery M&E Plan, which can be used to determine whether the Hatchery M&E Plan needs adjusting. The statistical report will not include recommendations. Recommendations will be included in the comprehensive report, which will be drafted every 10 years. This reporting schedule is consistent with the respective HCPs; it will just align better with other HCP processes and there will be more information developed along the way to help inform HCP actions. The PUDs are preparing an SOA for consideration during the next HCP Hatchery Committees meeting on February 15, 2017. Ferguson asked who will conduct the statistical analyses. Hillman said this was not discussed; however, this task will likely fall under the same groups who draft the reports (i.e., WDFW, BioAnalysts, etc.).
- *Stray Rate Targets*: During the last HCP Hatchery Committees meeting on October 19, 2016, Grant PUD discussed stray rate targets and the possible need to revise the brood year stray rate target. During the January meeting, Grant PUD provided a presentation on stray rate targets for within population, among population, and brood year. The HCP Hatchery Committees do not wish to change the within or among population stray rate targets because they are based on extinction risk and are included in the Recovery Plan. On the other hand, the Hatchery M&E Plan does allow brood year stray rate targets to change if the best available information suggests it is appropriate to do so. The HCP Hatchery Committees

discussed a recently published paper (Ford et al. 2015)[2] showing stray rates in natural-origin spring Chinook salmon in the Wenatchee River basin. The paper indicates that stray rates can range from 1 to 100% depending on what spawning aggregate is considered. Hillman said Grant PUD plans to present a short white paper on brood year stray rates and the Committees will evaluate and determine if the brood year stray rate target needs adjusting. The current brood year stray rate target is 5%.

- *Next Steps*: The next meeting of the HCP Hatchery Committees will be on February 15, 2017.

V. HCP Administration

A. CCT HCP Alternate Representation (John Ferguson)

John Ferguson said a letter requesting Casey Baldwin be designated the CCT Alternate Representative for the HCP Hatchery Committees and Coordinating Committees was distributed to the Coordinating Committees by Kristi Geris on January 6, 2017. Ferguson clarified there is no approval process on designation of representatives; therefore, the letter serves as notification of the designation. *(Note: Baldwin has been added to the appropriate email distribution lists, has been given member access to the HCP Hatchery Committees and Coordinating Committees HCP Extranet Sites, and given visitor access to the HCP Tributary Extranet Site.)*

B. NMFS HCP-HC Representation (John Ferguson)

John Ferguson said a letter designating Brett Farman as the NMFS HCP Hatchery Committees Representative and Charlene Hurst as the NMFS HCP Hatchery Committees Alternate was distributed to the Coordinating Committees by Sarah Montgomery (HCP Hatchery Committees Support Staff) on December 23, 2016. Ferguson said the representation transition does not officially take effect until February 1, 2017. *(Note: Justin Yeager and Craig Busack [current NMFS HCP Hatchery Committees Representative and Alternate, respectively] will be removed from the HCP Hatchery Committees email distribution lists and have HCP Hatchery Committees HCP Extranet Site access deactivated on February 1, 2017.)*

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[2] Ford, M.J., A. Murdoch, and M. Hughes, 2015. Using parentage analysis to estimate rates of straying and homing in Chinook salmon (*Oncorhynchus tshawytscha*). *Molecular Ecology* 24:1109-1121. Doi: 10.1111/mec.13091

C. Coordinating Committees Email Distribution – Sarah Montgomery (John Ferguson)

John Ferguson said Sarah Montgomery was added to the "final CC agenda only," "draft CC minutes only," and "final CC minutes only" email distribution lists (same as Tracy Hillman), to help with administration and support of the HCPs.

D. Draft 2016 HCP Annual Reports (John Ferguson)

John Ferguson recalled that the HCP annual reports summarize activities performed under each HCP during a given year. He said the Draft 2016 Wells HCP Annual Report will be distributed to the Coordinating Committees by Kristi Geris for a 30-day review by the Coordinating Committees on Wednesday, February 8, 2017. He said the Draft 2016 Rock Island and Rocky Reach HCP Annual Reports will be distributed for a 30-day review by the Coordinating Committees on Thursday, February 16, 2017. *(Note: please coordinate review of the reports with respective HCP Tributary and Hatchery Committees representatives, as needed.)*

Geris sent an email to the Coordinating Committees on February 8, 2017, notifying them the Draft 2016 Wells HCP Annual Report is available for a 30-day review with edits and comments due to Geris by Wednesday, March 8, 2017. Geris sent an email to the Coordinating Committees on February 16, 2017, notifying them the Draft 2016 Rock Island and Rocky Reach HCP Annual Reports are available for a 30-day review with edits and comments due to Geris by Thursday, March 16, 2017.

E. Next Meetings

John Ferguson said, in October 2016, Bob Rose began discussing with Brian Burke (NMFS) about possibly presenting to the Coordinating Committees an update on his "Blob" presentation (last presented to the Coordinating Committees in October 2015). Ferguson recalled the last correspondence suggested providing the presentation to the PRCC and Coordinating Committees in February 2017. Ferguson said he also contacted Michelle Rub about possibly presenting an update on her presentation about pinniped predation in the Columbia River Estuary (last presented to the Coordinating Committees in June 2015). Scott Carlon said Rub is providing a presentation during the PRCC meeting tomorrow, January 25, 2017. Carlon said he believes the presentation is regarding requesting No Net Impact funds to conduct research on trap designs to further study pinniped predation. He said this presentation may be separate from the one Rub last provided to the Coordinating Committees. Ferguson said Burke indicated he is available to present during the Coordinating Committees meeting on February 28, 2017, but Ferguson has not yet received a response from Rub. Ferguson said he will follow-up with Rub regarding possibly presenting during a future meeting.

The February 28, 2017, meeting will be held in-person at the Grant PUD Wenatchee Office in Wenatchee, Washington. The March 28, 2017, and April 25, 2017, meetings will be held by conference call or in-person at the Grant PUD Wenatchee Office in Wenatchee, Washington, as is yet to be determined.

F. List of Attachments

Attachment A	List of Attendees
Attachment B	2016/2017 Rock Island and Rocky Reach Dams Adult Fish Ladder Maintenance Period, Fish Rescue Numbers
Attachment C	Wells Dam East Fishway Fish-Salvage Memorandum
Attachment D	Wells Dam West Fishway Fish-Salvage Memorandum

Attachment A
List of Attendees

Name	Organization
John Ferguson	Anchor QEA, LLC
Kristi Geris	Anchor QEA, LLC
Tracy Hillman†	BioAnalysts
Lance Keller*	Chelan PUD
Alene Underwood††	Chelan PUD
Steve Hemstrom*††	Chelan PUD
Catherine Willard†††	Chelan PUD
Tom Kahler*	Douglas PUD
Scott Carlon*	National Marine Fisheries Service
Jim Craig*	U.S. Fish and Wildlife Service
Casey Baldwin*	Colville Confederated Tribes
Bob Rose*	Yakama Nation

Notes:
* Denotes Coordinating Committees member or alternate
† Joined by phone for the HCP Tributary and Hatchery Committees Update
†† Joined for select Chelan PUD items
††† Joined by phone for select Chelan PUD items

From: Kristi Geris
To: Kristi Geris
Subject: RE: Summary CPUD Adult Ladder Fish Rescue Numbers
Date: Thursday, February 16, 2017 6:24:14 PM

From: Keller, Lance [mailto:Lance.Keller@chelanpud.org]
Sent: Thursday, February 16, 2017 11:25 AM
To: Kristi Geris <kgeris@anchorqea.com>
Subject: Summary CPUD Adult Ladder Fish Rescue Numbers

Results From Rock Island Right Adult Ladder Fish Rescue

Species	Alive	Mortalities
Wild Rainbow Trout/Steelhead	23	0
Hatchery Rainbow Trout/Steelhead	8	0
Northern Pikeminnow	2	0
Wild Summer Chinook Smolt	6	0
Smallmouth Bass	2	0
Sucker	7	0
Adult Lamprey	100	0
Chiselmouth	1	0
Red Sided Shiner	40	0
Three-Spined Stickleback	12	0

Results From Rock Island Center Adult Ladder Fish Rescue

Species	Alive	Mortalities
Wild Rainbow Trout/Steelhead	4	0
Northern Pikeminnow	1	0
Sculpin	1	0

Results From Rock Island Left Adult Ladder Fish Rescue

Species	Alive	Mortalities
Wild Rainbow Trout/Steelhead	11	0
Hatchery Rainbow Trout/Steelhead	2	0

Results From Rocky Reach Adult Ladder Fish Rescue

Species	Alive	Mortalities
Wild Rainbow Trout/Steelhead	24	1
Hatchery Rainbow Trout/Steelhead	49	5

Mountain Whitefish	101	15
Adult Lamprey	169	0
Sucker	2	0
Shiner	2	0
Sculpin	1	0
Sandroller	1	0
Wild Adult Steelhead	1	0
Wild Cutthroat Trout	1	0
Wild Chinook Smolt	1	0
Bull Trout	1	0

Lance Keller
Senior Fisheries Biologist
Chelan County PUD #1
Office: 509-661-4299
Cell: 509-669-8722
E-mail: lance.keller@chelanpud.org

Memorandum

TO: Scott Carlon, NOAA National Marine Fisheries Service
FROM: Tom Kahler, Douglas PUD
SUBJECT: Fish Salvage During Annual Maintenance Outage of Wells Dam East Fishway
DATE: December 9, 2016

The Wells Dam east fishway was taken out of service for annual maintenance on the morning of December 7, 2016. At 8:30 AM, we closed the ladder exits, and at 9:30 AM commenced operations to salvage fish remaining in the ladder, and completing those operations shortly after 11:30 AM. We released salvaged fish to the Columbia River above the dam (Wells Project boat launch on the east embankment).

We completed the dewatering of the east fishway by draining the collection gallery on December 8, 2016, commencing fish-salvage operations around 1:50 PM when water depth receded to a level that allowed entry by the salvage crew, and completing those operations around 2:45 PM. We released salvaged fish to the Columbia River above the dam (Wells Project boat launch on the east embankment).

The following tables summarize the fish salvaged from both the ladder and collection gallery.

Actual number of fishes salvaged from the east ladder at Wells Dam on December 7, 2016

Species	Live	Dead
Whitefish	98	0
Chiselmouth	4	0
Oncorhynchus mykiss	13	0
O. tshawytscha (parr)	1	0

Estimated numbers of fish salvaged from the east-fishway collection gallery at Wells Dam on December 8, 2016

Species	Live	Dead
O. mykiss	8	0
O. tshawytscha (parr)	1	0
Northern Pikeminnow	13	0
Sculpin sp	2	1
Whitefish spp	28	0
Sticklebacks	18	2

c: Wells HCP Coordinating Committee,
Ritchie Graves, NOAA NMFS

Memorandum

TO: Scott Carlon, NOAA National Marine Fisheries Service
FROM: Tom Kahler, Douglas PUD
SUBJECT: Fish Salvage During Annual Maintenance Outage of Wells Dam West Fishway
DATE: January 19, 2017

The Wells Dam west fishway was taken out of service for annual maintenance on the morning of January 16, 2017. At 9:00 AM, we closed the ladder exits, and at 10:30 AM commenced operations to salvage fish remaining in the ladder, and completed those operations shortly after 12:00 PM. We released salvaged fish to the Columbia River at the Wells Project boat launch near the Wells Hatchery outfall.

A failed gate motor on the fishway entrance prevented the completion of the dewatering of the collection gallery on January 17 as scheduled, and necessitated the rescheduling of salvage activities for January 19. We completed the dewatering of the west fishway by draining the collection gallery on January 19, 2017, commencing fish-salvage operations around 10:40 AM when water depth receded to a level that allowed entry by the salvage crew, and completed those operations around 11:25 AM. We released salvaged fish to the Columbia River at the Wells Project boat launch near the Wells Hatchery outfall.

The following tables summarize the fish salvaged from both the ladder and collection gallery.

Actual number of fishes salvaged from the west ladder at Wells Dam on January 16, 2017

Species	Live	Dead
Whitefish spp (Mountain and Lake)	43	0
Oncorhynchus mykiss	10	3*
O. tshawytscha (parr)	1	0

*The three mortalities were residual hatchery steelhead

Estimated numbers of fish salvaged from the west-fishway collection gallery at Wells Dam on January 19, 2017

Species	Live	Dead
O. mykiss	12	0
Burbot (with prey fish protruding from mouth)	1	0
Northern Pikeminnow	7	1
Sculpin spp	4	0
Suckers	9	1
Whitefish	20	0
Peamouth Chub	15	0
Sticklebacks	20	1


Burbot (*Lota lota*), with prey, captured in the Wells Dam west-fishway collection gallery on January 19, 2017.

c: Wells HCP Coordinating Committee,
Ritchie Graves, NOAA NMFS

FINAL

720 Olive Way, Suite 1900
Seattle, Washington 98101
206.287.9130

ANCHOR QEA

Memorandum

To: Wells, Rocky Reach, and Rock Island HCPs Coordinating Committees

Date: March 30, 2017

From: John Ferguson, HCP Coordinating Committees Chairman

cc: Kristi Geris

Re: Final Minutes of the February 28, 2017, HCP Coordinating Committees Meeting

The Wells, Rocky Reach, and Rock Island Hydroelectric Projects Habitat Conservation Plans (HCPs) Coordinating Committees met at the Grant PUD Office in Wenatchee, Washington, on Tuesday February 28, 2017, from 10:00 a.m. to 1:00 p.m. Attendees are listed in Attachment A to these meeting minutes.

Action Item Summary

- Alene Underwood (Chelan PUD Fish and Wildlife Program Manager) will provide Chelan PUD's comments on the Federal Columbia River Power System (FCRPS) National Environmental Policy Act (NEPA) Scoping Process to Kristi Geris for distribution to the Coordinating Committees (Item I-C).
- Tom Kahler will provide fish passage count data for winter months at Wells Dam for review regarding timing of winter maintenance at Wells Dam to Kristi Geris for distribution to the Coordinating Committees (Item I-C).
- John Ferguson will request from Michelle Rub (National Marine Fisheries Service [NMFS]) an estimation of survival of adult spring/summer Chinook salmon from the Columbia River estuary to Bonneville Dam in 2016 (Item I-C). *(Note: Rub indicated she does not yet have a final estimate for 2016, as distributed to the Coordinating Committees by Kristi Geris on March 13, 2017.)*
- Lance Keller will discuss internally proposals regarding the Rock Island and Rocky Reach Coho Salmon Phase Designation and report back to the Coordinating Committees with a recommended path forward that will be discussed during the meeting on March 28, 2017 (Item III-A).
- Lance Keller will inquire internally about the basis for the fish spill patterns implemented at Rock Island and Rocky Reach dams, as well as how these patterns are evaluated for efficacy (Item III-C).
- Tom Kahler will finalize the 2015 Douglas PUD Pikeminnow Program Annual Report and provide the final report to Kristi Geris for distribution to the Coordinating Committees (Item IV-A). *(Note: Kahler provided the final report to Geris prior to the meeting on March 28, 2017, which Geris distributed to the Coordinating Committees that same day.)*

- **The Coordinating Committees meeting on March 28, 2017, will be held in-person at the Grant PUD office in Wenatchee, Washington (Item V-A).**

Decision Summary

- The Wells HCP Coordinating Committee approved the 2016 Wells HCP Annual Report after no disapprovals were received prior to the 30-day review deadline.

Agreements

- There were no HCP Agreements discussed during today's meeting.

Review Items

- Kristi Geris sent an email to the Coordinating Committees on February 8, 2017, notifying them the Draft 2016 Wells HCP Annual Report is available for a 30-day review with edits and comments due to Geris by Friday, March 10, 2017.
- Kristi Geris sent an email to the Coordinating Committees on February 16, 2017, notifying them the Draft 2016 Rock Island and Rocky Reach HCP Annual Reports are available for a 30-day review with edits and comments due to Geris by Monday, March 20, 2017.
- Kristi Geris sent an email to the Coordinating Committees on February 17, 2017, notifying them the Draft 2016 Rocky Reach Juvenile Fish Bypass System (RRJFBS) Report is available for a 30-day review, with edits and comments due to Lance Keller by Monday, March 20, 2017.
- Kristi Geris sent an email to the Coordinating Committees on February 22, 2017, notifying them the Draft 2017 Rock Island and Rocky Reach Fish Spill Plan is available for a 30-day review with edits and comments due to Lance Keller by Friday, March 24, 2017 (Item III-C).
- Kristi Geris sent an email to the Coordinating Committees on February 23, 2017, notifying them the Draft 2017 Wells HCP Action Plan is available for review. Douglas PUD will request approval of the plan during the Coordinating Committees meeting on March 28, 2017.
- Kristi Geris sent an email to the Coordinating Committees on March 1, 2017, notifying them the Draft Rocky Reach Total Dissolved Gas Alternative Analysis Report is available for review with edits and comments due to Marcie Clement (Chelan PUD) by April 1, 2017.
- Kristi Geris sent an email to the Coordinating Committees on March 3, 2017, notifying them the Draft 2017 Broodstock Collection Protocols are available for an expedited review. Douglas PUD will request approval of the protocols during the Coordinating Committees meeting on March 28, 2017.

Finalized Documents

- Kristi Geris sent an email to the Coordinating Committees on March 24, 2017, notifying them that the 2016 Wells HCP Annual Report was finalized following a 30-day review period, which ended on March 10, 2017. Comments received on the draft report were incorporated into the final report.
- The Final 2015 Douglas PUD Pikeminnow Program Annual Report was distributed to the Coordinating Committees by Kristi Geris on March 28, 2017.

I. Welcome

A. Review Agenda (John Ferguson)

John Ferguson welcomed the Coordinating Committees and reviewed the agenda. Ferguson asked for any additions or changes to the agenda. Tom Kahler added an update on the 2015 Douglas PUD Pikeminnow Program Annual Report.

B. Meeting Minutes Approval (John Ferguson)

The Coordinating Committees reviewed the revised draft January 24, 2017, meeting minutes. Kristi Geris said a second revised draft was distributed to the Coordinating Committees on February 22, 2017, which included corrections to document and review item dates. Geris said she also added the Draft 2017 Wells HCP Action Plan under the review items, which will be a decision item for Douglas PUD during the Coordinating Committees meeting on March 28, 2017. Geris said all comments and revisions received from members of the Committees were incorporated into the revised minutes. Coordinating Committees members present approved the January 24, 2017, meeting minutes, as revised. The Washington Department of Wildlife (WDFW) abstained, because a WDFW representative was not present during the January 24, 2017, meeting.

C. Last Meeting Action Items (John Ferguson)

Action items from the Coordinating Committees meeting on January 24, 2017, and follow-up discussions, were as follows. *(Note: italicized text corresponds to agenda items from the meeting on January 24, 2017):*

- *Alene Underwood will provide Chelan PUD's comments on the FCRPS NEPA Scoping Process to Kristi Geris for distribution to the Coordinating Committees (Item II-B).*
  This action item will be carried forward.
- *Lance Keller will revise the draft Statement of Agreement (SOA), "Acknowledgement of Rock Island Powerhouse 1 Units B1-B4 Consultation," as discussed, and will provide the revised draft SOA to Kristi Geris for distribution to the Coordinating Committees (Item II-C).*

The revised draft SOA was distributed following the meeting on January 24, 2017, and was available for a 10-day review with vote via email due to Keller by Friday, February 3, 2017 (the SOA was approved, as reflected in the Coordinating Committees meeting minutes from January 24, 2017).

- *Lance Keller will revise the Draft 2017 Rock Island and Rocky Reach HCP Action Plan, as discussed, and will provide the revised draft plan to Kristi Geris for distribution to the Coordinating Committees (Item II-D).*

  The revised draft plan was distributed following the meeting on January 24, 2017, and is available for review with edits and comments due to Keller by Wednesday, February 22, 2017.
- *Lance Keller will provide fish rescue numbers from the 2016/2017 Rock Island and Rocky Reach dams adult fish ladder maintenance periods to Kristi Geris for distribution to the Coordinating Committees (Item II-E).*

  Keller provided fish rescue numbers to Geris on February 16, 2017, which Geris distributed to the Coordinating Committees on February 17, 2017.
- *Lance Keller will notify the Rocky Reach HCP Coordinating Committee when the Rocky Reach Dam adult fish ladder is brought back online from the 2016/2017 Rocky Reach Dam adult fish ladder maintenance period (Item II-E).*

  Keller provided notification that the Rocky Reach Dam adult fishway was returned to service on February 14, 2017, which was distributed to the Coordinating Committees by Kristi Geris that same day.
- *Tom Kahler will provide fish passage count data for winter months at Wells Dam for review regarding timing of winter maintenance at Wells Dam to Kristi Geris for distribution to the Coordinating Committees (Item III-A).*

  This action item will be carried forward.
- *Tom Kahler will notify the Wells HCP Coordinating Committee when the Wells Dam west fishway is brought back online from the 2016/2017 Wells Dam fishway maintenance period (Item III-A).*

  Kahler provided this notification to Kristi Geris on February 21, 2017, which Geris distributed to the Coordinating Committees that same day.
- *Tracy Hillman (HCP Tributary Committees Chairman) will provide U.S. Fish and Wildlife Service's (USFWS's) presentation on the Silver Side-Channel Rehabilitation Project to Kristi Geris for distribution to the Coordinating Committees (Item IV-A).*

  The presentation was posted to the Coordinating Committees HCP Extranet Site (file was too large to email), and the Coordinating Committees were notified by Geris following the meeting on January 24, 2017.
- *John Ferguson will follow up with Michelle Rub regarding possibly presenting an update on her presentation, "Estimation of Survival and Run Timing of Adult Spring/Summer Chinook from the*

Columbia River Estuary to Bonneville Dam," to the Coordinating Committees during a future meeting (Item V-E).

Ferguson said he contacted Rub and she indicated she recently provided a comprehensive presentation on her work to the Priest Rapids Coordinating Committee (PRCC) and suggested providing another presentation after more data are collected in 2017. Tom Kahler noted that he and Lance Keller did not attend the presentation to the PRCC and would be interested in obtaining the 2016 estimation of survival of adult spring/summer Chinook salmon from the Columbia River estuary to Bonneville Dam. Ferguson said he will request this from Rub. *(Note: Rub indicated she does not yet have a final estimate for 2016, as distributed to the Coordinating Committees by Kristi Geris on March 13, 2017.)*

II. HCP Tributary and Hatchery Committees Update

A. HCP Tributary and Hatchery Committees Update (Tracy Hillman)

Tracy Hillman reported that the HCP Tributary Committees did not meet in February 2017 and plan to meet next on March 9, 2017.

Hillman updated the Coordinating Committees on the following actions and discussions that occurred during the HCP Hatchery Committees meeting on February 15, 2017:

- *DECISION: Draft 2017 Rock Island and Rocky Reach HCP Action Plan*: The HCP Hatchery Committees received the Draft 2017 Rock Island and Rocky Reach HCP Action Plan in January 2017 and in February 2017, the Rock Island and Rocky Reach HCP Hatchery Committees approved the hatchery portion of the plan. The HCP Tributary Committees will review the tributary portion in March 2017. Hillman added that the HCP Tributary Committees will also review the tributary portion of the Draft 2017 Wells HCP Action Plan in March 2017.
- *Egg-to-Fry Survival Study in the Twisp River*: In January 2017, the HCP Hatchery Committees approved the use of surplus Twisp River steelhead for a pilot study on egg-to-fry survival. Douglas PUD in consultation with the lead on the study, Phil Roni (Cramer Fish Sciences), has now decided to switch the focus of the study to spring Chinook salmon (instead of steelhead). Jeff Korth asked what the driver was to change the study. Tom Kahler explained that in the Upper Columbia River basin, spring Chinook salmon are the only endangered species. He said with regard to lifecycle, Douglas PUD has data for spring Chinook salmon at all life stages but egg-to-fry and fry-to-parr. He said, therefore, obtaining a complete dataset for spring Chinook salmon is more urgent than for steelhead.
- *USFWS Bull Trout Consultation Update*: USFWS is in the process of finalizing the draft Biological Opinion covering hatchery programs in the Wenatchee basin. However, the process is on hold because Chelan PUD and WDFW have not yet provided comments.

- *NMFS Consultation Update*: NMFS has signed the permits for Methow spring Chinook salmon, which will then be sent to the permittees for signature. Kahler said Douglas PUD received and signed the permits. Korth said WDFW received the permits, which are now in Olympia, Washington, for signature. Hillman said comments were also received on the Colville Confederated Tribes (CCT) Tribal Resources Management Plan (TRMP). Casey Baldwin said the CCT received the comments and are incorporating some edits into the TRMP. He said the CCT are expecting authorization within days.
- *Draft 2017 Broodstock Collection Protocols:* Typically, in February of each year, WDFW provides draft broodstock collection protocols to the HCP Hatchery Committees for review and approval (per the SOA, *Annual Broodstock Collection Protocols*, approved by the HCP Hatchery and Coordinating Committees on September 17 and October 28, 2014, respectively). This year, however, WDFW did not yet have the spring Chinook salmon forecast and could not finish the draft protocols for review during the month of February. WDFW has the forecast now, and the protocols will be provided to the HCP Hatchery Committees before the HCP Hatchery Committees meeting on March 13, 2017. The protocols will also require review and approval by the Wells HCP Coordinating Committee.
- *Spring Chinook Salmon Outplanting in the Chewuch River*: The HCP Hatchery Committees developed a draft plan for outplanting surplus MetComp fish in the Chewuch River, with the goal of determining whether these fish stay in the Chewuch River. The fish will be planted at two locations, including near the Chewuch campground (upstream from the uppermost Chewuch River passive integrated transponder [PIT] array), and then downstream by the Memorial Bridge (upstream from the lower Chewuch River PIT array). The fish will be monitored for movement and will be evaluated for potential spawning success (female carcasses will be examined for egg retention). A final plan is expected to be approved during the HCP Hatchery Committees meeting on March 13, 2017.
- *Hatchery Monitoring and Evaluation Report Scheduling*: The HCP Hatchery Committees have been discussing the timing of hatchery monitoring and evaluation (M&E) reporting in the future (including annual reporting), creating an updated 5-year statistical report (to replace the 5-year report currently specified in the Hatchery M&E Plan), and continuing the 10-year program review report. The HCP Hatchery Committees discussed including more statistics in the annual report to help inform development of the Hatchery M&E Plan, and then the 5-year statistical report can be more about comparing supplemented and un-supplemented populations. The HCP Hatchery Committees also discussed synchronizing the 5-year statistical report with the 10-year program review report. Currently, the 5-year statistical report is scheduled to be completed in 2018, and the 10-year program review report is scheduled for 2020 (2-year gap). The HCP Hatchery Committees decided to align the two reports to avoid the need of developing additional statistical analyses. A final reporting schedule is expected to

be approved during the HCP Hatchery Committees meeting on March 13, 2017. Kahler asked if a 5-year statistical report and 10-year program review report will be prepared when the deadlines align. Hillman said the 10-year program review report includes the information in the 5-year statistical report; therefore, only the 10-year program review report will be written in overlapping years.

- *Expanded Sampling at the Off-ladder Fish Trap*: The HCP Hatchery Committees discussed a proposal by WDFW to expand sampling at the off-ladder fish trap (OLAFT) with the purpose of increasing monitoring to include evaluation of spring Chinook salmon. The proposal includes PIT-tagging spring Chinook salmon and operating the OLAFT earlier (instead of trapping from July to mid-November, start trapping in mid-April through November). This schedule captures the spring Chinook salmon run-at-large, which improves estimates of abundance and escapement, and informs proportion of hatchery-origin spawners and proportionate natural influence. WDFW wants to verify the HCP Hatchery Committees support for this proposal before moving forward. If approved, this plan may result in less trapping at Tumwater and Wells dams. The HCP Hatchery Committees requested WDFW prepare a white paper outlining the proposal. Kahler asked when WDFW would like to implement this plan, and Korth said this spring 2017. Hillman added that the 2017 Broodstock Collection Protocols were drafted to include flexibly in case the plan with the OLAFT is approved.
- *Stray Rate Targets*: Todd Pearsons (Grant PUD) provided a presentation on stray rates to the HCP Hatchery Committees in January 2017, and the HCP Hatchery Committees requested Pearson provide a white paper. The HCP Hatchery Committees reviewed and discussed the white paper; however, the Committees were unable to reach resolution on stray rate targets. Three stray rate targets were discussed. Two targets are related to the recipient stock, which are linked to extinction risk and are included in the Recovery Plan; therefore, the HCP Hatchery Committees will not change those. The other target stipulates a 5% brood-year stray rate (i.e., among the brood year released, 95% need to return to the natal stream). There seems to be no scientific justification for the 5% value. The Hatchery M&E Plan indicates if empirical data suggest a different stray rate, then the target can be re-evaluated. Ford et al. (2015)[1] addressed this and indicated that stray rates can range from 1 to 100% depending on what spawning aggregate is considered. The HCP Hatchery Committees are now considering setting a management goal for a brood-year stray rate.

[1] Ford, M.J., A. Murdoch, and M. Hughes, 2015. Using parentage analysis to estimate rates of straying and homing in Chinook salmon (*Oncorhynchus tshawytscha*). *Molecular Ecology* 24:1109-1121. Doi: 10.1111/mec.13091.

- *Next Steps*: The next meeting of the HCP Hatchery Committees will be on Monday, March 13, 2017.

III.Chelan PUD

A. DECISION: Rock Island and Rocky Reach Coho Salmon Phase Designation (Lance Keller, Steve Hemstrom, and Catherine Willard)

Lance Keller said the draft SOA, "Designation of Rock Island and Rocky Reach Juvenile Coho in Phase III (Standard Achieved)," (Attachment B), and the report by John Skalski (Skalski Statistical Services) and Rich Townsend (Columbia Basin Research), "Comparison of Juvenile Survival of Chinook Salmon, Sockeye Salmon, Steelhead, and Coho Salmon through the Chelan PUD Projects, 2010–2016," (Attachment C), were distributed to the Coordinating Committees by Kristi Geris on February 15, 2017. Keller said Skalski's and Townsend's report (Attachment C) summarizes those data included in the draft SOA (Attachment B). Keller said the draft SOA background section reviews the history of previous SOAs and summarizes a comparison of data illustrating that juvenile spring Chinook and coho salmon survive similarly through the hydrosystem, which translates into a ratio that is applied to Rock Island and Rocky Reach juvenile spring Chinook salmon survival rates to generate values for juvenile coho salmon. He said the last page of the draft SOA includes the math of the conversion (or adjustment) for the Rock Island and Rocky Reach Projects. He read the draft SOA agreement statement and noted the last sentence is key; the data presented indicate yearling Chinook salmon are a good surrogate for juvenile coho salmon, resulting in 93% survival for coho salmon at Rock Island and Rocky Reach projects.

John Ferguson said projected coho salmon survival through the Rocky Reach Project was calculated to be 92.94% with a standard error of 0.0081, and the Rock Island Project was calculated to be 93.98% with a standard error of 0.0233. Keller said that is correct. Jeff Korth asked if 93% is the standard, and Keller said yes, it is. Keller told Korth (who was unable to attend the last meeting), that during the last Coordinating Committees meeting on January 24, 2017, Steve Hemstrom thoroughly explained the analyses included in the draft SOA. Keller said these analyses are similar to the Grant PUD data, i.e., same approach and utilizing PIT-tag data. Korth asked how this designation aligns with the next 10-year check-in. Keller said this would put coho salmon on the same track as the other Plan species, with a check-in for the Rock Island HCP in 2020 and for the Rocky Reach HCP in 2021.

Bob Rose said the Yakama Nation (YN) are uncomfortable with the way the draft SOA is stated. Casey Baldwin said after Hemstrom's presentation last month, the CCT are comfortable with the draft SOA. Jim Craig said USFWS is also comfortable with the draft SOA. He added that this SOA has been discussed for several months now. Ferguson agreed with Craig, noting the several iterations of reports Skalski and Townsend updated.

Keller said approving this SOA in the Coordinating Committees allows Chelan PUD to move forward with developing a hatchery compensation plan with the HCP Hatchery Committees, given the 93% value. Rose said he understands the application of this SOA with regard to moving forward with developing a hatchery compensation plan. He said he believes the data included in the SOA can still be used for that purpose; however, using these data for re-designation is the issue. He said 92.94% is not 93%. He said the way the SOA is stated sets an element of permanency. Ferguson said he is not certain phase designation can be separated from the hatchery compensation process. Keller said Chelan PUD understands that mean coho salmon survival at the Rocky Reach Project is below 93% by 0.06%; however, the mean at the Rock Island Project is almost a full percentage point above 93%. He recalled that the SOA, "Regarding District's Coho Obligation" (approved by the Rock Island and Rocky Reach HCP Coordinating Committees on June 26, 2007), states:

> "Juvenile coho [salmon] survival studies will not be performed unless there is compelling[2] information that demonstrates hydro project operations have an impact of greater than 7% mortality on coho [salmon]."

Keller said Chelan PUD believes these data can be used to provide comfort that this is not the case. He said compelling evidence is not leaning toward a large effect on juvenile coho salmon. Ferguson also noted there are multiple years of data behind these values. Korth said he typically does not view the mean to be the most important factor; rather, he becomes concerned when the standard errors are out of bounds. Ferguson agreed.

Rose said he believes the Coordinating Committees can disassociate the phase designation aspect of this SOA from what the HCP Hatchery Committees need to move forward with developing a hatchery compensation plan. He added that he does not want to hold up the HCP Hatchery Committees; however, the YN wants to further discuss the phase designation. Ferguson asked what this changes. Keller said he views the designation, Phase III (Standard Achieved), as tied to the 93% value. He said, if the Coordinating Committees provide the HCP Hatchery Committees with 92.94% survival for juvenile coho salmon, this is not really Phase III (Standard Achieved). He said, however, using the

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[2] "Compelling" evidence could relate to information collected as part of the hatchery monitoring and evaluation program. For example, smolt-to-adult survivals for coho [salmon] that are significantly lower than other species in the same geographical area may be compelling evidence that coho [salmon] are experiencing differential mortality rates at project passage. In all cases, the evidence should be empirical and related to Project survival.

values from the analysis and considering the standard errors better demonstrates how 93% survival for coho salmon at Rock Island and Rocky Reach projects is reasonable. He added that the analyses show how close to 93% the Rocky Reach Project is, and there is room to spare in the Rock Island Project.

Rose said Keller is making a fundamental assumption that survival through the Rock Island and Rocky Reach projects can be combined. Rose said with the way the HCPs are written, he does not believe Chelan PUD has the ability to do this. Keller asked if Rose is suggesting separate SOAs for each Project. Rose said he is noting that the Rocky Reach and Rock Island projects are different Projects, and it seems Chelan PUD is proposing a relationship similar to the Grant PUD Priest Rapids and Wanapum projects, under the Grant PUD Salmon and Steelhead Settlement Agreement. Keller said Chelan PUD understands Rock Island and Rocky Reach are two different HCPs, and the reason Chelan PUD is proposing one SOA is consistent with the 2007 SOA. Keller said he understands Rose's point, and Keller said his intention is simply to look at the picture as a whole. Rose said he is struggling with that notion, and setting these precedents is bothersome.

Baldwin asked about the downside of continuing in Phase III (Standard Achieved – Interim Value) for juvenile coho salmon for the Rocky Reach Project. Keller said the goal of the Rocky Reach HCP is to achieve Phase III (Standard Achieved). He said Chelan PUD would like to use Skalski's and Townsend's analyses to show the goal has been achieved. He said data were reviewed for the natural juvenile coho salmon run through the Juvenile Bypass System at the Rocky Reach Project, and most likely, a study would not be feasible due to low sample size. He said Skalski's and Townsend's analyses are the best-available data for moving forward. He said achieving Phase III (Standard Achieved) would align coho salmon with the other Plan species with regard to the 10-year check-in.

Rose said there is a difference between best-available data and sufficient data. He said just because these are the data in-hand, does not mean it is enough. Ferguson said Chelan PUD is just saying this is a good dataset. He said 93% at both Projects falls well within the confidence intervals. He reiterated that it is not the mean that counts, it is how tight the dataset is. He said, in this case, the dataset is awfully tight.

Hemstrom said Chelan PUD would approach coho salmon in the same manner as the other Plan species if there was the ability to; however, there is not. He said the Projects could be split into two SOAs; however, the data would be the same as presented in the single SOA. He said Chelan PUD strives to meet the goals established in the HCPs and is attempting to do so with the data that are available. He asked Rose if he had suggestions about what to do alternatively.

Rose said he is interested in being explicit to the HCPs. He said, in this case, there probably should be two SOAs, which is more appropriate with regard to the separate HCPs. He said Section 5.2.2 of the Rocky Reach HCP states:

> "If Juvenile Project Survival for each Plan Species is measured to be greater than or equal to 93%, then the District will proceed to Phase III (Standard Achieved)."

Rose said the HCP does not say 92%, plus or minus some value. He said he wants to avoid setting this precedence, which could turn into a slippery slope. He said there is no clear rationale to do something different than what was agreed to in the HCPs. Korth said he understands Rose's point; however, he noted that this circumstance is not nearly as egregious as what has occurred in other committees. Ferguson noted that the HCP also does not specify mean, average, or otherwise, and he would hope that the HCP Coordinating Committees would not be affected by the actions of other committees. He said 93% could be an absolute level or fall within the 95% confidence interval. He said the Coordinating Committees could interpret this in several ways. Baldwin added that the HCP could be interpreted as both the mean and standard error need to be above 93%, which may never be achieved. He said he is not proposing this; however, if the HCP does not say 'mean,' it could be interpreted this way. Ferguson said, if Chelan PUD writes an SOA that states the Rock Island Project meets the standard, but the Rocky Reach Project does not, given the data, it seems the error is larger around 93.98%, which means there is more uncertainty around the Rock Island Project than the Rocky Reach Project. Rose said this is the problem; twisting the language around. He said he disagrees with these interpretations. He said, if these details were intended when writing the HCPs, they would have been written this way. He said he does not believe the Coordinating Committees have this leeway to go with these interpretations.

Rose said the YN are not yet ready to vote on this draft SOA. He suggested instead, two SOAs, providing the HCP Hatchery Committees with 92.94% to move forward with hatchery compensation planning and continuing to discuss coho salmon phase designation for the Rocky Reach Project during the Coordinating Committees meeting on March 28, 2017. Ferguson asked if the proposed Rock Island Project SOA would indicate Phase III (Standard Achieved), and Rose said this is correct. Rose added, he is only uncomfortable with the proposed Phase III (Standard Achieved) designation for the Rocky Reach Project. Keller questioned if Chelan PUD writes two different SOAs, should the Rock Island Project SOA indicate 93.98% instead of only 93%. Craig asked if this would reduce the coho salmon compensation for that Project, and Keller said yes, it would. Keller also questioned, if discussions are coming down to these numbers (small percentages), should Chelan PUD include the numbers from Skalski's and Townsend's report.

Scott Carlon said he is comfortable with Chelan PUD producing two SOAs. Rose asked Carlon what he thinks about only one SOA. Carlon replied that two SOAs is the cleanest approach for purposes of explaining this in layman terms.

Korth said, next year, 2017 data can be added and the analyses can be recalculated. Keller questioned then, what the duration of the Rocky Reach Project SOA would be. He said Chelan PUD is essentially building a hatchery compensation program based on the SOA and its duration. He asked if the analyses are recalculated, is the hatchery compensation only good for 1 year. Korth asked what does the HCP state regarding adding other data. Tom Kahler said the Wells HCP stipulates anytime a survival study is conducted, that value is included in a multi-year-average value and hatchery compensation is based on that new value for subsequent brood years. Keller said he believes the Rocky Reach and Rock Island HCPs stipulate the same.

Keller said one option would be to draft a 10-year SOA using the interim value stated in the 2007 SOA, and have the HCP Hatchery Committees develop a hatchery program based on that value. Ferguson said this option would avoid a hatchery compensation that fluctuates up and down. Keller agreed, noting that a fluctuating compensation would affect a lot of moving parts, including planning and permitting.

Ferguson asked how much work is involved to operate under an annual number if mitigation for the Rocky Reach Project is adjusted each year with new PIT-tag data. Catherine Willard (Chelan PUD HCP Hatchery Committees Alternate Representative) said this is something that would be applied to future years. She said whatever is determined for 2017 would be applied to brood year 2019. She said there is no way to adapt the program that quickly. She said, in terms of percentages, 93% versus 93.98%, converted to number of smolts, for mitigation the difference is not very large. Korth added that the hatchery permits incorporate a level of flexibility that would accommodate the types of adjustments being discussed.

Hemstrom said the Rock Island and Rocky Reach projects have operated under the 2007 SOA, which assumed 93% survival and compensated 7% for coho salmon for both Projects. He said if Chelan PUD drafts two separate SOAs, with Rock Island establishing Phase III (Standard Achieved) and Rocky Reach not quite at 93%, he asked if compensation would continue at 7% for the Rocky Reach Project. Willard said this is correct. Ferguson asked about the duration of the SOA for the Rocky Reach Project. Korth suggested assigning an appropriate duration that avoids an annual check-in. Ferguson suggested drafting a 5-year SOA. He added that if Chelan PUD continues recalculating the data each year and the Rocky Reach Project achieves 93% survival for coho salmon, Chelan PUD can draft a new SOA. Rose said he does not recall the Coordinating Committees ever discussing this topic in the past because there was no need to. He said, however, he is also uncomfortable with the notion of just considering the average each year, and when the average finally reaches 93%, this is considered acceptable. He suggested instead establishing a block of time. He said he does not believe phase designation should be considered on an annual basis. Korth asked Rose what block of time would he be comfortable with. Rose said 5 years may be sufficient. He also suggested aligning the SOA with the next check-in for the Rocky Reach Project (2021).

Keller said because this draft SOA has evolved into something completely different, he will want to discuss internally the proposals regarding the Rock Island and Rocky Reach Coho Salmon Phase Designation and report back to the Coordinating Committees with a recommended path forward that will be discussed during the meeting on March 28, 2017.

Ferguson recalled the driver behind finalizing these decisions is that the hatchery compensation for the Rock Island and Rocky Reach projects is expiring soon, and Keller said this is correct.

Hemstrom noted there was a lot of discussion about what dataset to use. He said, initially, Skalski was not planning to use all the years included in the final analysis. Hemstrom said Chelan PUD asked Skalski to use them all in order to achieve the best-possible dataset. He questioned what data to use now. He asked if the analyses should continue to incorporate all years to represent multiple hydrosystem passage years. He said whatever is decided will make a difference in the results. He said Skalski initially suggested using only 2 years of data in which acoustic tag survival studies occurred (2010 and 2011). Hemstrom said had Chelan PUD agreed to this, the standards would have been met for both Projects a while ago. He said, however, Chelan PUD wanted to take a closer look and use all the available information. Baldwin said this is important to know. He said the more years added to the analyses, the more certainty. He said this brings up another point. He said although there are tight standard errors on the acoustic data, the standard errors are not as tight for PIT-tag estimates. He said the data appear tight; however, in reality, there is more uncertainty with PIT-tag data. He said he appreciates Chelan PUD using the full dataset.

B. Rock Island and Rocky Reach Adult Ladder Maintenance Update (Lance Keller)

Lance Keller said the right bank adult fishway at Rock Island Dam was returned to service on February 2, 2017, and the adult fishway at Rocky Reach Dam was watered up and back in operation on February 14, 2017, which was distributed to the Coordinating Committees by Kristi Geris that same day. He said, as of February 27, 2017, the left bank adult fishway at Rock Island Dam was back in operation. He summarized that all fishways at Rock Island and Rocky Reach dams are now operational.

C. Draft 2017 Fish Spill Plan (Lance Keller)

Lance Keller said Kristi Geris sent an email to the Coordinating Committees on February 22, 2017, notifying them the Draft 2017 Rock Island and Rocky Reach Fish Spill Plan is available for a 30-day review with edits and comments due to Keller by Friday, March 24, 2017.

Keller said he received a question from Bob Rose regarding the shape of spill at the Projects and how these came to be. Rose said he also does not recall if monitoring is conducted to verify the spill shapes are still relevant. Keller said he spoke with Steve Hemstrom who said the spill shapes are based on historical hydroacoustic data and there is no real method available for doublechecking those data, outside of conducting another hydroacoustic study.

Keller said, at Rock Island Dam, a diel shape is implemented for summer and spring spill, as outlined in the fish spill plan. He said, at Rocky Reach Dam, summer spill shifts from a 9% spill during the first hour, to 6%, back to 9%, then to 12%, and back to 9% (daily shape), and, in total, spill averages out to be 9%. He said the volume spilled varies based on the flow estimate for each day, and the shape is applied to that (also outlined in the fish spill plan).

Rose asked if the spill pattern is germane throughout the course of a season, or from 1 year to the next. He asked if there is a way to monitor that the best spill pattern is being implemented for smolts. He said the fish spill plan states:

> Spill-shaping attempts to optimize spill water volume to maximize spill passage effectiveness for smolts.

Rose asked how to verify this is occurring. Keller said he will ask Thad Mosey (Chelan PUD Fish Biologist and Spill Coordinator) about the basis for the fish spill patterns implemented at Rock Island and Rocky Reach dams, as well as how these patterns are evaluated for efficacy.

D. Chelan PUD Documents for Review (Lance Keller)

Lance Keller said Kristi Geris sent an email to the Coordinating Committees on January 23, 2017, notifying them the Draft 2016 Rock Island Smolt Monitoring Program and Gas Bubble Trauma Report was available for a 30-day review, with edits and comments due to Keller by Wednesday, February 22, 2017. Geris also sent an email to the Coordinating Committees on February 17, 2017, notifying them the Draft 2016 RRJFBS Report is available for a 30-day review, with edits and comments due to Keller by Monday, March 20, 2017.

Keller said USFWS provided comments on the Draft 2016 Rock Island Smolt Monitoring Program and Gas Bubble Trauma Report on February 14, 2017, and on the Draft 2016 RRJFBS Report on February 21, 2017, as distributed to the Coordinating Committees those same days. Keller said some comments were regarding number discrepancies, which he explained was due to version-control issues. He said another comment was regarding the 53% mortality rate documented for juvenile salmonids on April 1, 2016, at Rock Island Dam. He explained that the new RO4 gate was set open too far, which resulted in a number of deaths due to impingement at the traveling water screens. He also noted that the mortalities on April 1, 2016, accounted for 20% of the observed mortalities for the year. He said the gate was adjusted that same day, and fishway attendants now regularly monitor the settings on the gate to avoid the same issue in the future. Keller said USFWS also provided comments regarding differences in species compositions at both dams, which Keller explained is due to different sampling methodologies (active sampling versus 24 hour gatewell collections). Keller said analyses conducted by Scott Hopkins (Chelan PUD) also indicate that in 2015 at the Rocky Reach Juvenile Sampling Facility there were zero collections under 1 minute, whereas, in 2016, there were 24 collections under 1 minute. He said if there were not so many sockeye salmon causing short index collections, other species may have been collected. He said, during spring 2015, there were also more sample minutes. He said, lastly, the Rock Island Dam gatewell collection system has an unknown collection efficiency, versus collection efficiency being very good at Rocky Reach Dam, confirmed by acoustic survival studies.

Keller said the CCT also provided comments on both draft reports on February 15, 2017, as distributed to the Coordinating Committees that same day. Keller said, in the Draft 2016 RRJFBS Report, there was confusion about condition sampling. He said as formerly written, it appeared only the first 100 fish were sampled for condition; however, the language was revised to clarify that condition sampling was performed on all fish sampled.

IV. Douglas PUD

A. 2015 Douglas PUD Pikeminnow Program Annual Report (Tom Kahler)

Tom Kahler said Kristi Geris sent an email to the Coordinating Committees on December 15, 2016, notifying them the Draft 2015 Douglas PUD Pikeminnow Program Annual Report is available for a 60-day review period, with edits and comments due to Kahler by Monday, February 13, 2017. Kahler said comments were received from USFWS, which will be incorporated into the final draft. Kahler said he will have the 2015 Douglas PUD Pikeminnow Program Annual Report finalized and provide the final report to Geris for distribution to the Coordinating Committees.

V. HCP Administration

A. Next Meetings

The next scheduled Coordinating Committees meeting is on March 28, 2017, to be held in-person at the Grant PUD Wenatchee Office in Wenatchee, Washington.

The April 25 and May 23, 2017, meetings will be held by conference call or in-person at the Grant PUD Wenatchee Office in Wenatchee, Washington, as is yet to be determined.

VI. NMFS

A. PRESENTATION: The "Blob" (Brian Burke)

Brian Burke (NMFS) shared a presentation titled, "Recent Oceanographic and Biological Observations" (Attachment D), which was distributed to the Coordinating Committees by Kristi Geris on March 1, 2017. This presentation is an update on Burke's "Blob" presentation, which was presented to the Coordinating Committees in October 2015.

This presentation provided an overview of recent oceanographic and biological observations including, supporting field sampling and data sources, large-scale oceanographic patterns (the "Blob" and El Niño), the resulting ecology, and models. NMFS scientists annually collect migration data for juvenile salmon. The data indicate that outmigration timing for juvenile salmon affects survival. In 2016, yearling Chinook, sockeye, and coho salmon, and steelhead outmigrated earlier than typical, which can affect adult return rates. Also, in recent years, the abundance of sea lions below Bonneville Dam and in the lower Columbia River is also peaking earlier, which can affect predation levels on spring migrating adults returning to the Columbia River, and especially the early migrating stocks from the Upper Columbia River and Snake River. In 2013, a warming of sea surface temperatures in the offshore northern Pacific Ocean, or the "Blob," was observed. The primary driver of the "Blob" is related to a ridge of high pressure forming, which happens periodically; however, what typically occurs is nowhere near the magnitude that was recently experienced. This is because of the simultaneous occurrence of warm water in the Gulf of Alaska and along the coast (the "Blob") and warm water coming up onto the shelf from the south as a result of an El Niño event. Certain biological responses to this warming are becoming evident, such as the sudden radical shift in jellyfish and copepod species composition and total krill abundance along the offshore eastern Pacific Ocean. In 2015 and 2016, shifts in ichthyoplankton composition were also observed. Anchovies and sardines were found in the northern transect more than usual, which was also an indication that they spawned earlier. The basin-scale and regional physical indices and regional biological indices suggest mostly poor conditions for salmon occurred in 2015 and 2016. Although data suggest bad conditions for salmon, these new food sources (sardines and anchovies) may be helpful. Overall, Burke indicated modeling based on the biological and physical metrics sampled suggests there will be a substantial decrease in spring and fall Chinook salmon returns to the Columbia River in 2017.

VII. List of Attachments

Attachment A	List of Attendees
Attachment B	Designation of Rock Island and Rocky Reach Juvenile Coho in Phase III (Standard Achieved) SOA

Attachment C	Comparison of Juvenile Survival of Chinook Salmon, Sockeye Salmon, Steelhead, and Coho Salmon through the Chelan PUD Projects, 2010–2016
Attachment D	Recent Oceanographic and Biological Observations Presentation

Attachment A
List of Attendees

Name	Organization
John Ferguson	Anchor QEA, LLC
Kristi Geris	Anchor QEA, LLC
Tracy Hillman[1,3]	BioAnalysts
Lance Keller*	Chelan PUD
Steve Hemstrom*[2]	Chelan PUD
Catherine Willard†[2]	Chelan PUD
Tom Kahler*	Douglas PUD
Scott Carlon*	National Marine Fisheries Service
Brian Burke†[3]	National Marine Fisheries Service
Jim Craig*	U.S. Fish and Wildlife Service
Jeff Korth*	Washington Department of Fish and Wildlife
Casey Baldwin*	Colville Confederated Tribes
Bob Rose*†	Yakama Nation

Notes:
* Denotes Coordinating Committees member or alternate
† Joined by phone
[1] Joined for the HCP Tributary and Hatchery Committees Update
[2] Joined for select Chelan PUD items
[3] Joined for the NMFS presentation

DRAFT

Rocky Reach and Rock Island Habitat Conservation Plans Coordinating Committees

Statement of Agreement

Designation of Rock Island and Rocky Reach Juvenile Coho in Phase III (Standard Achieved)

(February 28, 2017)

Agreement Statement

The Rock Island and Rocky Reach HCP Coordinating Committees (CC) have reviewed PIT-tag based estimates of juvenile coho passage survival compared with PIT-tag based yearling spring Chinook passage survival in the Columbia River hydropower system, prepared by J. Skalski and R. Townsend (2017). The CC agrees that comparison of PIT-tag based juvenile coho survival and yearling spring Chinook survival using juveniles released in the Methow sub-basin upstream of the Rocky Reach Project over seven consecutive migration years (2010-2016) demonstrates that juvenile coho survive hydropower system passage similar to yearling spring Chinook. Because juvenile coho and yearling spring Chinook passage survival is comparably similar, and because Chelan PUD has measured direct passage survival of yearling spring Chinook through Rocky Reach ($\hat{S}$ = 92.72) and Rock Island ($\hat{S}$ = 93.75) in HCP acoustic tag survival studies, the CC also agrees that juvenile coho survival can be estimated using Chelan PUD's yearling Chinook acoustic tag survival estimates and coho PIT-tag based survival estimates. Yearling spring Chinook are in Phase III (Standard Achieved) at both Rock Island and Rocky Reach. The CC acknowledges that based on the estimated juvenile coho survival of 93.98% at Rock Island and 92.94% at Rocky Reach (Skalski and Townsend 2017), the CC agrees to move juvenile coho at both Projects from Phase III Standard Achieved Interim-Value to designation of Phase III Standard Achieved, with 93% survival at both Projects.

Background

The Rocky Reach and Rock Island HCP Coordinating Committees reviewed and approved an SOA on June 26, 2007 and agreed that (1) an interim coho juvenile survival value of 93% would be assumed and (2) juvenile coho survival studies would not be performed unless there was compelling information that demonstrated hydro project operations were having an impact greater than seven percent mortality on coho. As approved, juvenile coho were designated as Phase III (Standard Achieved – Interim Value) for the Rocky Reach and Rock Island Projects.

Comparison of Juvenile Coho and Yearling Spring Chinook PIT-tag Survival Estimates Through the Mid-Columbia

PIT-tag based estimates of survival for hatchery released juvenile coho and hatchery released yearling spring Chinook through the Mid-Columbia can be used to evaluate how juvenile coho survive relative to yearling spring Chinook. Skalski and Townsend (2017) analyzed PIT-tagged juvenile coho and PIT-tagged yearling spring Chinook released from Winthrop National Fish Hatchery, Methow Hatchery and all Methow Sub-basin acclimation sites to estimate juvenile passage survival from Rocky Reach tailrace to McNary tailrace, and survival from McNary to John Day tailrace, 2010 through 2016 (Table 1) .

Table 1. Cormack-Jolly-Seber PIT tag survival estimates of juvenile coho salmon and yearling spring Chinook salmon from Rocky Reach (RRH) to McNary (MCN) and McNary to John Day (JD) for pooled releases from the Winthrop National Fish Hatchery, Methow Hatchery, and Methow sub-basin final acclimation sites.

Year	Release Sizes Coho/Chinook	PIT Survival Coho/Chinook RRH to MCN	$\hat{S}$ SE Coho/Chinook	PIT Survival Coho/Chinook MCN to JD	$\hat{S}$ SE Coho/Chinook
2010	11,859 / 25,806	88.15% / 76.17%	(0.0915)/ (0.0421)	96.73%/ 100.1%	(0.1570)/ (0.1228)
2011	20,873 / 28,117	66.55% / 62.65%	(0.0411)/ (0.0314)	120.3%/ 97.11%	(0.1778)/ (0.1022)
2012	17,891 / 29,569	67.78% / 72.07%	(0.0362)/ (0.0336)	84.39%/ 78.38%	(0.0742)/ (0.0549)
2013	23,851 / 35,498	83.34%/ 82.15%	(0.0547)/ (0.0423)	83.26%/ 91.25%	(0.0931)/ (0.0916)
2014	23,489 / 22,475	72.60%/ 75.39%	(0.0436)/ (0.0565)	87.25%/ 93.0%	(0.0822)/ (0.1255)
2015	24,233 / 31,913	75.18%/ 71.08%	(0.0863)/ (0.0422)	91.69%/ 80.44%	(0.2036)/ (0.0837)
2016	17,885 / 31,884	67.73% / 76.09%	(0.0223)/ (0.0252)	98.66%/79.70%	(0.0828)/ (0.0502)

(Source: Skalski and Townsend 2017)

The PIT-tag survival estimates for juvenile coho and yearling spring Chinook were generated for fish migrating in the same river reaches in the same years, Rocky Reach to McNary and McNary to John Day, 2010 to 2016 (Skalski and Townsend 2017). Comparison of Rocky Reach to McNary reach survival estimates suggest juvenile coho salmon and yearling spring Chinook have the most comparable survivals with a survival ratio near 1.0000. In six of seven years of comparison, reach survival ratios for juvenile coho to yearling spring Chinook were not significantly different between the two species and the seven year weighted mean reach survival ratio was not significantly different (weighted mean=0.9549; SE=0.0307; P=0.1921) (Table 2).

Table 2. Ratios of multiple-project (hydro system) reach survivals for the above Rocky Reach release groups of juvenile coho and yearling spring Chinook salmon, (2010–2016). Numbers in bold indicate survival ratios that are significantly different from 1 ($P < 0.05$).

Species Ratio	Year	Rocky Reach to McNary	P (≠ 1)	McNary to John Day	P (≠ 1)
Coho/Spr Chinook	2010	1.1573 (0.1361)	0.2478	0.9602 (0.1949)	0.8382
	2011	1.0623 (0.0845)	0.4612	1.2392 (0.2248)	0.2873
	2012	0.9405 (0.0667)	0.3720	1.0767 (0.1210)	0.5264
	2013	1.0145 (0.0846)	0.8641	0.9124 (0.1371)	0.5231
	2014	0.9630 (0.0925)	0.6890	0.9382 (0.1544)	0.6888
	2015	1.0577 (0.1367)	0.6730	1.1399 (0.2795)	0.6168
	2016	0.8901 (0.0416)	**0.0082**	1.2379 (0.1299)	0.0670

(Source: Skalski and Townsend 2017)

<u>Projection of Coho Salmon Project Survival Using Acoustic Tag/PIT Tag Survival Estimates</u>

A ratio estimator was used to project coho salmon acoustic-tag passage survival based on PIT-tag data on juvenile coho salmon, and PIT-tag and acoustic-tag data on yearling Chinook salmon. Using PIT-tag releases, reach survivals from Rocky Reach tailrace (detections in the Rocky Reach bypass) to McNary tailrace were estimated for coho and spring Chinook salmon for the years 2010–2016 (Table 1). In addition, acoustic-tag investigations were performed on spring Chinook salmon at Rocky Reach (i.e., 2010, 2011) and Rock Island (i.e., 2007, 2008, and 2010) as part of the HCPs' survival compliance testing. Assuming the PIT-tag studies and acoustic-tag studies are each reliably estimating the same quantities, ratios of reach survivals for juvenile coho and yearling Chinook salmon should be the same whether they were estimated using acoustic or PIT tags.

Table 3: PIT-tag reach survival estimates from Rocky Reach tailrace to McNary tailrace $\left(\hat{S}_{\mathrm{RR-MCN}}^{\mathrm{PIT}}\right)$, ¼-root survival $\left(\hat{S}^{1/4}\right)$, and coho-to-Chinook-salmon survival ratios through the four Mid-Columbia projects $\left(\hat{R}\right)$. Standard error in parentheses.

	$\hat{S}_{\mathrm{RR-MCN}}^{\mathrm{PIT}}$		$\hat{S}^{1/4}$		
Year	Coho	Chinook	Coho	Chinook	$\hat{\bar{R}}_{\mathrm{Coho/Chin}}^{\mathrm{PIT}}$
2010	0.8815	0.7615	0.9690	0.9342	1.037
2011	0.6655	0.6265	0.9032	0.8897	1.015
2012	0.6778	0.7207	0.9074	0.9214	0.985
2013	0.8334	0.8215	0.9554	0.9520	1.004
2014	0.7260	0.7539	0.9231	0.9318	0.991
2015	0.7518	0.7108	0.9312	0.9182	1.014
2016	0.6773	0.7609	0.9072	0.9340	0.971
				Average	**1.0024** (0.0084)

(Source: Skalski and Townsend 2017)

The value of $\hat{\hat{R}}$ = **1.0024** in Table 3 above was used to project average direct-measured yearling Chinook salmon acoustic tag passage survival at the Rocky Reach Project of $\hat{S}_{\mathrm{Chin}_{\mathrm{ACO}}}$ = 0.9272 into a coho salmon project passage survival estimate, where

$$\begin{aligned}\hat{S}_{\mathrm{Coho}_{\mathrm{ACO}}} &= \hat{\hat{R}}^{\mathrm{PIT}}_{\mathrm{Coho/Chin}} \cdot \hat{\hat{S}}_{\mathrm{Chin}_{\mathrm{ACO}}} \\ &= 1.0024(0.9272) \\ &= \mathbf{0.9294}\ \left(\widehat{\mathrm{SE}} = 0.0081\right).\end{aligned}$$

The same coho-to-Chinook-salmon survival ratio of $\hat{\hat{R}}$ = **1.0024** was used to project average direct-measured yearling acoustic tag passage survival at the Rock Island Project of $\hat{S}_{\mathrm{Chin}_{\mathrm{ACO}}}$ = 0.9375 into a coho salmon project passage survival estimate, where

$$\hat{S}_{\mathrm{Coho}_{\mathrm{ACO}}} = \hat{\hat{R}}^{\mathrm{PIT}}_{\mathrm{Coho/Chin}} \cdot \hat{\hat{S}}_{\mathrm{Chin}_{\mathrm{ACO}}}$$

$$= 1.0024(0.9375)$$

$$= \mathbf{0.9398}\ \left(\widehat{\mathrm{SE}} = 0.0233\right).$$

Skalski, J.R. and R. L. Townsend, 2017. Comparison of Juvenile Survival of Chinook Salmon, Sockeye Salmon, Steelhead, and Coho Salmon through the Chelan PUD Projects, 2010-2016. Columbia Basin Research, School of Aquatic and Fishery Science, University of Washington. January 26, 2017.

Attachment C

COLUMBIA BASIN RESEARCH

Comparison of Juvenile Survival of Chinook Salmon, Sockeye Salmon, Steelhead, and Coho Salmon through the Chelan PUD Projects, 2010–2016

26 January 2017

TO: STEVEN HEMSTROM
PUD No. 1 of Chelan County
P.O. Box 1231, Wenatchee, Washington 98801

FROM: JOHN R. SKALSKI AND RICHARD L. TOWNSEND
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Table of Contents

1.0 Introduction....1
2.0 Comparison of PIT-tag Survival Estimates through the Mid-Columbia 1
2.1 Methods....1
2.2 Results....1
2.2.1 Winthrop, Methow, and Osoyoos Releases 1
2.2.2 Rock Island Dam Releases....2
3.0 Comparison of Acoustic-tag and PIT-tag Project Survival Estimates....15
4.0 Projection of Coho Salmon Acoustic-tag Estimates of Project Survival....15
5.0 Discussion....19
6.0 Literature Cited 19
Appendix A....21

1.0 Introduction

Juvenile coho salmon survival has not been directly estimated through Rocky Reach and Rock Island projects. However, there are PIT-tag estimates of survival through the Mid-Columbia that can be used to evaluate how coho salmon survivals would rank against that of spring Chinook salmon, steelhead, and sockeye salmon, and whether any of these other species could be used as a surrogate for coho salmon. As such, PIT-tag releases from Winthrop and Methow fish hatcheries and Osoyoos Lake were used to estimate smolt survival from Rock Reach tailrace to McNary tailrace, 2010 to 2016. The year 2010 marked the year when the new PIT-tag detection system went into operation at Rocky Reach Dam.

In addition, a ratio estimator was developed for coho salmon based on a combination of PIT-tag and acoustic-tag data to estimate project passage survival at either Rocky Reach or Rock Island dams. The ratio estimator was available from 2010–2011 when concurrent PIT-tag and acoustic-tag releases were occurring as part of the survival compliance trials at the two projects. The ratio estimator was used to project coho salmon survival on a per-project basis at the two sites.

2.0 Comparison of PIT-tag Survival Estimates through the Mid-Columbia

2.1 Methods

Two sets of PIT-tag survival analyses were performed. The first set was based on coho salmon, spring Chinook salmon, and steelhead hatchery releases above Rocky Reach Dam from the Winthrop and Methow hatcheries, and sockeye salmon releases from Osoyoos Lake. For these four release groups, survival was estimated from Rocky Reach tailrace to McNary tailrace and from McNary tailrace to John Day tailrace. The second set was based on PIT-tag releases from Rock Island Dam of coho, sockeye, spring Chinook salmon, and steelhead. Release sizes were an order of magnitude smaller in this second set of survival analyses. Smolt survival was estimated from Rock Island tailrace to McNary tailrace, and from McNary tailrace to John Day tailrace in the second set of analyses.

2.2 Results

2.2.1 Winthrop, Methow, and Osoyoos Releases

Reach survival estimates from Rocky Reach tailrace to McNary tailrace are summarized in Table 1, associated detection probabilities in Table 2, and harmonic mean travel times in Table 3. Comparison of Rocky Reach to McNary reach survival estimates suggests coho salmon and spring Chinook salmon had the most comparable values (Table 4) with a mean ratio of 0.95 ($\widehat{\text{SE}}$ = 0.03). In 6 of 7 years of comparison, reach survival was not significantly different between the two species. Survival between both coho and spring Chinook salmon were also comparable within the McNary tailrace to the John Day tailrace reach with a mean ratio of 1.06 ($\widehat{\text{SE}}$ = 0.05) (Table 4). The survival of spring Chinook and coho salmon was not significantly correlated between Rocky Reach and McNary tailraces (r = 0.61, P = 0.14) nor between McNary and John Day tailraces (r = 0.39, P = 0.38) (Table 5). The survival of steelhead and coho salmon was not significantly correlated between Rocky Reach and McNary tailraces (r = 0.41, P = 0.36), but was between McNary and John Day tailraces (r = 0.80, P = 0.03) (Table 5).

2.2.2 Rock Island Dam Releases

Reach survival estimates from Rock Island tailrace to McNary tailrace are summarized in Table 6, associated detection probabilities in Table 7, and harmonic mean travel times in Table 8. None of the comparisons between coho salmon and the other salmonids were significantly different for the years 2013–2016, with the exception of the McNary to John Day reach in 2016 (Table 9), in which coho had a dramatically lower estimated survival rate than historically observed. The small sample sizes and large standard errors contributed to the lack of significant differences. Survival estimates between coho and the other salmonids were generally uncorrelated (Table 10), again because of small sample sizes and large standard errors. The exception was the correlation in survival of spring Chinook and coho salmon between the McNary and John Day tailraces (r = 0.95, P = 0.0520).

Table 1: Cormack–Jolly–Seber (CJS) survival estimates for pooled releases of coho salmon, spring Chinook salmon, and steelhead from Winthrop and Methow hatcheries (2010–2016) and sockeye salmon releases in Osoyoos Lake (2013–2016).

Release Year and Species	Release Size	Probability of Survival: Rocky Reach to McNary	Probability of Survival: McNary to John Day
2010			
Coho	11,859	0.8815 (0.0915)	0.9673 (0.1570)
Spring Chinook	25,806	0.7617 (0.0421)	1.0074 (0.1228)
Steelhead	39,361	0.6787 (0.0296)	0.9999 (0.0666)
2011			
Coho	20,873	0.6655 (0.0411)	1.2034 (0.1778)
Spring Chinook	28,117	0.6265 (0.0314)	0.9711 (0.1022)
Steelhead	46,177	0.6161 (0.0228)	1.4578 (0.1042)
2012			
Coho	17,891	0.6778 (0.0362)	0.8439 (0.0742)
Spring Chinook	29,569	0.7207 (0.0336)	0.7838 (0.0549)
Steelhead	42,646	0.5769 (0.0257)	0.8562 (0.0522)
2013			
Coho	23,851	0.8334 (0.0547)	0.8326 (0.0931)
Sockeye	2,840	1.0583 (0.2805)	1.0937 (0.5870)
Spring Chinook	35,498	0.8215 (0.0423)	0.9125 (0.0916)
Steelhead	37,148	0.6088 (0.0420)	1.0293 (0.0986)
2014			
Coho	23,489	0.7260 (0.0436)	0.8725 (0.0822)
Sockeye	3,693	0.7022 (0.0909)	2.4541 (1.2199)
Spring Chinook	22,475	0.7539 (0.0565)	0.9300 (0.1255)
Steelhead	35,301	0.6750 (0.0514)	0.8582 (0.0957)
2015			
Coho	24,233	0.7518 (0.0863)	0.9169 (0.2036)
Sockeye	1,739	1.1917 (0.4944)	0.3934 (0.2151)
Spring Chinook	31,913	0.7108 (0.0422)	0.8044 (0.0837)
Steelhead	37,831	0.6402 (0.0449)	0.8687 (0.1199)
2016			
Coho	17,885	0.6773 (0.0223)	0.9866 (0.0828)
Sockeye	4,796	0.8145 (0.1165)	0.6457 (0.1774)
Spring Chinook	31,884	0.7609 (0.0252)	0.7970 (0.0502)
Steelhead	28,623	0.6455 (0.0287)	0.8207 (0.0601)

Table 2: Cormack–Jolly–Seber (CJS) estimates of detection probabilities for pooled releases of coho salmon, spring Chinook salmon, and steelhead released above Rocky Reach Dam (2010-2016) and sockeye Salmon releases in Osoyoos Lake (2013–2016).

Release Year and Species	Probability of Detection			Bonneville Combined Probability of Detection/Survival (λ)
	Rocky Reach	McNary	John Day	
2010				
Coho	0.5925 (0.0118)	0.0505 (0.0058)	0.0382 (0.0054)	0.2078 (0.0267)
Spring Chinook	0.4830 (0.0080)	0.0993 (0.0058)	0.0310 (0.0037)	0.1525 (0.0170)
Steelhead	0.5261 (0.0061)	0.0647 (0.0033)	0.0515 (0.0031)	0.2792 (0.0148)
2011				
Coho	0.6338 (0.0096)	0.1281 (0.0085)	0.1439 (0.0198)	0.0353 (0.0052)
Spring Chinook	0.3304 (0.0079)	0.1472 (0.0073)	0.1757 (0.0172)	0.0441 (0.0047)
Steelhead	0.4294 (0.0063)	0.1088 (0.0044)	0.1689 (0.0109)	0.0502 (0.0035)
2012				
Coho	0.4043 (0.0098)	0.1650 (0.0091)	0.1232 (0.0100)	0.1910 (0.0150)
Spring Chinook	0.1577 (0.0051)	0.1664 (0.0067)	0.1246 (0.0080)	0.1385 (0.0088)
Steelhead	0.3341 (0.0065)	0.1061 (0.0049)	0.2059 (0.0100)	0.1245 (0.0063)
2013				
Coho	0.5544 (0.0088)	0.0747 (0.0054)	0.0431 (0.0044)	0.2187 (0.0205)
Sockeye	0.2944 (0.0433)	0.0830 (0.0220)	0.0436 (0.0213)	0.0580 (0.0281)
Spring Chinook	0.3346 (0.0070)	0.1242 (0.0064)	0.0682 (0.0063)	0.0963 (0.0088)
Steelhead	0.3853 (0.0077)	0.0606 (0.0045)	0.0712 (0.0053)	0.1566 (0.0112)
2014				
Coho	0.5490 (0.0088)	0.0929 (0.0061)	0.0751 (0.0062)	0.2040 (0.0157)
Sockeye	0.3121 (0.0203)	0.2101 (0.0263)	0.0357 (0.0175)	0.0292 (0.0144)
Spring Chinook	0.3017 (0.0095)	0.1082 (0.0081)	0.0662 (0.0081)	0.1075 (0.0129)
Steelhead	0.4963 (0.0087)	0.0687 (0.0055)	0.0680 (0.0061)	0.1462 (0.0125)
2015				
Coho	0.4786 (0.0123)	0.0689 (0.0082)	0.0228 (0.0047)	0.1447 (0.0279)
Sockeye	0.4144 (0.0394)	0.0442 (0.0192)	0.0450 (0.0197)	0.3125 (0.1159)
Spring Chinook	0.4124 (0.0080)	0.0863 (0.0054)	0.0436 (0.0042)	0.1957 (0.0175)
Steelhead	0.6615 (0.0074)	0.0801 (0.0060)	0.0177 (0.0024)	0.2640 (0.0314)
2016				
Coho	0.6913 (0.0075)	0.2290 (0.0086)	0.0510 (0.0048)	0.2986 (0.0240)
Sockeye	0.4987 (0.0208)	0.1231 (0.0182)	0.0560 (0.0145)	0.1647 (0.0402)
Spring Chinook	0.3363 (0.0060)	0.2139 (0.0069)	0.0973 (0.0060)	0.1817 (0.0107)
Steelhead	0.4730 (0.0079)	0.1309 (0.0063)	0.0817 (0.0057)	0.2497 (0.0157)

Table 3: Harmonic travel-time estimates for pooled releases of coho salmon, spring Chinook salmon, and steelhead from released above Rocky Reach Dam (2010–2016) and sockeye salmon releases in Osoyoos Lake (2013–2016). Standard errors are in parentheses. The bold number indicates the number fish used to estimate travel time.

		Species	Travel Time To (in days)		
	Migration Year: 2010		McNary	John Day	Bonneville
From	Rocky Reach	Coho	8.32 (0.20) **167**	10.29 (0.23) **118**	11.72 (0.10) **702**
		Spring Chinook	9.85 (0.11) **681**	12.23 (0.24) **218**	13.89 (0.12) **918**
		Steelhead	10.56 (0.13) **559**	14.50 (0.17) **459**	14.88 (0.06) **2448**
	McNary	Coho		2.06 (0.13) **20**	3.37 (0.07) **47**
		Spring Chinook		3.28 (0.19) 49	4.61 (0.08) **200**
		Steelhead		3.55 (0.15) 69	5.07 (0.06) **291**
	John Day	Coho			1.33 (0.05) **44**
		Spring Chinook			1.78 (0.41) **61**
		Steelhead			2.00 (0.03) **239**
	Migration Year: 2011		McNary	John Day	Bonneville
From	Rocky Reach	Coho	5.61 (0.08) **512**	7.43 (0.07) **757**	8.72 (0.22) **114**
		Spring Chinook	12.38 (0.22) **452**	15.24 (0.26) **592**	16.96 (0.50) **109**
		Steelhead	7.17 (0.10) **638**	9.76 (0.08) **1594**	9.79 (0.11) **386**
	McNary	Coho		2.21 (0.04) **158**	3.39 (0.13) **29**
		Spring Chinook		3.30 (0.07) **269**	5.17 (0.14) **73**
		Steelhead		2.99 (0.07) **418**	3.90 (0.08) **111**
	John Day	Coho			1.15 (0.03) **25**
		Spring Chinook			1.64 (0.06) **61**
		Steelhead			1.18 (0.02) **128**
	Migration Year: 2012		McNary	John Day	Bonneville
From	Rocky Reach	Coho	6.67 (0.10) **422**	8.54 (0.13) **255**	10.03 (0.12) **348**
		Spring Chinook	10.57 (0.22) **398**	14.31 (0.37) **226**	14.95 (0.34) **225**
		Steelhead	7.256 (0.14) **497**	10.17 (0.13) **844**	10.79 (0.19) **399**
	McNary	Coho		2.82 (0.07) **114**	4.17 (0.06) **162**
		Spring Chinook		3.30 (0.07) **243**	4.55 (0.07) **261**
		Steelhead		3.26 (0.09) **276**	3.74 (0.08) **117**
	John Day	Coho			1.62 (0.04) **123**
		Spring Chinook			1.80 (0.03) **200**
		Steelhead			1.42 (0.02) **265**

Table 3: Harmonic mean travel-time estimates for pooled releases (continued).

		Species	Travel Time To (in days)		
	Migration Year: 2013		McNary	John Day	Bonneville
From	Rocky Reach	Coho	7.09 (0.10) **440**	8.680 (0.14) **224**	10.21 (0.07) **1082**
		Sockeye	4.4 (0.17) **34**	6.34 (0.21) **20**	8.23 (0.44) **13**
		Spring Chinook	8.83 (0.13) **766**	11.86 (0.21) **332**	12.64 (0.18) **422**
		Steelhead	6.90 (0.13) **274**	9.24 (0.11) **403**	9.67 (0.07) **696**
	McNary	Coho		2.48 (0.10) **41**	3.86 (0.06) **139**
		Sockeye		2.17 (0.18) **4**	4.82 (0.72) **4**
		Spring Chinook		3.03 (0.06) **162**	4.02 (0.07) **158**
		Steelhead		2.68 (0.11) **77**	3.46 (0.06) **77**
	John Day	Coho			1.53 (0.03) **81**
		Sockeye			1.53 (0.15) **3**
		Spring Chinook			1.57 (0.03) **86**
		Steelhead			1.41 (0.02) **136**
	Migration Year: 2014		McNary	John Day	Bonneville
From	Rocky Reach	Coho	5.68 (0.08) **450**	7.47 (0.09) **336**	8.30 (0.06) **899**
		Sockeye	3.95 (0.08) **98**	6.19 (0.19) **41**	7.22 (0.19) **30**
		Spring Chinook	10.36 (0.24) **295**	13.26 (0.41) **152**	12.99 (0.29) **238**
		Steelhead	6.26 (0.11) **375**	9.60 (0.16) **369**	9.26 (0.09) **701**
	McNary	Coho		2.25 (0.06) **77**	3.40 (0.05) **133**
		Sockeye		2.37 (0.13) **28**	4.24 (0.28) **18**
		Spring Chinook		3.11 (0.12) 61	3.92 (0.10) **83**
		Steelhead		3.01 (0.16) **42**	3.59 (0.07) **91**
	John Day	Coho			1.36 (0.02) **131**
		Sockeye			1.40 (0.16) **4**
		Spring Chinook			1.56 (0.05) **52**
		Steelhead			1.36 (0.03) **100**
	Migration Year: 2015		McNary	John Day	Bonneville
From	Rocky Reach	Coho	8.83 (0.19) **197**	13.43 (0.42) **66**	12.36 (0.12) **456**
		Sockeye	5.99 (0.35) **13**	9.42 (0.99) **5**	9.39 (0.28) **35**
		Spring Chinook	11.60 (0.14) **500**	14.86 (0.24) **186**	15.87 (0.13) **814**
		Steelhead	9.05 (0.13) **395**	12.50 (0.28) **128**	13.68 (0.07) **1775**
	McNary	Coho		2.77 (0.18) **10**	4.03 (0.07) **45**
		Sockeye		3.03 (NA) **1**	4.06 (0.003) **2**
		Spring Chinook		3.59 (0.13) **52**	4.34 (0.05) **164**
		Steelhead		3.25 (0.13) **19**	4.27 (0.07) **115**
	John Day	Coho			1.72 (0.06) **21**
		Sockeye			1.79 (0.05) **4**
		Spring Chinook			1.78 (0.04) **82**
		Steelhead			1.67 (0.03) **48**

Table 3: Harmonic mean travel-time estimates for pooled releases (continued).

		Species	Travel Time To (in days)		
	Migration Year: 2016		McNary	John Day	Bonneville
From	Rocky Reach	Coho	7.94 (0.07) **1102**	10.45 (0.16) **238**	11.42 (0.06) **1331**
		Sockeye	4.90 (0.09) **151**	7.07 (0.25) **35**	8.133 (0.10) **113**
		Spring Chinook	9.28 (0.09) **1102**	12.31 (0.17) **375**	12.58 (0.12) **706**
		Steelhead	7.90 (0.08) **672**	10.11 (0.14) **336**	10.86 (0.07) **970**
	McNary	Coho		2.55 (0.06) **91**	3.90 (0.02) **453**
		Sockeye		2.72 (0.30) **10**	3.57 (0.06) **30**
		Spring Chinook		3.11 (0.06) **253**	3.81 (0.03) **488**
		Steelhead		2.99 (0.09) **101**	3.97 (0.04) **277**
	John Day	Coho			1.54 (0.02) **99**
		Sockeye			1.41 (0.04) 14
		Spring Chinook			1.59 (0.02) **215**
		Steelhead			1.50 (0.02) **176**

Table 4: Ratios of juvenile reach survivals for the above Rocky Reach release groups, coho/spring Chinook salmon, coho salmon/steelhead, and coho/sockeye salmon (2010–2016). Numbers in bold indicate survival ratios that are significantly different from 1 ($P < 0.05$).

Species Ratio	Year	Rocky Reach to McNary	P (≠ 1)	McNary to John Day	P (≠ 1)
Coho/Spring Chinook	2010	1.1573 (0.1361)	0.2478	0.9602 (0.1949)	0.8382
	2011	1.0623 (0.0845)	0.4612	1.2392 (0.2248)	0.2873
	2012	0.9405 (0.0667)	0.3720	1.0767 (0.1210)	0.5264
	2013	1.0145 (0.0846)	0.8641	0.9124 (0.1371)	0.5231
	2014	0.9630 (0.0925)	0.6890	0.9382 (0.1544)	0.6888
	2015	1.0577 (0.1367)	0.6730	1.1399 (0.2795)	0.6168
	2016	0.8901 (0.0416)	**0.0082**	1.2379 (0.1299)	0.0670
	Weighted Mean	0.9549 (0.0307)	0.1921	1.0624 (0.0525)	0.2797
Coho/Steelhead	2010	**1.2988 (0.1462)**	**0.0410**	0.9674 (0.1697)	0.8477
	2011	1.0802 (0.0778)	0.3025	0.8255 (0.1355)	0.1977
	2012	**1.1749 (0.0817)**	**0.0323**	0.9856 (0.1055)	0.8916
	2013	**1.3689 (0.1304)**	**0.0047**	0.8089 (0.1191)	0.1086
	2014	1.0756 (0.1043)	0.4688	1.0167 (0.1484)	0.9106
	2015	1.1743 (0.1580)	0.2698	1.0555 (0.2760)	0.8406
	2016	1.0493 (0.0581)	0.3961	1.2021 (0.1339)	0.1311
	Weighted Mean	**1.1221 (0.0387)**	**0.0197**	0.9653 (0.0532)	0.5379
Coho/Sockeye	2013	0.7875 (0.2150)	0.3230	0.7613 (0.4174)	0.5673
	2014	1.0339 (0.1475)	0.8183	**0.3555 (0.1799)**	**0.0003**
	2015	0.6309 (0.2716)	0.1740	2.3307 (1.3754)	0.3333
	2016	0.8316 (0.1220)	0.1675	1.5280 (0.4389)	0.2291
	Weighted Mean	0.8695 (0.0712)	0.1166	0.5788 (0.2514)	0.1449

Table 5: Correlations of annual juvenile reach survivals for the above Rocky Reach release groups to coho salmon (2010–2016).

	Correlation to Coho Salmon Estimated Survival			
	Rocky Reach to McNary	P	McNary to John Day	P
Spring Chinook	+0.6133	0.1431	+0.3937	0.3822
Steelhead	+0.4127	0.3575	**+0.7961**	**0.0322**
Sockeye	+0.5754	0.4246	-0.4867	0.5133

Table 6: Cormack–Jolly–Seber (CJS) survival estimates for pooled releases of coho salmon, spring Chinook salmon, steelhead and sockeye salmon tagged in the Rock Island bypass trap (2010–2016). Stock source is indicated by H – hatchery, W – wild, and U – unknown.

Release Year and Species	Release Size	Probability of Survival: Rock Island to McNary	Probability of Survival: McNary to John Day
2010			
Coho (H)	458	0.8235 (0.2621)	2.4248 (1.8002)
Sockeye (U)	3,477	0.7731 (0.0616)	1.0627 (0.2211)
Steelhead (H)	4,611	0.5304 (0.0506)	1.3802 (0.2390)
2011			
Coho (H,W)	647	0.5330 (0.1146)	1.4656 (1.0037)
Sockeye (U)	2,927	0.7305 (0.0859)	0.6659 (0.1650)
Steelhead (H)	5,351	0.5701 (0.0625)	1.3179 (0.2709)
2012			
Coho (H,W)	515	0.8497 (0.2042)	0.7938 (0.3380)
Sockeye (U)	3,199	0.9462 (0.0849)	0.8282 (0.1534)
Steelhead (H)	4,296	0.4914 (0.0501)	1.1616 (0.2060)
2013			
Coho (H,W)	808	0.5487 (1.0466)	1.0466 (0.3906)
Sockeye (U)	2,672	0.7453 (0.0686)	1.1453 (0.2541)
Spring Chinook (H)	5,216	0.7847 (0.0641)	0.8024 (0.1344)
Steelhead (H)	3,740	0.6289 (0.0892)	1.0755 (0.2707)
2014			
Coho (H,W)	1,115	1.2213 (0.3476)	0.5973 (0.2383)
Sockeye (U)	3,073	0.4233 (0.0498)	0.9008 (0.2552)
Spring Chinook (H)	4,703	0.8735 (0.0896)	0.7737 (0.1345)
Steelhead (H)	4,245	0.5932 (0.0895)	0.8698 (0.1935)
2015			
Coho (H,W)	487	0.5452 (0.1839)	1.3600 (0.9858)
Sockeye (U)	1,662	0.7584 (0.1655)	0.5118 (0.1770)
Spring Chinook (H)	5,055	0.6032 (0.0687)	0.8285 (0.1767)
Steelhead (H)	3,749	0.6954 (0.1018)	0.6205 (0.1758)
2016			
Coho (H,W)	1,168	0.8503 (0.1003)	0.4203 (0.0787)
Sockeye (U)	4,017	0.7720 (0.0706)	1.1507 (0.2488)
Spring Chinook (H)	4,287	0.7214 (0.0547)	0.7810 (0.1351)
Steelhead (H)	4,182	0.5411 (0.0397)	0.9634 (0.1792)

Table 7: Cormack–Jolly–Seber (CJS) estimates of detection probabilities for pooled releases of coho salmon, spring Chinook salmon, steelhead, and sockeye salmon tagged in the Rock Island bypass trap (2010–2016).

Release Year and Species	Probability of Detection		Bonneville Combined Probability of Detection/Survival (λ)
	McNary	John Day	
2010			
Coho	0.0795 (0.0288)	0.0339 (0.0236)	0.0645 (0.0441)
Sockeye	0.1957 (0.0173)	0.0578 (0.0119)	0.1350 (0.0268)
Steelhead	0.0895 (0.0102)	0.0578 (0.0093)	0.1925 (0.0288)
2011			
Coho	0.1914 (0.0457)	0.1194 (0.0791)	0.0339 (0.0236)
Sockeye	0.1534 (0.0196)	0.1889 (0.0424)	0.0606 (0.0147)
Steelhead	0.0685 (0.0088)	0.1763 (0.0313)	0.0371 (0.0071)
2012			
Coho	0.1348 (0.0362)	0.1123 (0.0429)	0.1622 (0.0606)
Sockeye	0.1629 (0.0161)	0.1185 (0.0202)	0.1045 (0.0181)
Steelhead	0.1137 (0.0134)	0.1329 (0.0206)	0.1115 (0.0175)
2013			
Coho	0.0857 (0.0237)	0.0690 (0.0235)	0.2500 (0.0765)
Sockeye	0.1868 (0.0192)	0.0781 (0.0168)	0.1124 (0.0237)
Spring Chinook	0.1551 (0.0138)	0.0829 (0.0130)	0.1375 (0.0210)
Steelhead	0.0859 (0.0134)	0.0630 (0.0140)	0.1210 (0.0260)
2014			
Coho	0.0565 (0.0173)	0.0752 (0.0228)	0.1667 (0.0481)
Sockeye	0.2145 (0.0273)	0.1030 (0.0281)	0.1043 (0.0285)
Spring Chinook	0.1066 (0.0119)	0.1116 (0.0166)	0.1146 (0.0171)
Steelhead	0.0751 (0.0124)	0.0801 (0.0142)	0.1726 (0.0292)
2015			
Coho	0.1055 (0.0400)	0.0392 (0.0272)	0.1429 (0.0935)
Sockeye	0.0960 (0.0225)	0.0675 (0.0205)	0.2439 (0.0671)
Spring Chinook	0.1099 (0.0137)	0.0572 (0.0113)	0.1752 (0.0325)
Steelhead	0.1389 (0.0214)	0.0346 (0.0094)	0.2549 (0.0610)
2016			
Coho	0.2064 (0.0274)	0.1270 (0.0242)	0.4528 (0.0684)
Sockeye	0.1541 (0.0155)	0.0684 (0.0141)	0.0905 (0.0184)
Spring Chinook	0.2118 (0.0175)	0.0936 (0.0157)	0.1448 (0.0237)
Steelhead	0.1993 (0.0166)	0.0509 (0.0099)	0.2252 (0.0396)

Table 8: Harmonic mean travel-time estimates for pooled releases of coho salmon, Spring Chinook salmon, steelhead, and sockeye salmon tagged in the Rock Island bypass trap (2010–2016). Standard errors are in parentheses. The bold number indicates the number fish used to estimate travel time.

	Species		**Travel Time To** (in days)		
	Migration year: 2010		McNary	John Day	Bonneville
	Rock Island	Coho	7.76 (0.55) **30**	10.40 (0.50) **31**	12.09 (0.39) **56**
		Sockeye	9.44 (0.23) **524**	14.09 (0.58) **165**	13.57 (0.34) **320**
		Steelhead	7.93 (0.18) **206**	10.02 (0.19) **194**	12.55 (0.12) **604**
	McNary	Coho		2.10 (0.18) **6**	3.64 (NA) **1**
		Sockeye		4.08 (0.44) **32**	5.04 (0.24) **67**
		Steelhead		2.79 (0.15) **27**	4.23 (0.14) **47**
	John Day	Coho			1.23 (0.17) **2**
		Sockeye			1.79 (0.17) **16**
		Steelhead			1.60 (0.07) **34**
	Migration year: 2011		McNary	John Day	Bonneville
	Rock Island	Coho	4.55 (0.18) **65**	7.31 (0.28) **60**	7.21 (0.47) **14**
		Sockeye	6.55 (0.16) **328**	8.30 (0.23) **269**	9.16 (0.49) **64**
		Steelhead	4.92 (0.11) **209**	7.34 (0.08) **709**	7.54 (0.23) **103**
	McNary	Coho		2.49 (0.21) **11**	2.45 (0.05) **3**
From		Sockeye		3.17 (0.24) **43**	5.97 (0.60) **13**
		Steelhead		2.80 (0.20) **46**	3.19 (0.31) **7**
	John Day	Coho			NA **0**
		Sockeye			1.55 (0.08) **13**
		Steelhead			0.99 (0.04) **13**
	Migration year: 2012		McNary	John Day	Bonneville
	Rock Island	Coho	6.14 (0.23) **59**	8.75 (0.42) **39**	9.61 (0.29) **55**
		Sockeye	4.29 (0.05) **493**	7.56 (0012) **297**	8.47 (0.15) **219**
		Steelhead	5.51 (0.10) **240**	8.07 (0.11) **326**	8.47 (0.11) **220**
	McNary	Coho		3.32 (0.46) **6**	4.09 (0.19) **6**
From		Sockeye		2.94 (0.15) **44**	4.29 (0.23) **39**
		Steelhead		2.56 (0.13) **40**	3.77 (0.22) **22**
	John Day	Coho			1.79 (0.17) **6**
		Sockeye			1.64 (0.10) **27**
		Steelhead			1.36 (0.05) **29**

Table 8: Harmonic mean travel-time estimates for pooled releases (continued).

		Species	Travel Time To (in days) McNary	John Day	Bonneville
	Migration year: 2013		McNary	John Day	Bonneville
From	Rock Island	Coho	7.20 (0.32) **38**	8.75 (0.47) **32**	10.48 (0.22) **112**
		Sockeye	6.93 (0.19) **370**	9.84 (0.38) **178**	9.64 (0.28) **215**
		Spring Chinook	9.74 (0.02) **633**	12.94 (0.28) **272**	13.21 (0.22) **408**
		Steelhead	5.81 (0.11) **196**	7.93 (0.11) **159**	8.88 (0.09) **238**
	McNary	Coho		2.75 (0.25) **6**	4.08 (0.22) **8**
		Sockeye		3.83 (0.39) **36**	4.28 (0.28) **32**
		Spring Chinook		2.79 (0.10) **50**	3.96 (0.11) **57**
		Steelhead		2.59 (0.17) **14**	3.55 (0.08) **19**
	John Day	Coho			1.45 (0.07) **8**
		Sockeye			1.48 (0.05) **19**
		Spring Chinook			1.54 (0.05) **33**
		Steelhead			1.43 (0.08) **16**
	Migration year: 2014		McNary	John Day	Bonneville
From	Rock Island	Coho	4.58 (0.15) **73**	6.49 (0.19) **61**	7.62 (0.16) **127**
		Sockeye	6.01 (0.22) **273**	10.86 (0.72) **120**	10.36 (0.61) **89**
		Spring Chinook	8.58 (0.18) **430**	10.84 (0.22) **354**	11.74 (0.24) **319**
		Steelhead	5.11 (0.10) **155**	7.39 (0.14) **173**	7.95 (0.09) **310**
	McNary	Coho		2.71 (0.42) **4**	3.43 (0.11) **7**
		Sockeye		3.75 (0.52) **23**	4.08 (0.36) **19**
		Spring Chinook		3.20 (0.18) **45**	4.03 (0.18) **27**
		Steelhead		2.39 (0.15) **10**	3.28 (0.13) **20**
	John Day	Coho			1.35 (0.05) **7**
		Sockeye			1.63 (0.15) **9**
		Spring Chinook			1.48 (0.05) **35**
		Steelhead			1.17 (0.02) **25**
	Migration year: 2015		McNary	John Day	Bonneville
From	Rock Island	Coho	8.15 (0.47) **26**	14.53 (1.44) **14**	13.21 (0.51) **49**
		Sockeye	9.19 (0.48) **109**	12.93 (1.13) **43**	11.91 (0.39) **139**
		Spring Chinook	11.90 (0.23) **307**	15.77 (0.44) **143**	15.76 (0.22) **386**
		Steelhead	7.86 (0.15) **198**	11.36 (0.36) **52**	12.37 (0.12) **353**
	McNary	Coho		3.01 (NA) **1**	4.18 (0.29) **5**
		Sockeye		5.11 (1.53) **3**	5.00 (0.64) **13**
		Spring Chinook		3.61 (0.28) **16**	4.60 (0.16) **40**
		Steelhead		4.29 (0.54) **4**	4.37 (0.12) **26**
	John Day	Coho			1.68 (0.19) **2**
		Sockeye			1.62 (0.07) **10**
		Spring Chinook			1.74 (0.05) **21**
		Steelhead			1.77 (0.12) **12**

Table 8: Harmonic mean travel-time estimates for pooled releases (continued).

		Species	Travel Time To (in days)		
	Migration year: 2016		McNary	John Day	Bonneville
From	Rock Island	Coho	7.53 (0.14) **205**	10.36 (0.39) **53**	11.28 (0.16) **178**
		Sockeye	6.06 (0.12) **478**	10.00 (0.27) **244**	9.86 (0.22) **279**
		Spring Chinook	8.35 (0.11) **655**	11.09 (0.22) **226**	11.50 (0.16) **307**
		Steelhead	7.07 (0.08) **451**	9.20 (0.14) **111**	10.82 (0.09) **460**
	McNary	Coho		2.87 (0.34) **7**	3.81 (0.10) **37**
		Sockeye		3.33 (0.27) **38**	4.64 (0.32) **39**
		Spring Chinook		2.97 (0.11) **48**	3.63 (0.65) **65**
		Steelhead		2.72 (0.14) **18**	3.99 (0.07) **97**
	John Day	Coho			1.53 (0.04) **23**
		Sockeye			1.58 (0.06) **20**
		Spring Chinook			1.62 (0.07) **10**
		Steelhead			1.59 (0.05) **24**

Table 9: Ratios of juvenile reach survivals for the Rock Island release groups, coho/spring Chinook salmon, coho salmon/steelhead, and coho/sockeye salmon (2010–2016). Numbers in bold indicate survival ratios that are significantly different from 1 (P < 0.05).

Species Ratio	Year	Rock Island to McNary	$P\ (\neq 1)$	McNary to John Day	$P\ (\neq 1)$
Coho/Spring Chinook	2013	0.6992 (1.3350)	0.8218	1.3043 (0.5336)	0.5684
	2014	1.3982 (0.4230)	0.3465	0.7720 (0.3360)	0.4974
	2015	0.9038 (0.3218)	0.7651	1.6415 (1.2403)	0.6050
	2016	1.1787 (0.1653)	0.2797	0.5382 (0.1372)	**0.0008**
	Weighted Mean	1.1463 (0.0826)	0.1269	0.6210 (0.1205)	**0.0200**
Coho/Steelhead	2010	1.5526 (0.5159)	0.2841	1.7568 (1.3393)	0.5720
	2011	0.9349 (0.2256)	0.7730	1.1121 (0.7952)	0.8879
	2012	1.7291 (0.4514	0.1062	0.6834 (0.3152)	0.3151
	2013	0.8725 (1.6688)	0.9391	0.9731 (0.4381)	0.9511
	2014	2.0588 (0.6632)	0.1104	0.6867 (0.3137)	0.3179
	2015	0.7840 (0.2883)	0.4537	2.1918 (1.7058)	0.4848
	2016	1.5714 (0.2183)	**0.0089**	0.4363 (0.1151)	< **0.0001**
	Weighted Mean	1.2522 (0.1593)	0.1645	0.5353 (0.0851)	**0.0016**
Coho/Sockeye	2010	1.0652 (0.3495)	0.8520	2.2817 (1.7592)	0.4663
	2011	0.7296 (0.1788)	0.1305	2.2009 (1.6029)	0.4537
	2012	0.8980 (0.2304)	0.6580	0.9585 (0.4451)	0.9256
	2013	0.7362 (1.4059)	0.8512	0.9138 (0.3968)	0.8280
	2014	**2.8852 (0.8886)**	**0.0339**	0.6631 (0.3245)	0.2991
	2015	0.7189 (0.2888)	0.3304	2.6573 (2.1341)	0.4374
	2016	1.1014 (0.1644)	0.5373	0.3653 (0.1045)	< **0.0001**
	Weighted Mean	0.9339 (0.1099)	0.5695	0.4636 (0.1020)	**0.0019**

Table 10: Correlations of annual juvenile reach survivals for the Rock Island release groups to coho salmon (2010–2016).

	Correlation to Coho Salmon Estimated Survival			
	Rock Island to McNary	P	McNary to John Day	P
Spring Chinook	+0.7245	0.2755	+0.9480	**0.0520**
Steelhead	-0.4048	0.3677	+0.4998	0.2534
Sockeye	-0.5369	0.2140	-0.1317	0.7784

3.0 Comparison of Acoustic-tag and PIT-tag Project Survival Estimates

During the three years, 2002-2004, head-to-head comparisons of project passage survival at Rock Island Dam were performed using yearling Chinook salmon. Fish source, handling and release procedures were all comparable to permit direct comparison of project survival using the two tagging methods.

In two of the three years, acoustic-tag and PIT-tag survival estimates for yearling Chinook salmon were within 0.01 of each other. The third year, the difference was 0.028 (Table 11). In no year were the two estimates of project passage survival significantly different ($P > 0.10$). The 3-year average for acoustic-tag studies was $\hat{\bar{S}} = 0.9442$, and for PIT-tag studies, $\hat{\bar{\ }} = 0.9344$ (Table 11). These studies strongly suggest PIT-tag and acoustic-tag studies are estimating comparable values.

Table 11: Comparison of acoustic-tag and PIT-tag paired-release estimates of Rock Island project passage survival for yearling Chinook salmon, 2002-2004. Sample sizes are the combined upstream and downstream (i.e., $R_1 + R_2$) releases in the paired-release design. Statistical error in parentheses.

	Pit-tag		Acoustic-tag	
Year	$R_1 + R_2$	$\hat{S}$	$R_1 + R_2$	$\hat{S}$
2002	90,002	0.9555 (0.0249)	798	0.9520 (0.0263)
2003	103,730	0.9339 (0.0115)	999	0.9387 (0.0157)
2004	99,999	0.9139 (0.0227)	1,001	0.9419 (0.0118)
Average		0.9344		0.9442

4.0 Projection of Coho Salmon Acoustic-tag Estimates of Project Survival

A ratio estimator was used to project coho salmon acoustic-tag project passage survival based on PIT-tag data on coho salmon and PIT-tag and acoustic-tag data on Chinook salmon. Using PIT-tag releases, reach survivals from Rocky Reach tailrace to McNary tailrace were estimated for coho and spring Chinook salmon for the years 2010–2016 (see Section 2.0). In addition, acoustic-tag investigations were performed on spring Chinook salmon at Rocky Reach (i.e., 2010, 2011) and Rock Island (i.e., 2007, 2008, 2010) as part of the survival compliance testing. Assuming the PIT-tag and acoustic-tag studies are each reliably estimating the same quantities, ratios of reach survivals for coho and Chinook salmon should be the same whether they were estimated using acoustic or PIT tags. Hence, the identity of the form

$$\frac{\left(\hat{S}_{\mathrm{Coho}_{\mathrm{PIT}}}\right)^{\frac{1}{4}}}{\left(\hat{S}_{\mathrm{Chin}_{\mathrm{PIT}}}\right)^{\frac{1}{4}}} = \frac{\hat{S}_{\mathrm{Coho}_{\mathrm{ACO}}}}{\hat{S}_{\mathrm{Chin}_{\mathrm{ACO}}}}$$

suggests a ratio estimator

$$\hat{S}_{\mathrm{Coho}_{\mathrm{ACO}}} = \frac{\left(\hat{S}_{\mathrm{Coho}_{\mathrm{PIT}}}\right)^{\frac{1}{4}}}{\left(\hat{S}_{\mathrm{Chin}_{\mathrm{PIT}}}\right)^{\frac{1}{4}}} \cdot \hat{S}_{\mathrm{Chin}_{\mathrm{ACO}}},$$

or more simply,

$$\hat{S}_{\mathrm{Coho}_{\mathrm{ACO}}} = \hat{R}^{\mathrm{PIT}}_{\mathrm{Coho/Chin}} \cdot \hat{S}_{\mathrm{Chin}_{\mathrm{ACO}}}, \tag{1}$$

and where

$\hat{S}_{\mathrm{Coho}_{\mathrm{PIT}}}$ = estimated survival from Rocky Reach tailrace to McNary tailrace using PIT-tag data for coho salmon,

$\hat{S}_{\mathrm{Chin}_{\mathrm{PIT}}}$ = estimated survival from Rocky Reach tailrace to McNary tailrace using PIT-tag data for Chinook salmon,

$\hat{S}_{\mathrm{Chin}_{\mathrm{ACO}}}$ = estimated project survival (either Rocky Reach or Rock Island) using acoustic-tag data for Chinook salmon,

$\hat{R}^{\mathrm{PIT}}_{\mathrm{Coho/Chin}}$ = ratio of coho to Chinook salmon project passage survival based on PIT-tag data.

The 0.25-root of the PIT-tag estimate of survival from Rocky Reach tailrace to McNary tailrace (i.e., four projects) was used to express PIT-tag survival on a per-project basis consistent with the acoustic-tag estimates of survival. The ratio $\hat{R}^{\mathrm{PIT}}_{\mathrm{Coho/Chin}}$ estimates the relative survival of coho compared to Chinook salmon smolts through a Mid-Columbia River project.

The variance of $\hat{S}_{\mathrm{Coho}_{\mathrm{ACO}}}$ was estimated by

$$\begin{aligned}\widehat{\mathrm{Var}}\left(\hat{S}_{\mathrm{Coho}_{\mathrm{ACO}}}\right) = {} & \widehat{\mathrm{Var}}\left(\hat{\hat{R}}^{\mathrm{PIT}}_{\mathrm{Coho/Chin}}\right)\hat{\hat{S}}^{2}_{\mathrm{Chin}_{\mathrm{ACO}}} \\ & +\widehat{\mathrm{Var}}\left(\hat{\hat{S}}_{\mathrm{Chin}_{\mathrm{ACO}}}\right)\left(\hat{\hat{R}}^{\mathrm{PIT}}_{\mathrm{Coho/Chin}}\right)^{2} \\ & -\widehat{\mathrm{Var}}\left(\hat{\hat{R}}^{\mathrm{PIT}}_{\mathrm{Coho/Chin}}\right)\cdot\widehat{\mathrm{Var}}\left(\hat{\hat{S}}_{\mathrm{Chin}_{\mathrm{ACO}}}\right),\end{aligned}$$

based on Goodman (1960). The variance estimates for $\hat{\hat{R}}$ and $\hat{\hat{S}}$ were based on the empirical variance for sample means.

In order to use the maximum amount of tag information available, the average coho-to-Chinook-salmon survival ratio $\hat{\hat{R}}^{\text{PIT}}_{\text{Coho/Chin}}$ was calculated over the years 2010–2016 (Note: 2010 was the first year the PIT-tag detector was operational at the Rocky Reach juvenile bypass). The average ratio over the seven-year period was $\hat{\hat{R}}$ = 1.0024 ($\widehat{\text{SE}}$ = 0.0084) (Table 12). An R-value of 1.0024 suggests coho salmon survival is ever so slightly higher than Chinook salmon through a Mid-Columbia project. The value of $\hat{\hat{R}}$ = 1.0024 was then used to calibrate average observed Chinook salmon project passage survival at the Rocky Reach Project (Table 13) of $\hat{S}_{\text{Chin}_{\text{ACO}}}$ = 0.9272 into coho salmon project passage survival, where

$$\hat{S} \qquad \hat{\hat{R}} \quad {}_{\text{o/Chin}} \; \hat{\hat{S}}$$

$$0024(0\ 9272)$$

$$\left(\widehat{\text{SE}} \qquad 0081\right).$$

Hence, Rocky Reach project passage survival for coho salmon is projected to be 0.9294 ($\widehat{\text{SE}}$ = 0.0081).

Similarly, the average estimate of Chinook salmon project passage survival for the three years of acoustic-tag study—2007, 2008, and 2010—at Rock Island was $\hat{S}_{\text{Chin}_{\text{ACO}}}$ = 0.9375 ($\widehat{\text{SE}}$ = 0219)(Table 13). Using the same coho-to-Chinook-salmon survival ratio (i.e., 1.0024), the coho salmon project passage survival at Rock Island was projected to be

$$\hat{S} \qquad \hat{\hat{R}} \quad {}_{\text{o/Chin}} \; \hat{\hat{S}}$$

$$4(0\ 9375)$$

$$\left(\widehat{\text{SE}} \qquad 0233\right).$$

Consequently, Rock Island project passage survival for coho salmon is projected to be 0.9398 ($\widehat{\text{SE}}$ = 0.0233).

Table 12: PIT-tag reach survival estimates from Rocky Reach tailrace to McNary tailrace $(\hat{S}\quad)$, ¼-root survival $(\hat{S}^{1/4})$, and coho-to-Chinook-salmon survival ratios through Mid-Columbia projects $(\hat{R})$. Standard error in parentheses.

	$\hat{S}$		$\hat{S}^{1/}$		
Year	Coho	Chinook	Coho	Chinook	$\hat{\hat{R}}$ ho/C
2010	0.8815	0.7615	0.9690	0.9342	1.0372
2011	0.6655	0.6265	0.9032	0.8897	1.0152
2012	0.6778	0.7207	0.9074	0.9214	0.9848
2013	0.8334	0.8215	0.9554	0.9520	1.0036
2014	0.7260	0.7539	0.9231	0.9318	0.9906
2015	0.7518	0.7108	0.9312	0.9182	1.0141
2016	0.6773	0.7609	0.9072	0.9340	0.9713
				Average	1.0024 (0.0084)

Table 13: Chinook salmon smolt project passage survival estimates through Rocky Reach and Rock Island, along with arithmetic averages. Standard errors in parentheses.

	$\hat{S}$	
Year	Rocky Reach	Rock Island
2007		0.9785
2008		0.8972
2010	0.9250	0.9428
2011	0.9294	
Average	0.9272 (0.0022)	0.9375 (0.0219)

5.0 Discussion

Given the small sample sizes of the Rock Island Dam releases, comparison between coho and other salmonids is best performed using the upstream releases above Rocky Reach Dam. Spring Chinook appear to be most comparable to coho salmon, with a strong positive correlation and a survival ratio near 1 between Rocky Reach and McNary tailraces and between McNary and John Day tailraces (Tables 4 and 5). From these perspectives, one might expect coho salmon survival through the Mid-Columbia hydroprojects to be similar to that seen for spring Chinook salmon.

Using that positive correlation between coho and spring Chinook salmon PIT-tag survival estimates, a ratio estimator (1) was used to produce project-specific estimates of coho salmon survival at Rocky Reach or Rock Island Dam. Projected coho salmon survival through the Rocky Reach Project was calculated to be $\hat{S}$ = 0.9294 ($\widehat{\mathrm{SE}}$ = 0.0081). For Rock Island, coho salmon project passage survival was estimated to be $\hat{S}$ = 0.9398 ($\widehat{\mathrm{SE}}$ = 0.0233).

6.0 Literature Cited

Goodman, L. A. 1960. On the exact variance of products. Journal of the American Statistical Association 55:708-713.

Appendix A

The appendix lists tag files used in the above Rocky Reach analysis. The criteria used in the selection of release groups were: releases in the general area above Rkm 843.080 during the April to May period; consisted primarily of Winthrop or Methow stock or raised by Winthrop or Methow hatcheries; and had an individual release size, or could be reasonably pooled into a group (i.e., a close succession of smaller releases at the same site), that was greater than 500 fish. Sockeye salmon were released in Osoyoos Lake (OSOYOL) or at Osoyoos Lake Narrows Hwy 3 Bridge (OSOYBR).

Rock Island virtual releases were based on yearly pooled releases of spring Chinook salmon, and sockeye salmon, or steelhead tagged at the Rock Island bypass trap, or coho salmon detected as a recapture at Rock Island Dam.

Table A: Tagging information on coho, spring Chinook salmon, steelhead, and sockeye used in the Rocky Reach analysis.

Release Year	Tagging Group(s)			
	Coho	Spring Chinook	Steelhead	
2010	CMK09348.WB1	CGS10107.KAA	CGS09278.W01	CGS09278.W17
	CMK09348.WB2	CGS10111.KAC	CGS09278.W02	CGS09278.W18
	CMK09348.WB3	CLD10067.001	CGS09278.W03	CGS09278.W19
	CMK09348.WB4	CLD10068.001	CGS09278.W04	CGS09278.W20
	CMK10013.W15	CLD10069.001	CGS09278.W05	CGS09278.W21
	CMK10013.W16	CLD10069.003	CGS09278.W06	CGS09278.W22
		CLD10070.001	CGS09278.W07	CGS09278.W23
		CLD10071.001	CGS09278.W08	CGS09278.W24
		MRC09287.WT1	CGS09278.W09	MRC09279.WT1
		MRC09288.WT2	CGS09278.W10	MRC09279.WT2
			CGS09278.W11	MRC09281.WT3
			CGS09278.W12	MRC09281.WT4
			CGS09278.W13	MRC09281.WT5
			CGS09278.W14	MRC09281.WT6
			CGS09278.W15	MRC09282.WT7
			CGS09278.W16	MRC09282.WT8
2011	CMK10341.W04	CGS11108.KAA	CGS11111.W04	CGS11132.W23
	CMK10341.W05	CGS11110.KAA	CGS11115.TWP	CGS11136.W24
	CMK10341.W07	CGS11117.KAA	CGS11116.W05	CGS11136.W25
	CMK10341.W08	CMK10312.ME1	CGS11117.W06	CGS11138.W26
	CMK10344.W15	CMK10313.ME2	CGS11117.W07	CGS11138.W27
	CMK10344.W16	CMK10314.BD1	CGS11119.W08	CGS11138.W28
		CMK10315.BD2	CGS11122.W09	CGS11138.W29
		CMK10344.W10	CGS11122.W10	CGS11138.W30
		CMK10344.W11	CGS11123.W11	CGS11138.W31
		MRC10281.WT1	CGS11123.W12	MRC10277.WT2
		MRC10281.WT2	CGS11124.W13	MRC10278.WT1
		MRC10281.WT3	CGS11126.W14	MRC10278.WT3
		MRC10281.WT4	CGS11129.W15	MRC10278.WT4
			CGS11129.W16	MRC10279.WT1
			CGS11130.W17	MRC10279.WT2
			CGS11130.W18	MRC10280.WT3
			CGS11131.W19	MRC10280.WT4
			CGS11131.W20	MRC10280.WT5
			CGS11131.W21	MRC10280.WT6
			CGS11131.W22	
2012	CMK11306.WI1	CGS12108.KAA	CGS11308.W01	CGS11308.W17
	CMK11306.WI2	CGS12114.MH1	CGS11308.W02	CGS11308.W21
	CMK11311.TW1	CMK11306.WC1	CGS11308.W03	CGS11308.W24
	CMK11311.TW2	CMK11306.WC2	CGS11308.W04	CGS11308.W25
	CMK11312.WI1	CMK11307.M15	CGS11308.W05	CGS11310.BM2
	CMK11312.WI2	CMK11307.M16	CGS11308.W06	CGS12114.TWW
		CMK11308.M01	CGS11308.W07	CGS12114.WL1
		MRC11277.WT1	CGS11308.W08	MRC11277.WT5
		MRC11277.WT2	CGS11308.W09	MRC11277.WT6
		MRC11277.WT3	CGS11308.W10	MRC11278.WT7
		MRC11277.WT4	CGS11308.W11	MRC11278.WT8
			CGS11308.W12	MRC11279.WT1
			CGS11308.W13	MRC11279.WT2
			CGS11308.W14	MRC11280.WT3
			CGS11308.W15	MRC11280.WT4
			CGS11308.W16	

Table A: Tagging information for coho and spring Chinook salmon and steelhead used in the Rocky Reach analysis (continued).

Release Year	Tagging Group(s)			
	Coho	Spring Chinook	Steelhead	Sockeye
2013	CMK12313.W14	CGS13108.CHP	CGS12315.MHS	ONA13127.001
	CMK12313.W15	CGS13108.TWP	CGS13108.TSH	ONA13107.001
	CMK12318.GC1	CMK12312.W08	MRC12276.WT1	ONA13109.001
	CMK12318.TW1	CMK12312.W09	MRC12276.WT2	ONA13115.001
	CMK12318.TW2	CMK12312.W10	MRC12276.WT3	ONA13115.002
	CMK12318.WB1	CMK12312.W11	MRC12276.WT4	ONA13120.OS1
		CMK12314.M15	MRC12277.WT5	ONA13121.OS1
		CMK12314.M16	MRC12277.WT6	ONA13121.OS2
		MRC12279.WT1	MRC12278.WT7	ONA13122.OS2
		MRC12279.WT2	MRC12278.WT8	
		MRC12279.WT3		
		MRC12279.WT4		
2014	CMK13317.W14	CGS14112.TWP	CGS14112.TPK	ONA14097.001
	CMK13350.WB1	CMK13317.M01	CGS14112.TPU	ONA14101.001
	CMK13350.WB2	CMK13318.M02	CGS14115.MET	ONA14105.001
	CMK13351.GC1	CMK13318.M03	MRC13275.WT1	ONA14107.001
	CMK13351.GC2	MRC13277.WT1	MRC13275.WT2	ONA14112.001
	CMK13351.LT1	MRC13277.WT2	MRC13276.WT3	ONA14113.001
	CMK13351.LT2	MRC13277.WT3	MRC13276.WT4	ONA14114.001
	CMK13351.LT3	MRC13277.WT4	MRC13295.WT1	ONA14115.O01
	CMK13351.LT4		MRC13295.WT2	ONA14118.O01
			MRC13295.WT3	ONA14119.O01
			MRC13295.WT4	ONA14120.O01
			MRC13296.WT5	ONA14121.O01
			MRC13296.WT6	ONA14122.O01
			MRC13296.WT7	ONA14125.O01
			MRC13296.WT8	
2015	CMK14273.12A	CGS14322.MCH	CGS14324.MET	ONA15099.AO1
	CMK14273.12B	CGS14322.TCH	CGS14324.TSH	ONA15103.AO1
	CMK14342.WB1	CME14223.001	MRC14279.WT1	ONA15105.BO1
	CMK14342.WB2	CME14224.001	MRC14279.WT2	ONA15107.BO1
	CMK14343.GC1	CME14225.001	MRC14280.WT3	ONA15111.BO1
	CMK14343.GC2	CME14226.001	MRC14280.WT4	ONA15113.BO1
	CMK14343.TW1	CME14227.001	MRC14281.WT5	ONA15117.BO1
	CMK14343.TW2	MRC14282.WT1	MRC14281.WT6	ONA15119.BO1
		MRC14282.WT2	MRC14281.WT7	ONA15121.BO1
		MRC14282.WT3	MRC14281.WT8	
		MRC14282.WT4	MRC14283.WT1	
		MRC14282.WT5	MRC14283.WT2	
		MRC14282.WT6	MRC14295.WT3	
			MRC14296.WT4	
			MRC14296.WT5	
			MRC14296.WT6	
			MRC14297.WT7	

Table A: Tagging information for coho and spring Chinook salmon and steelhead used in the Rocky Reach analysis (continued).

Release Year	Tagging Group(s)			
	Coho	Spring Chinook	Steelhead	Sockeye
2016	CMK15271.13A	CGS15321.CHE	CGS15322.MS1	ONA16103.OB1
	CMK15271.13B	CGS15321.MHC	CGS15322.MS2	ONA16106.OB1
	CMK15272.GC1	CGS15321.TCH	CGS15322.MS3	ONA16110.OB1
	CMK15272.GC2	MRC15281.WT1	CGS15323.TSH	ONA16082.OL1
	CMK15273.WC1	MRC15281.WT2	MRC15279.WT1	ONA16097.OL1
	CMK15273.WC2	MRC15281.WT3	MRC15279.WT2	ONA16098.OS1
		MRC15282.WT2	MRC15279.WT3	ONA16103.OL1
		MRC15282.WT5	MRC15279.WT4	ONA16103.OL2
		MRC15282.WT7	MRC15280.WT5	ONA16104.OL1
		MRC15282.WT8	MRC15280.WT6	ONA16111.OL1
			MRC15280.WT7	ONA16111.OL2
			MRC15280.WT8	ONA16111.OL3

Recent Oceanographic and Biological Observations

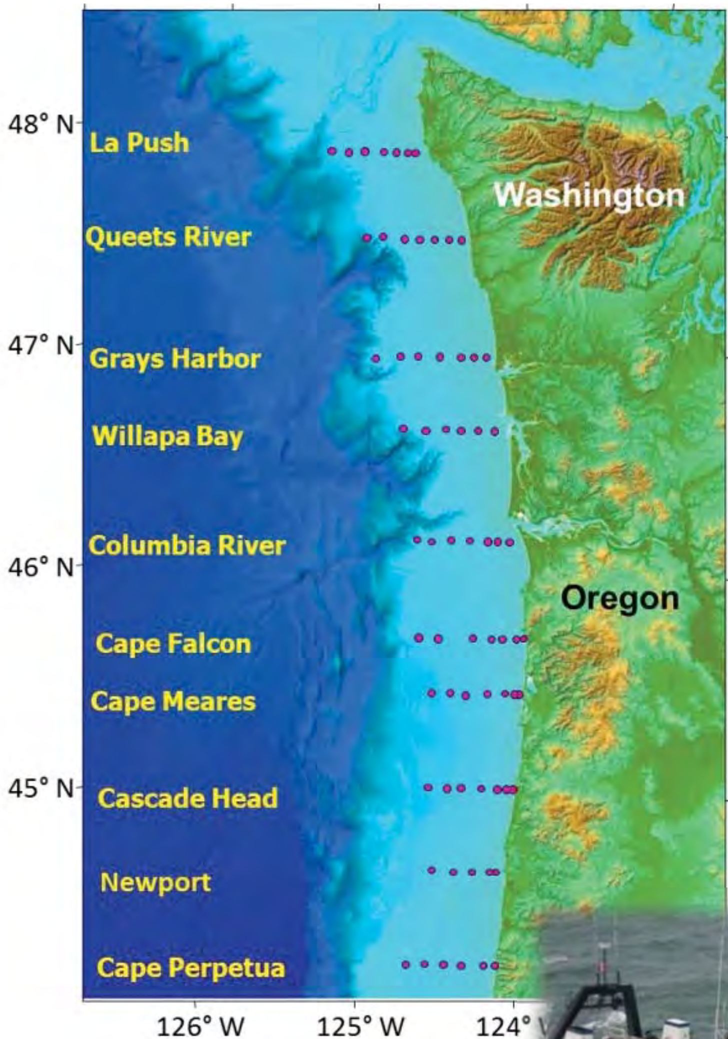
Grant and Douglas County PUD
December 13th – 14th, 2016

Brian Burke
NOAA Fisheries, NWFSC

Supported by:

- **Field Sampling / Data Sources**
- Large-scale Oceanographic Patterns

  (The blob and El Niño)
- Altered Ecology
- Models



Field Sampling

Juvenile salmon sampling:

- May (2006 – 2012, 2015 - present)
- June (1998 – present)
- September (1998 – 2012, 2015)

Newport Line

- Biweekly (1996-present)

Micronekton Survey, 30 m

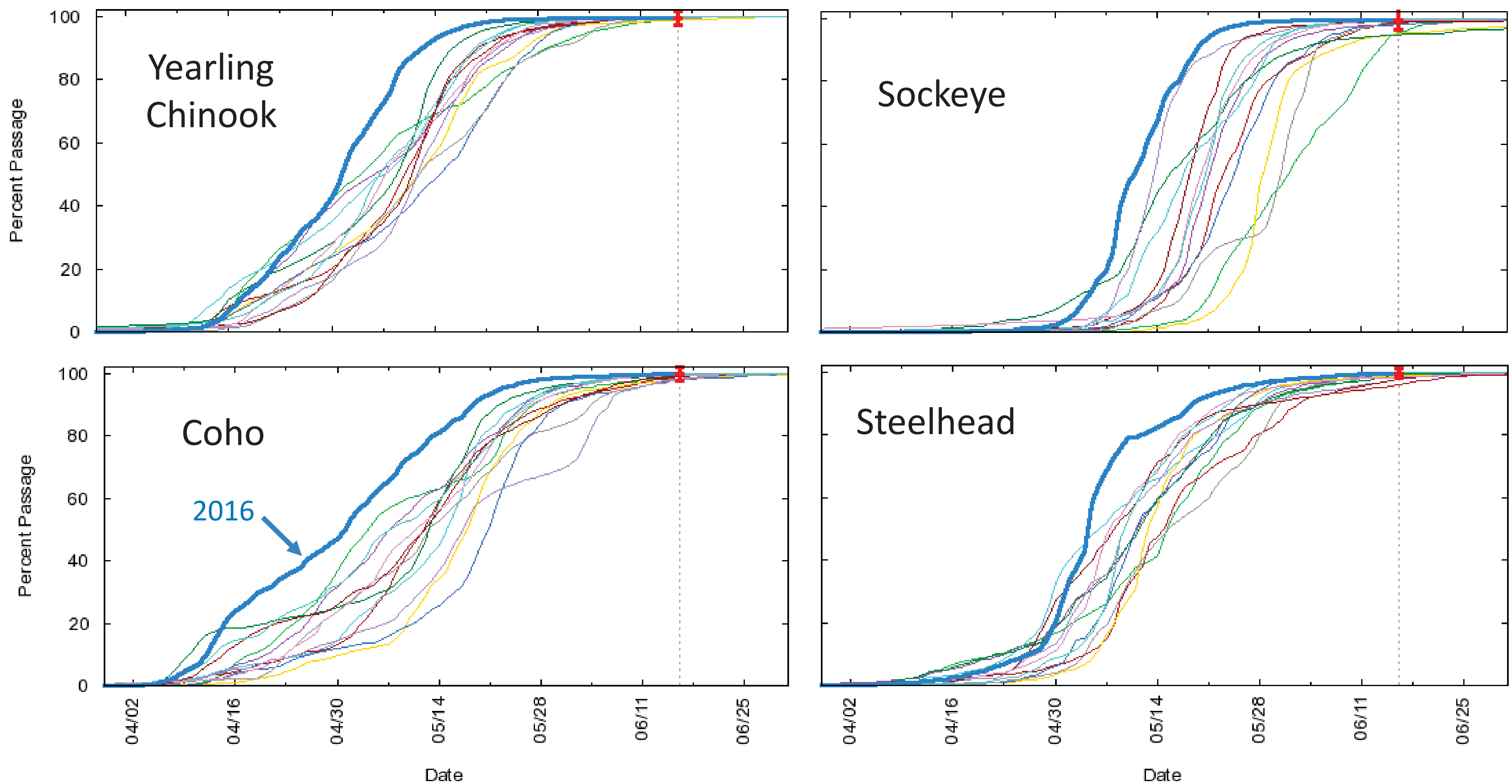
- June (2011, 2013 - 2016)


Pacific Drone

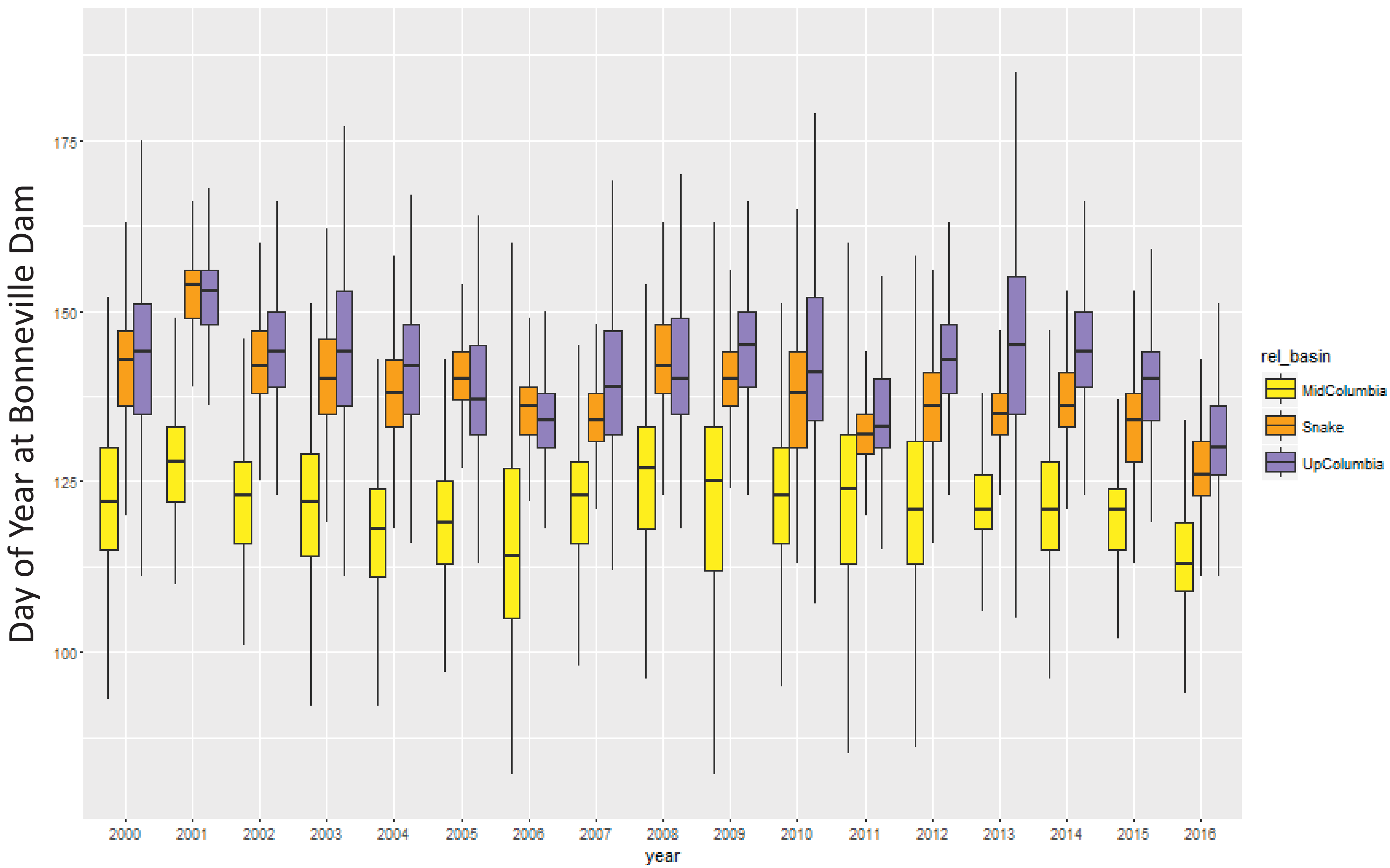

FROSTI
FROSTI
RESEARCH

Migration Timing is Important

Early out-migration in 2016



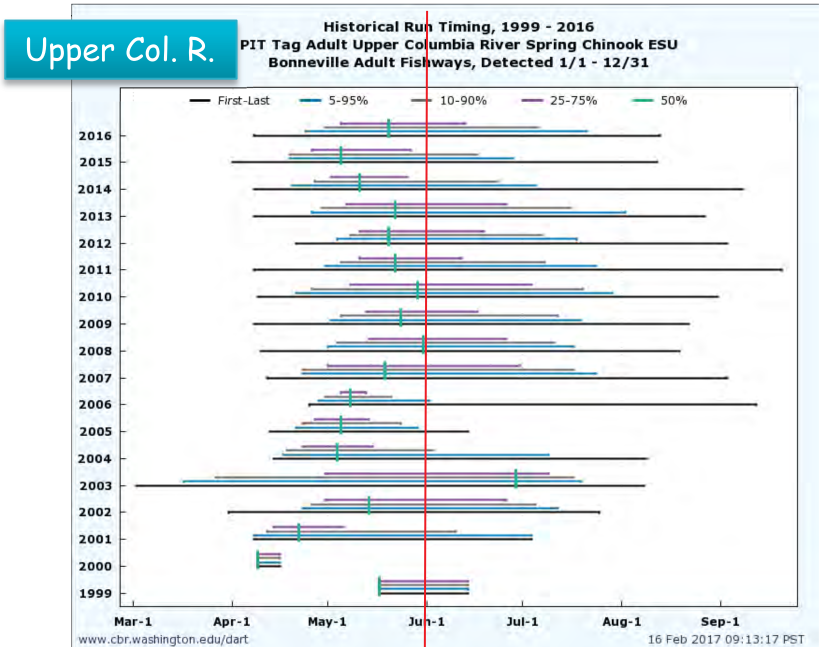
Incorporating stock-specific information

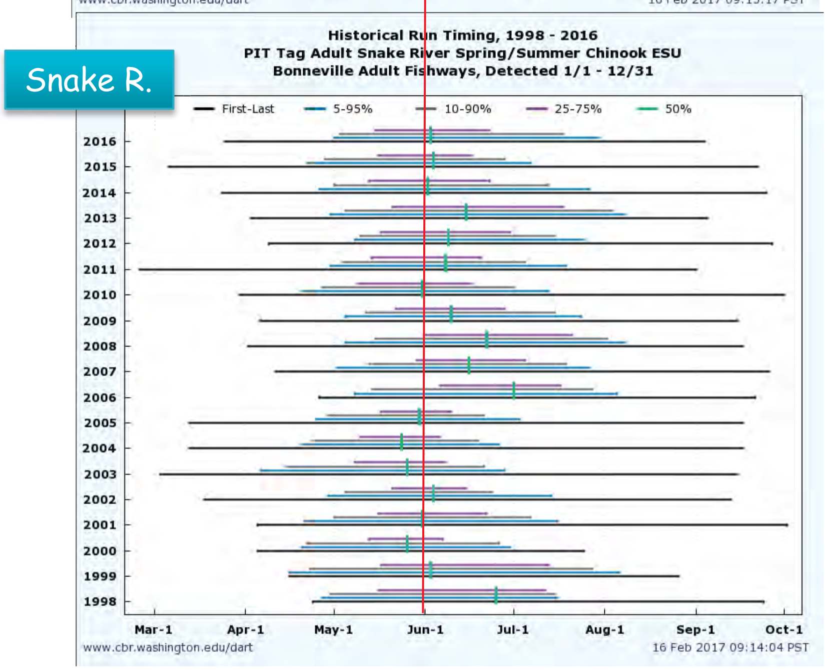


Data obtained from PTAGIS

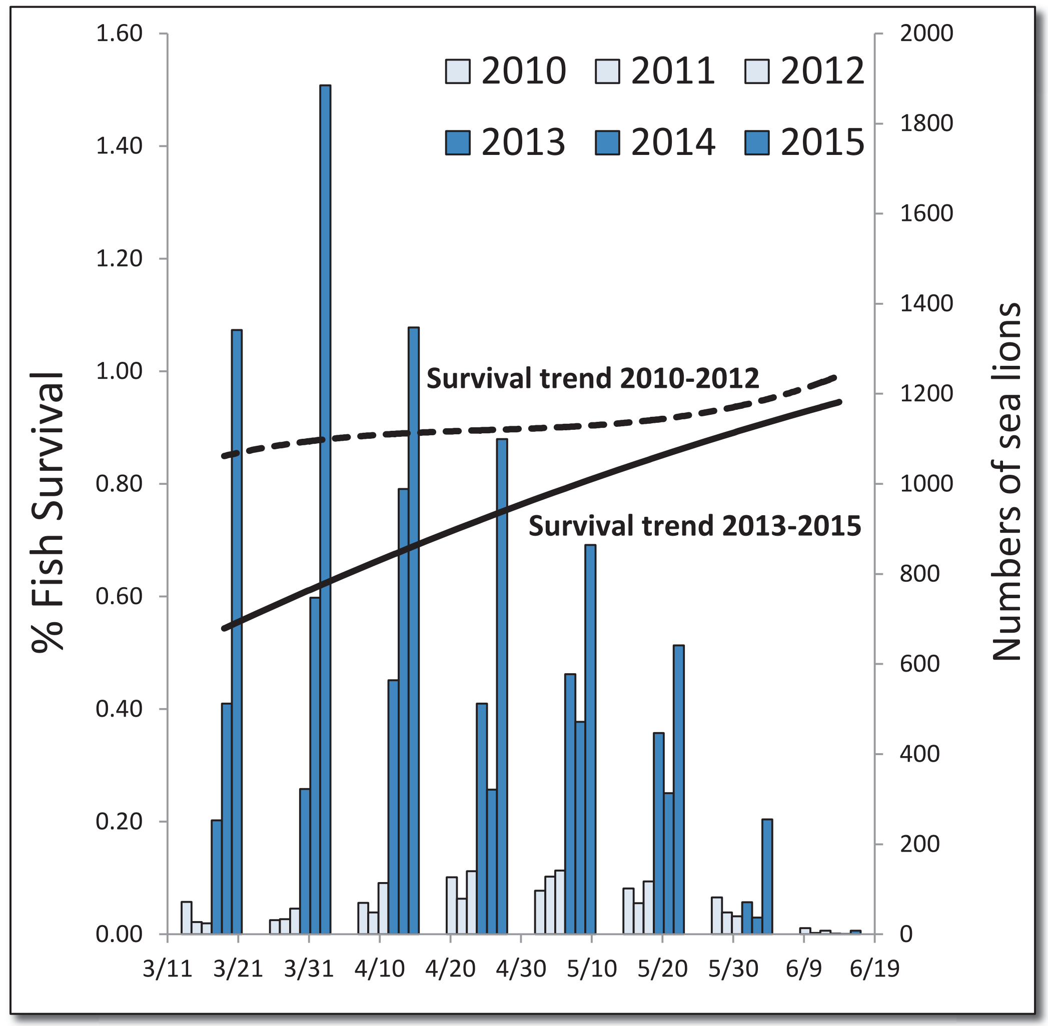
Adult PIT detections at Bonneville Dam

(from CBR DART)



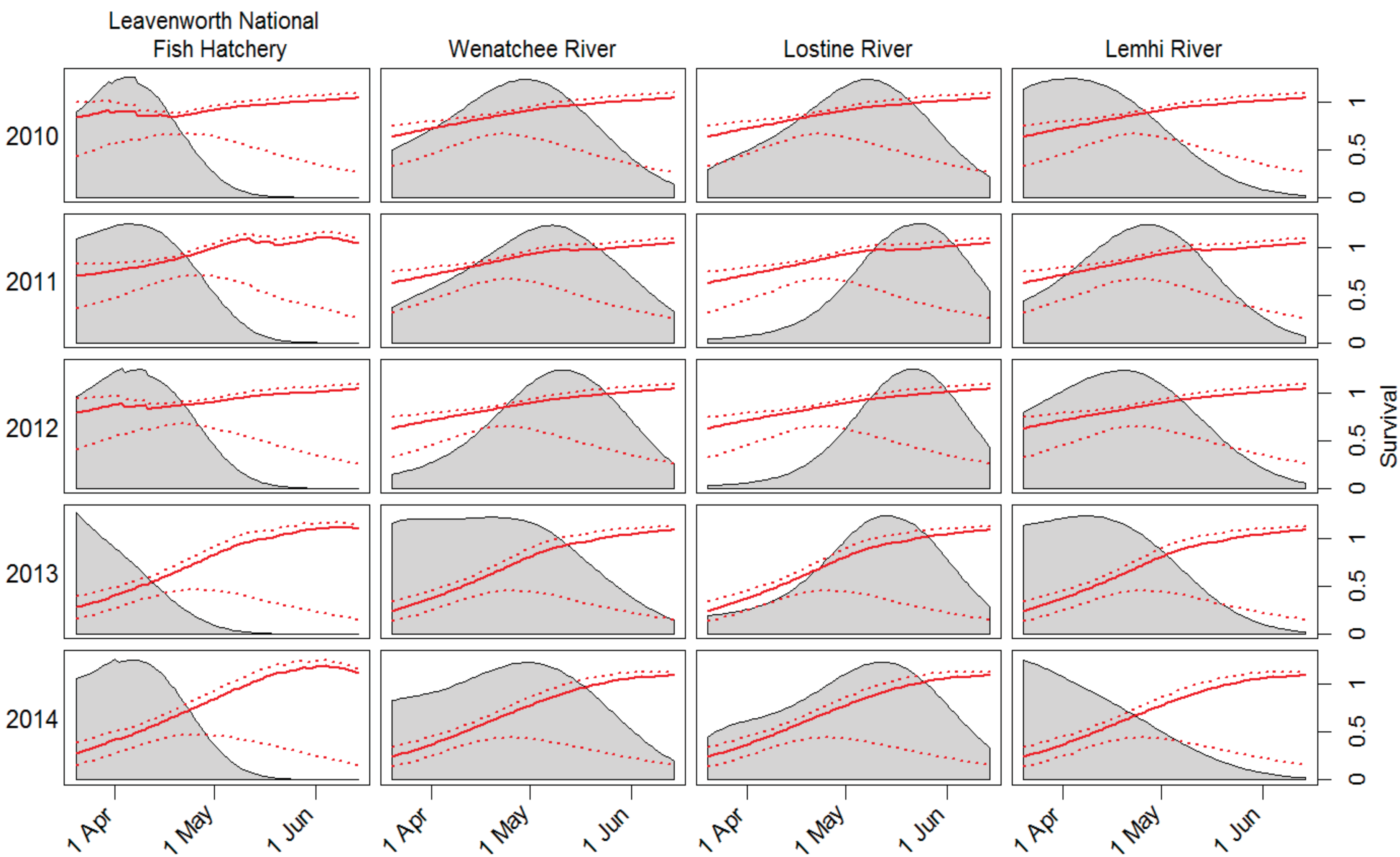


Sea Lions



CSL data provided by Matt Tennis of ODFW

Modeling river entry timing to estimate population specific survival



Analyses by Mark Sorel (NOAA Fisheries)

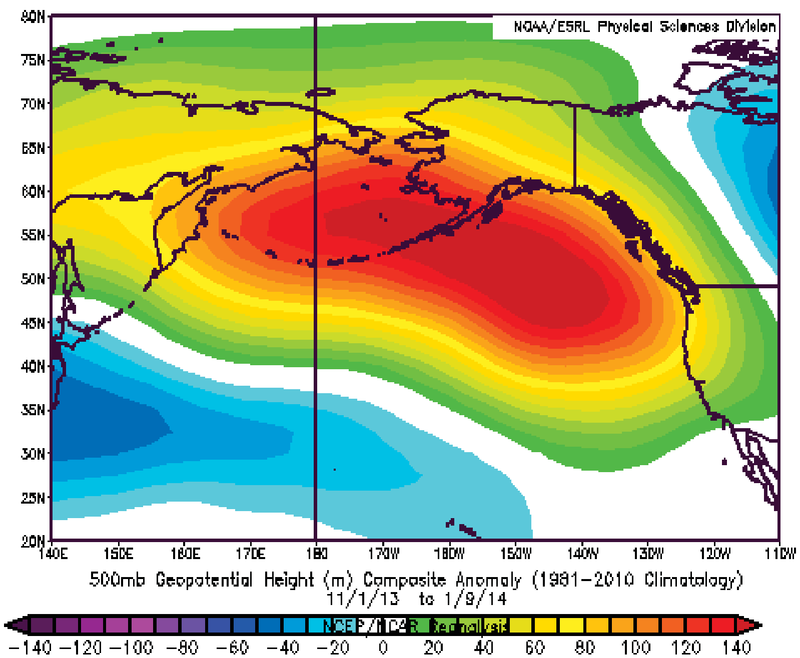
- Field Sampling / Data Sources
- **Large-scale Oceanographic Patterns**

  (The blob and El Niño)
- Altered Ecology
- Models

Formation of the warm blob:

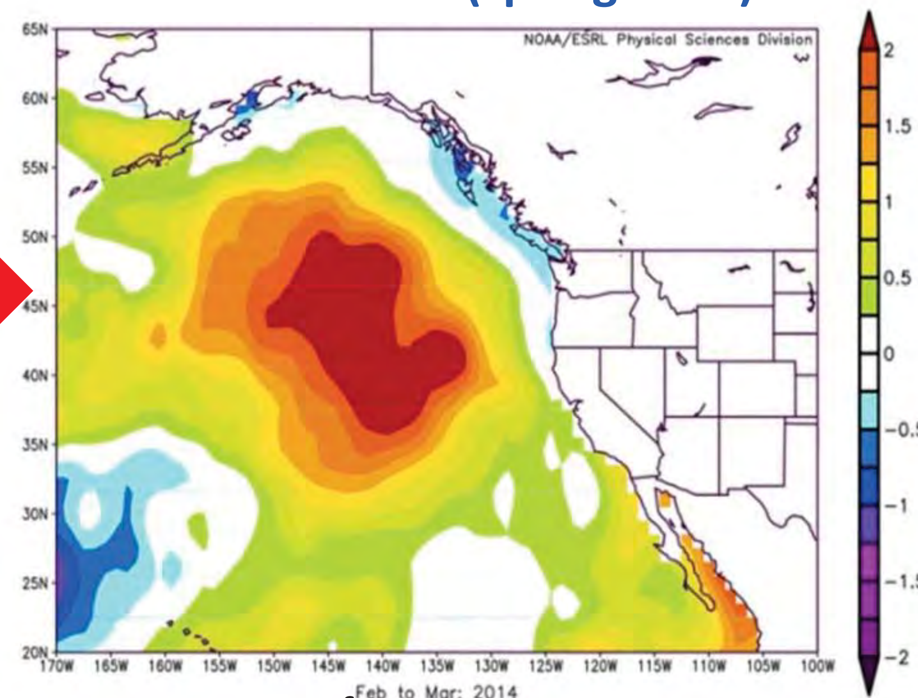
Unusually high pressure over the North Pacific in winter 2013/2014 blocked storms that normally redistribute ocean heat to atmosphere and deep water

Ridiculously resilient ridge (RRR):



Atmospheric pressure anomalies

The warm blob (spring 2014)

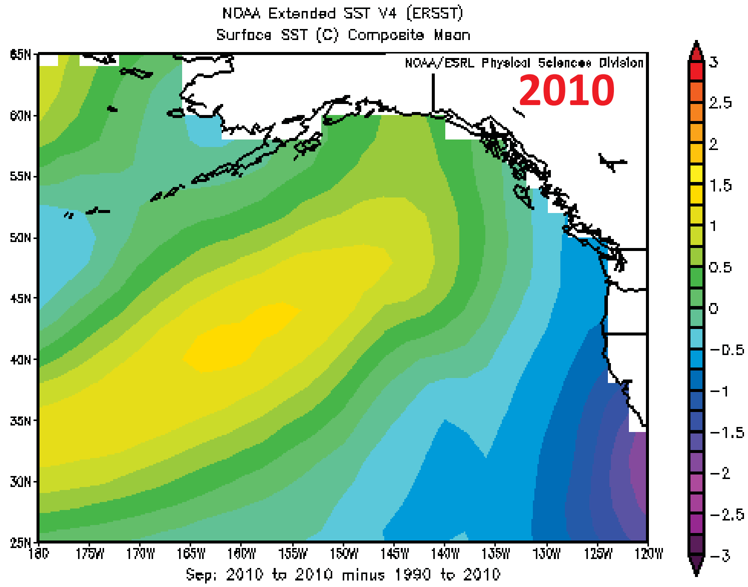


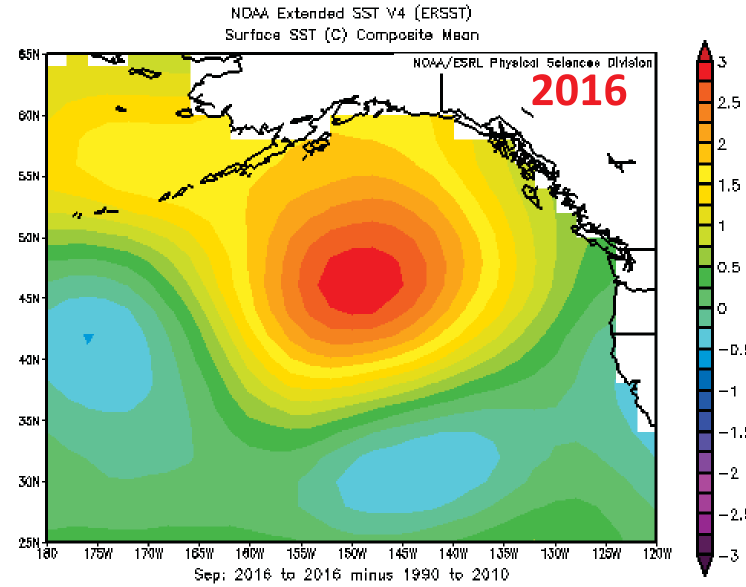
Sea surface temperature (SST) anomalies

Attachment D

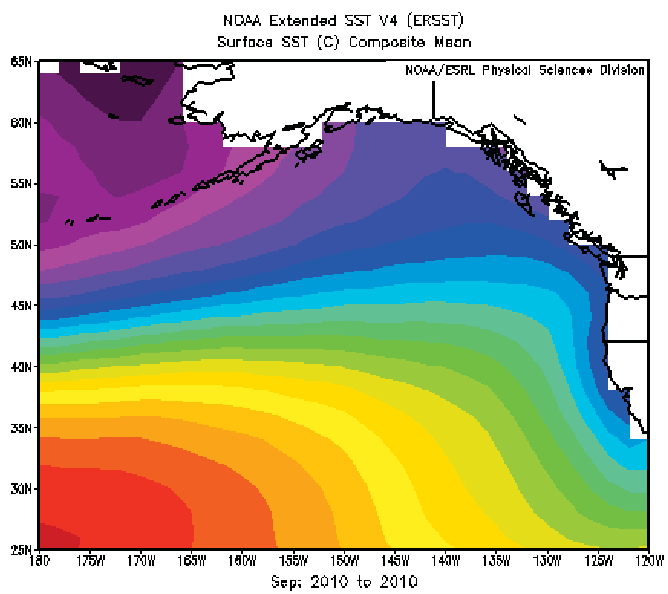
September 2010 and 2016

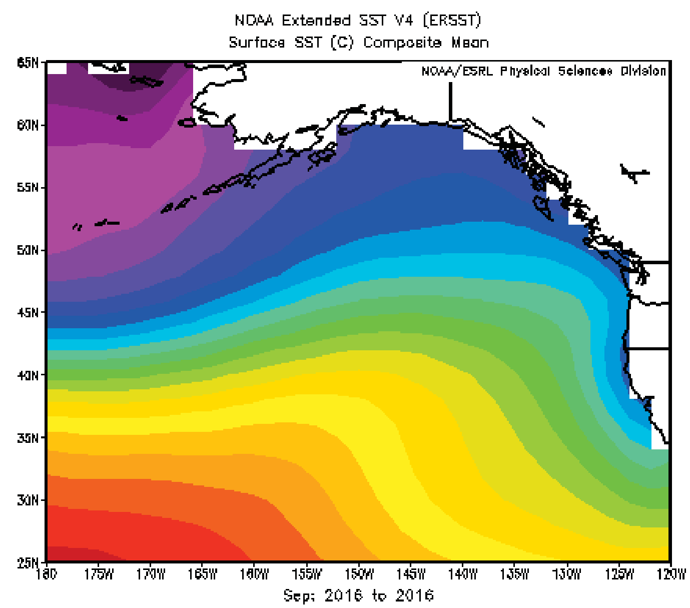
SST Anomaly





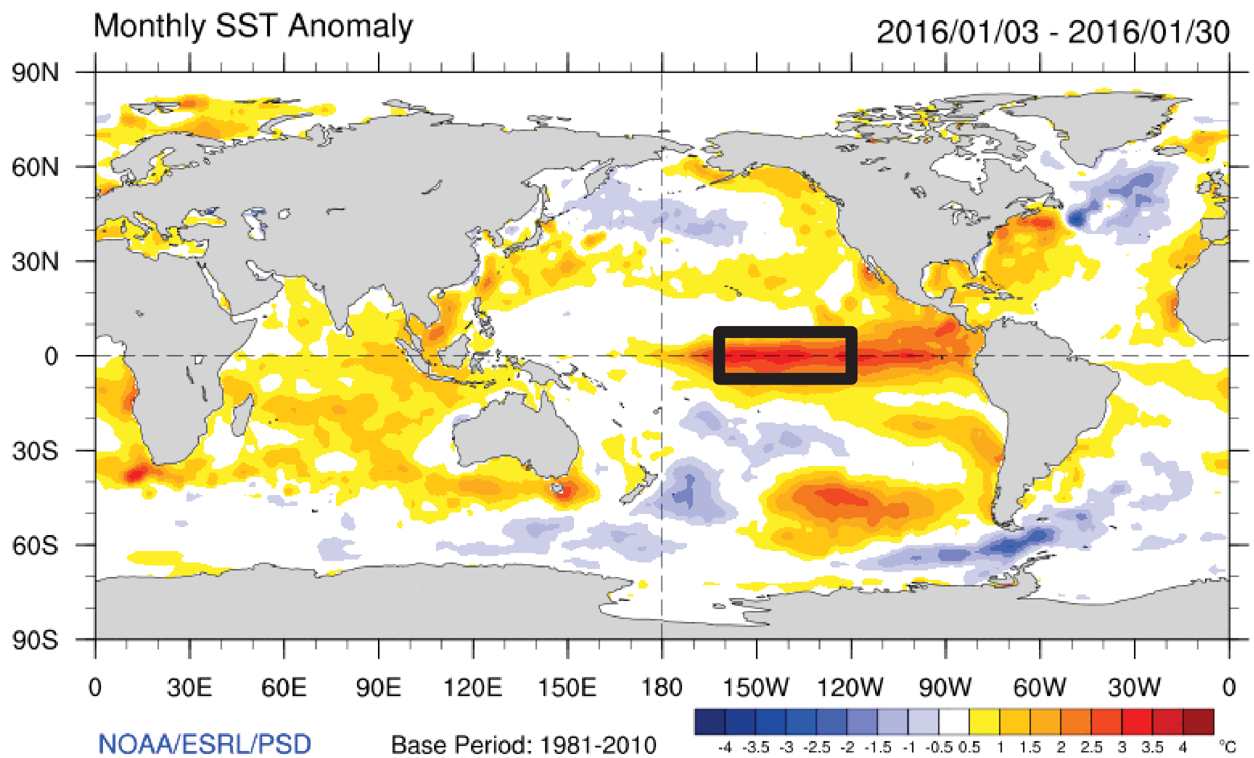
SST

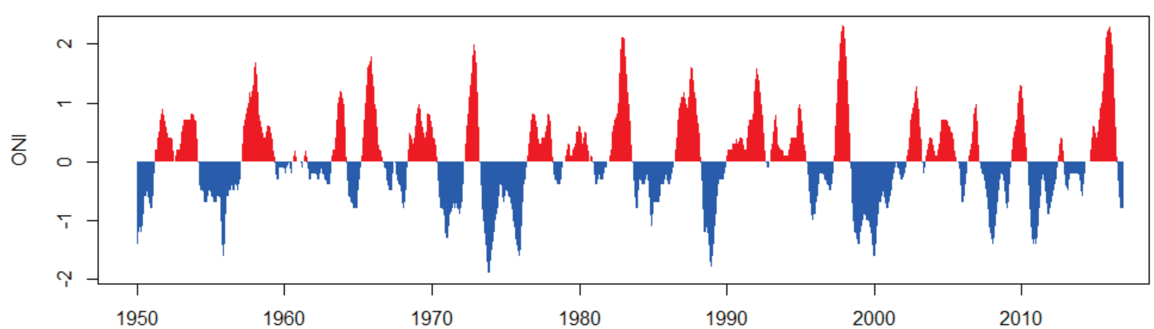




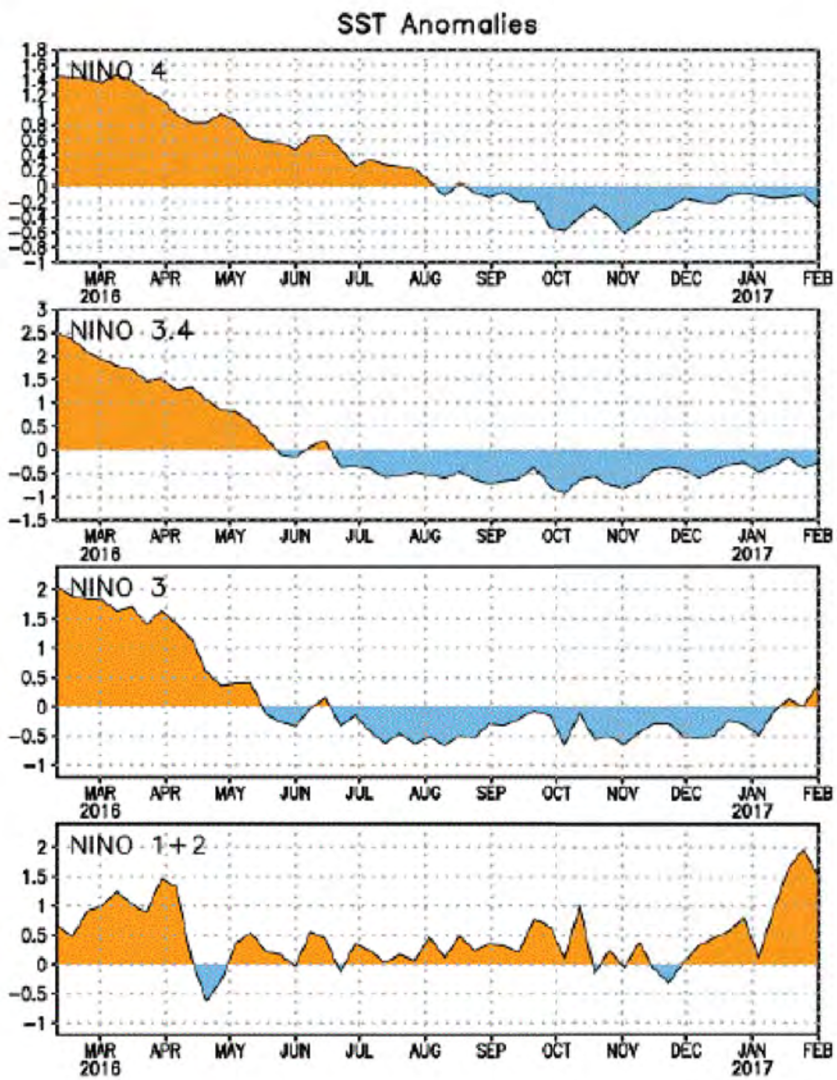
http://www.esrl.noaa.gov/

El Niño


Monthly SST Anomaly
2016/01/03 - 2016/01/30
90N
60N
30N
0
30S
60S
90S
0
30E
60E
90E
120E
150E
180
150W
120W
90W
60W
30W
0
NOAA/ESRL/PSD
Base Period: 1981-2010
-4 -3.5 -3 -2.5 -2 -1.5 -1 -0.5 0.5 1 1.5 2 2.5 3 3.5 4
°C


ONI
2
1
0
-1
-2
1950
1960
1970
1980
1990
2000
2010

El Niño, La Niña, Neutral



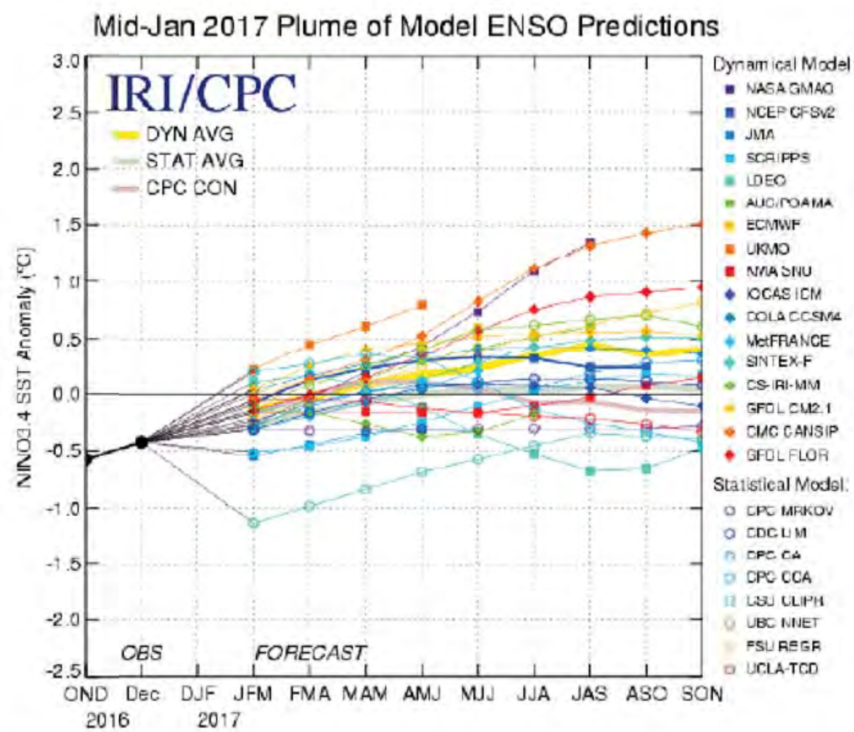
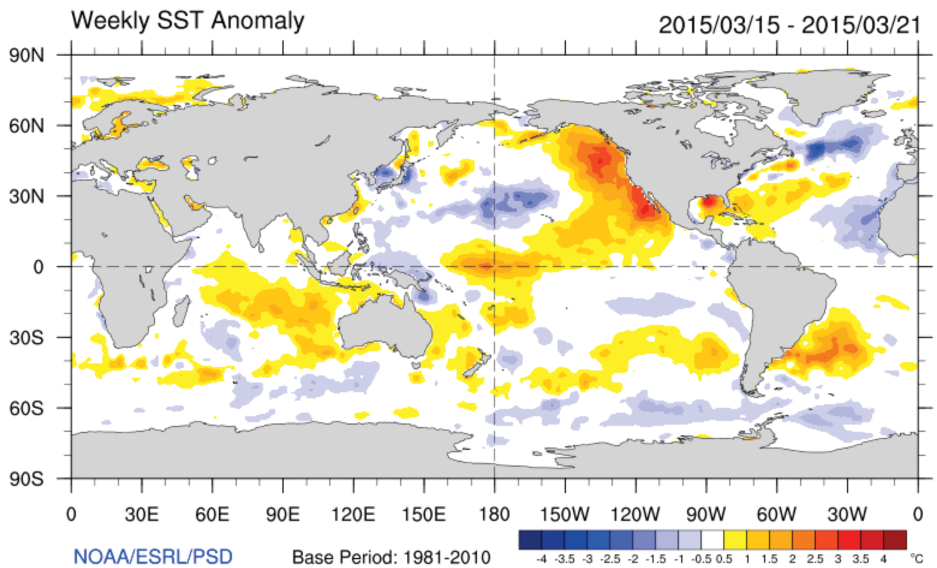


Figure 6. Forecasts of sea surface temperature (SST) anomalies for the Niño 3.4 region (5°N-5°S, 120°W-170°W). Figure updated 18 January 2017.

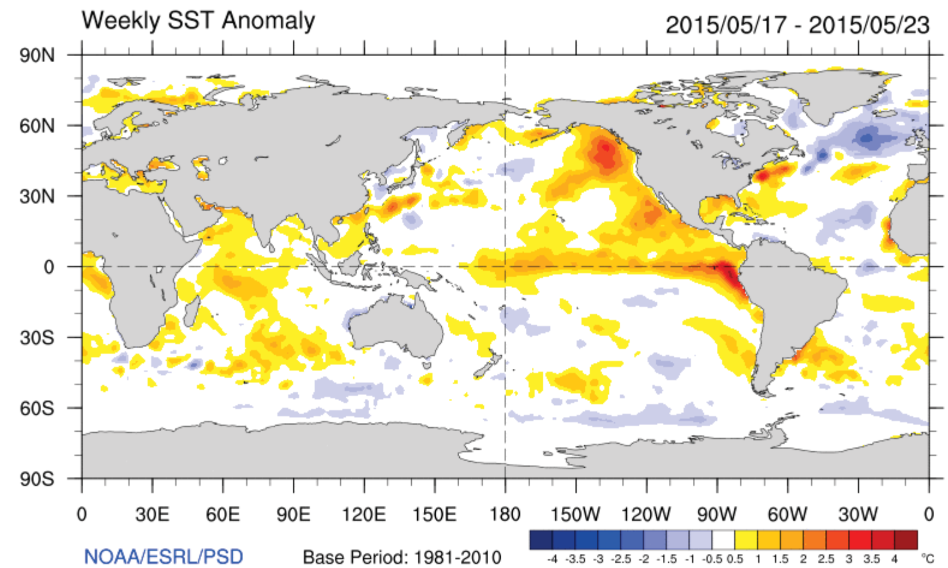
Figure provided by the Climate Prediction Center/NCEP/NWS (updated 10 February 2017).

Attachment D

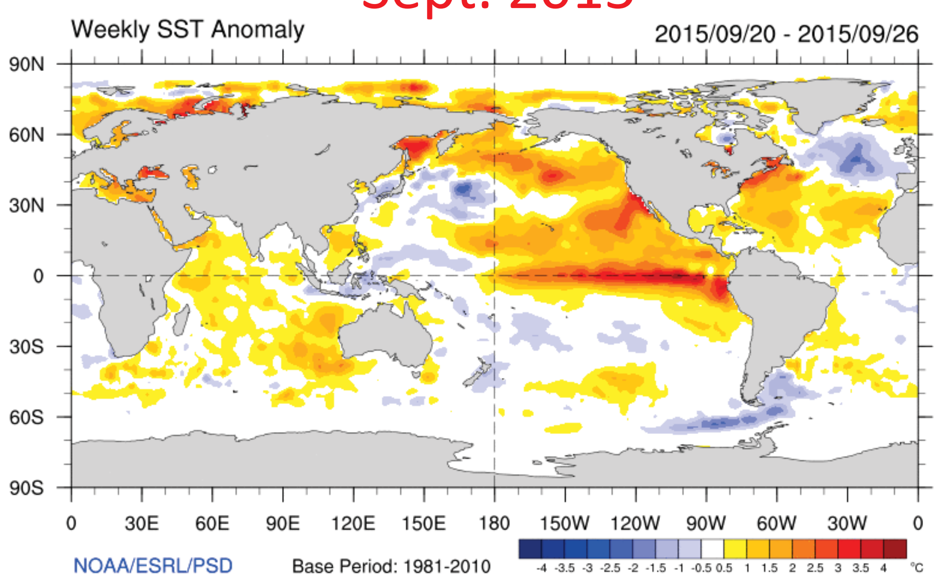
March 2015



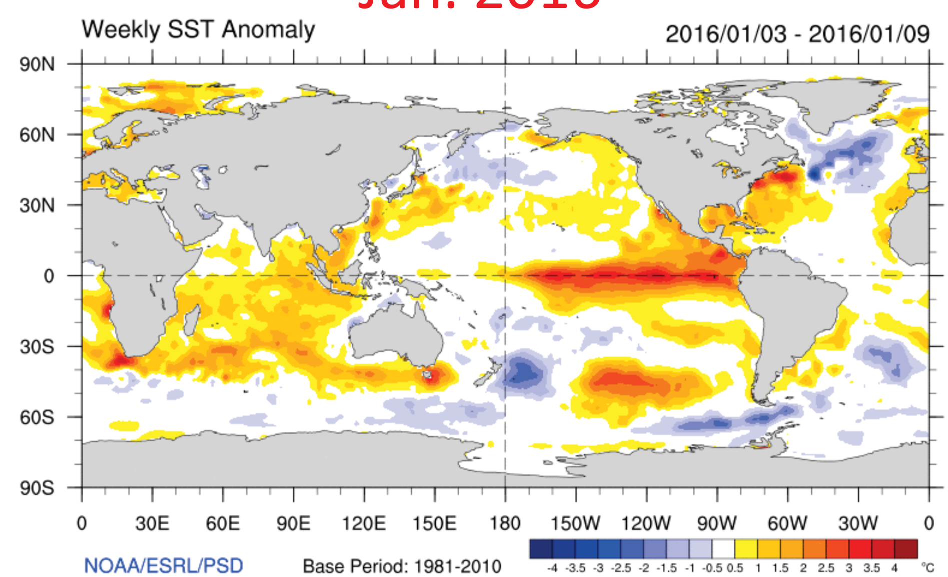
May 2015



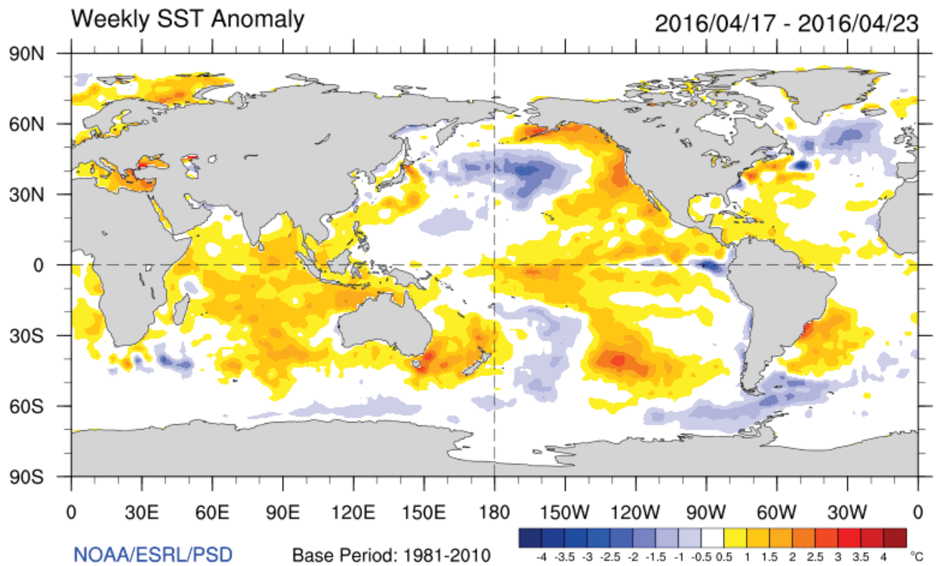
Sept. 2015



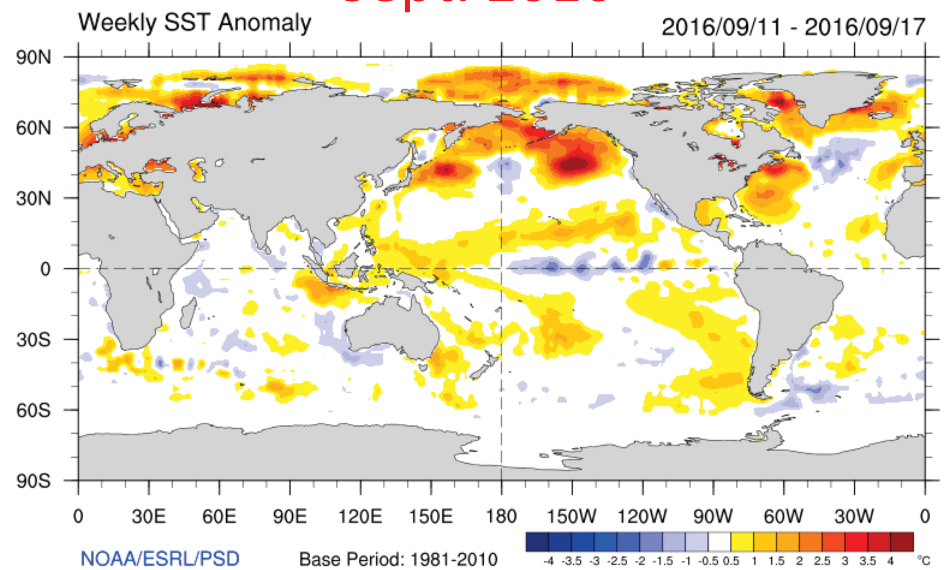
Jan. 2016



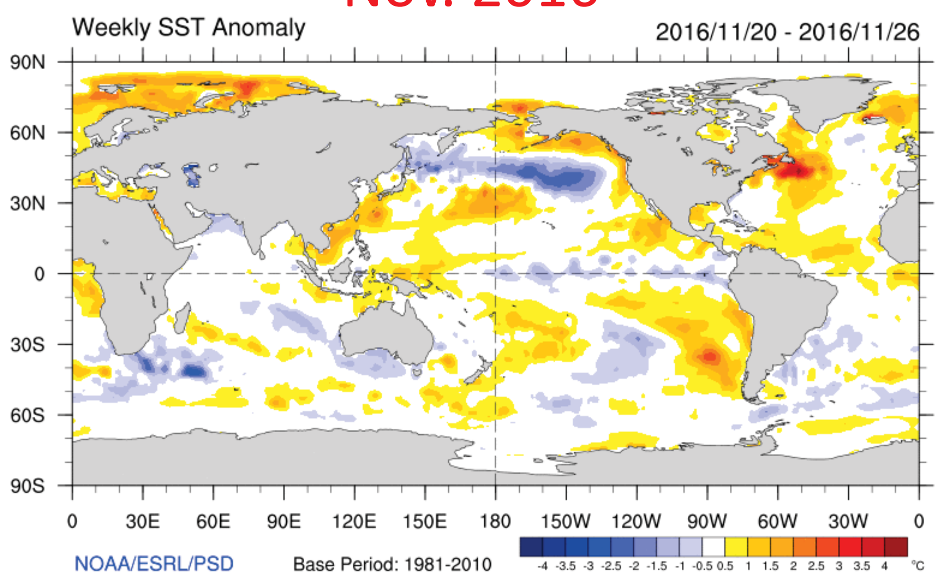
April 2016



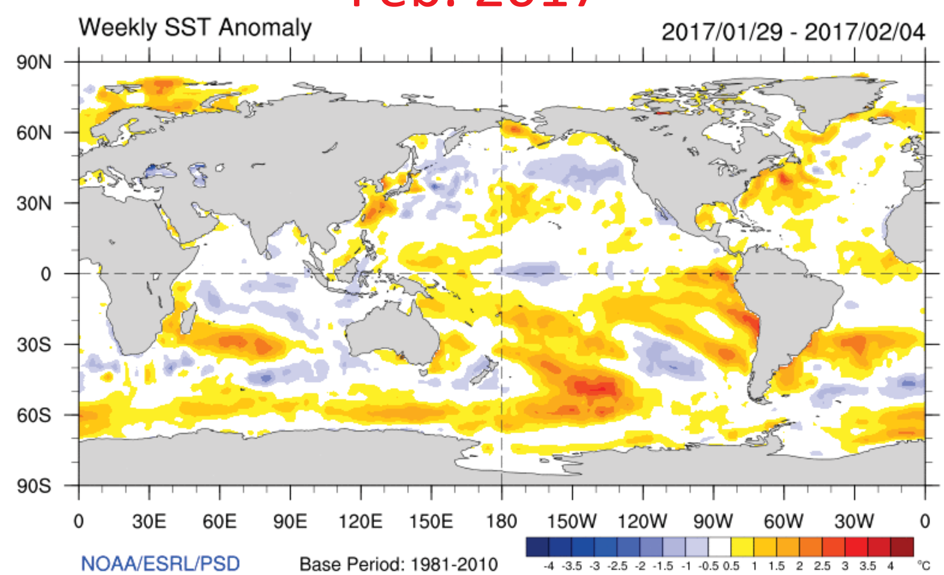
Sept. 2016



Nov. 2016



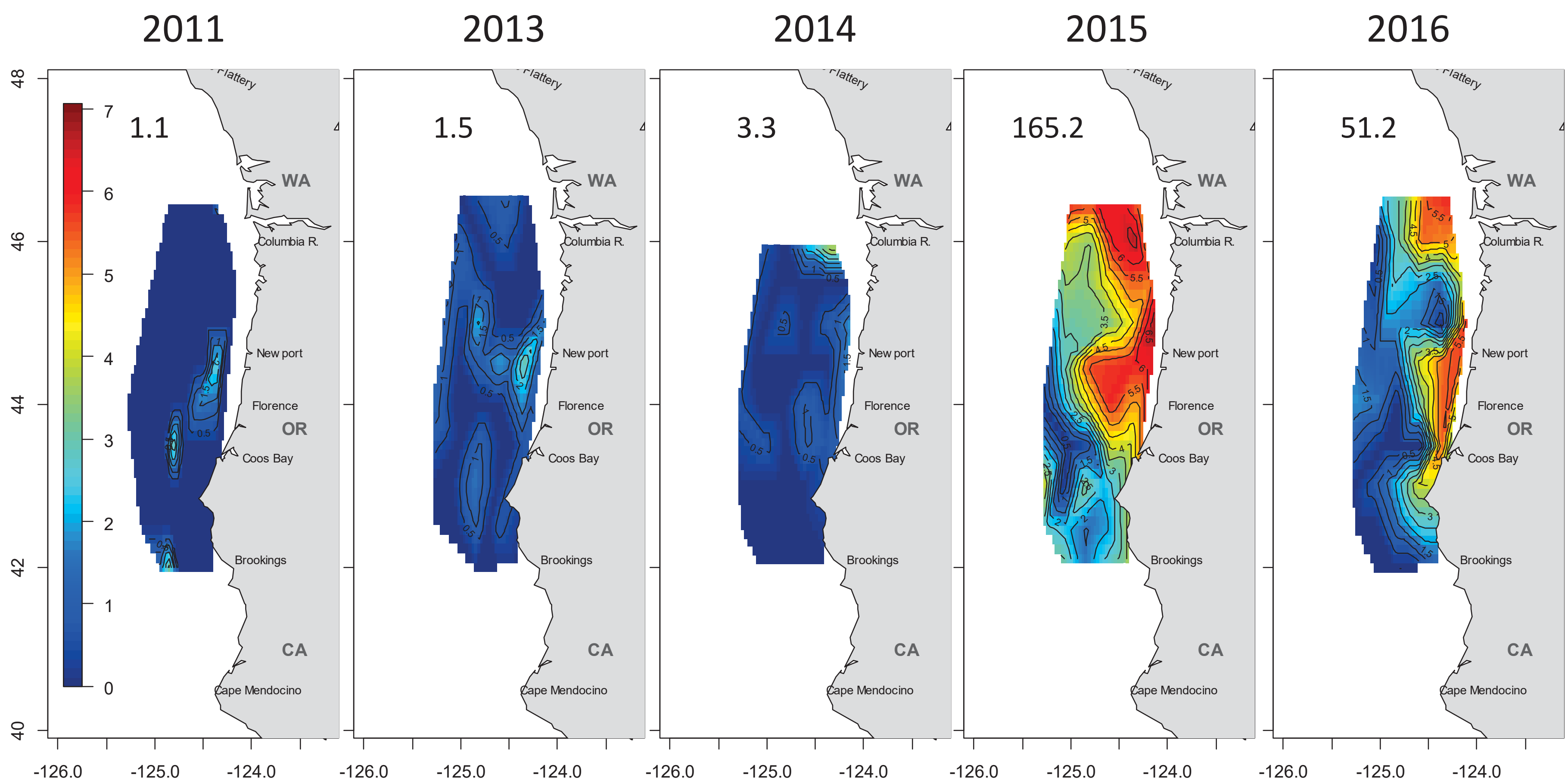
Feb. 2017



- Field Sampling / Data Sources
- Large-scale Oceanographic Patterns

  (The blob and El Niño)
- **Altered Ecology**
- Models

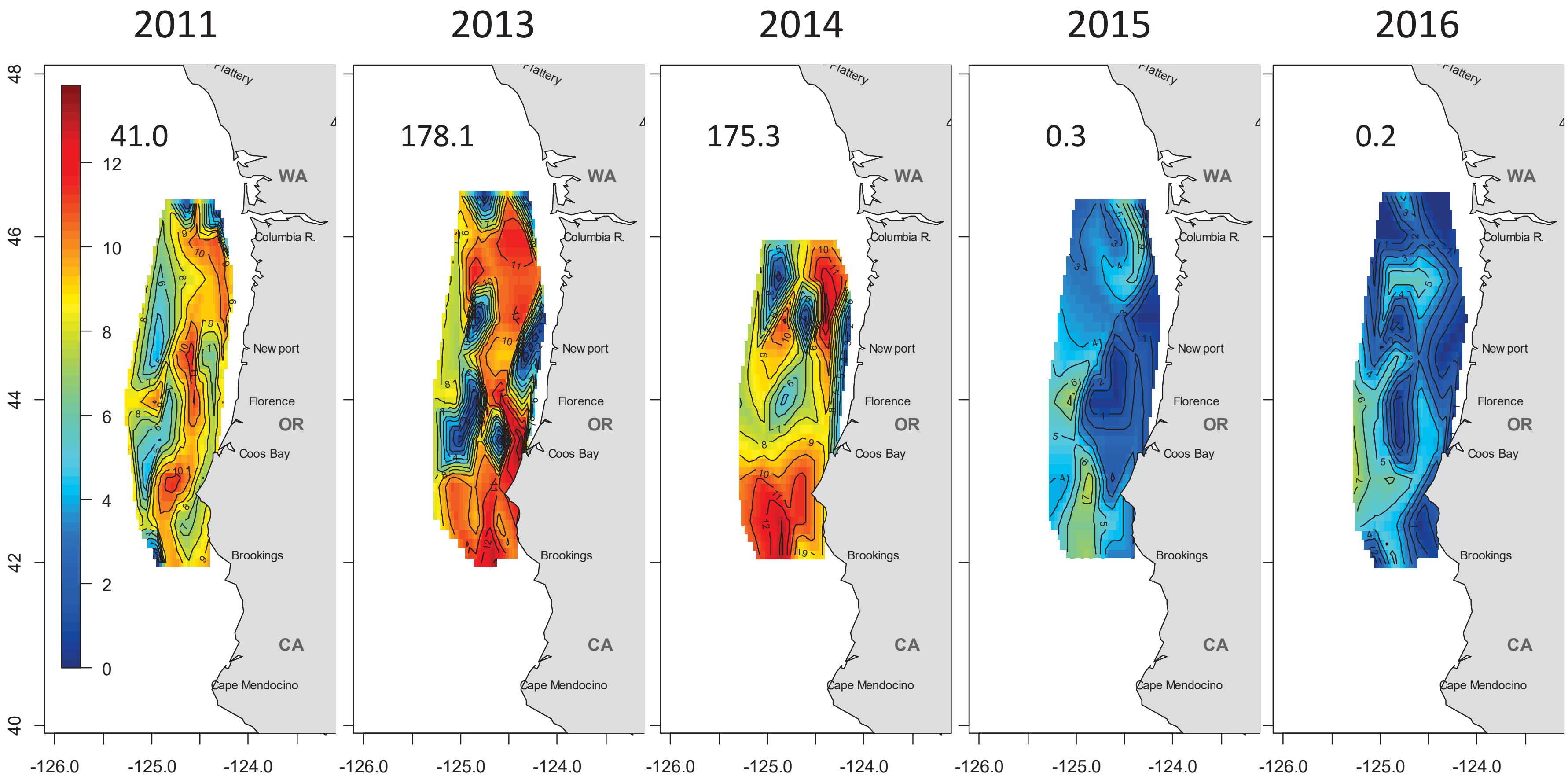
Water Jellies
(*Aequorea victoria*)



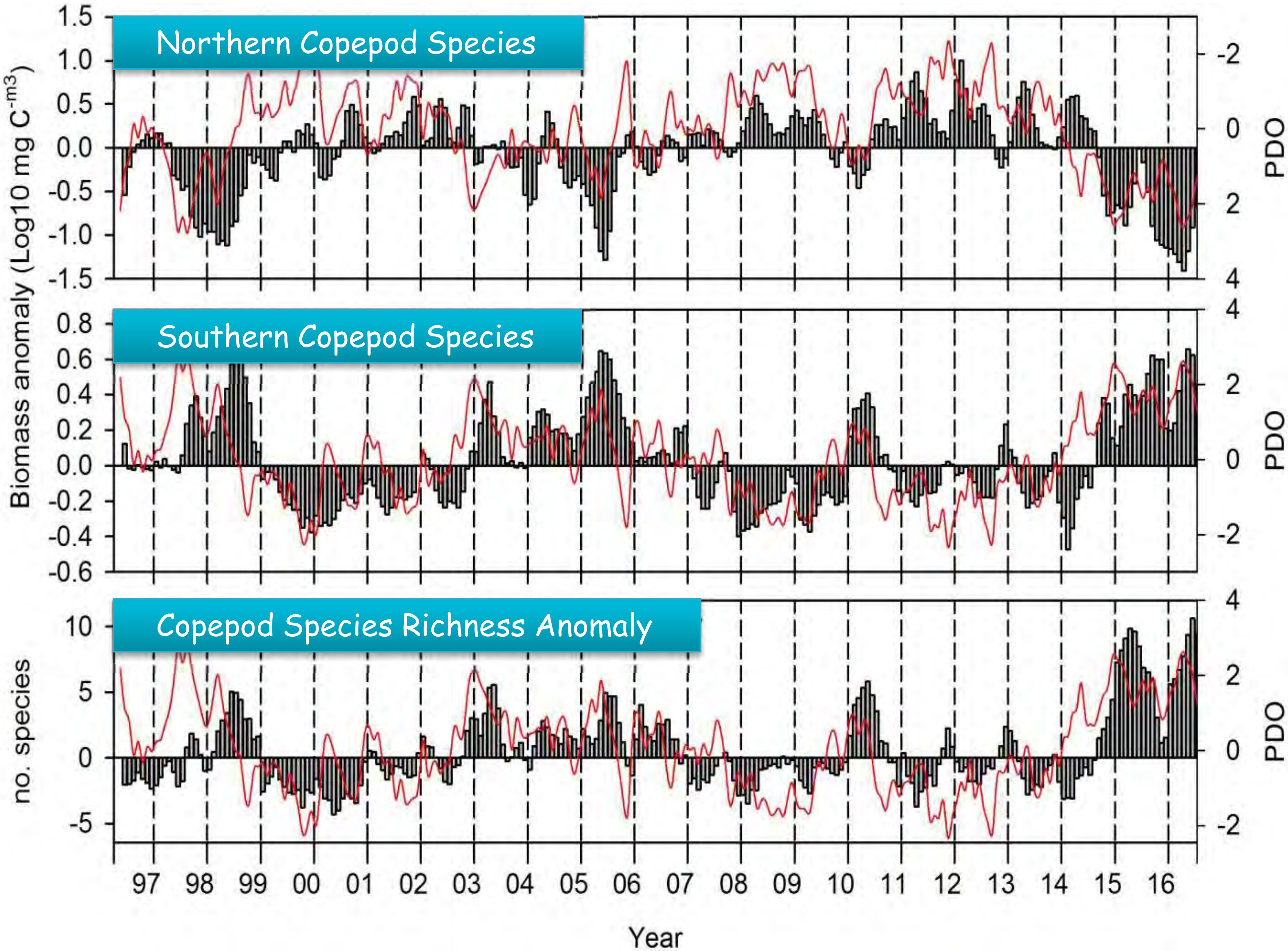
Scale bar = log (abundance)
Number = Geometric mean abundance

Data from Ric Brodeur, NOAA Fisheries

Total Krill
Euphausiidae

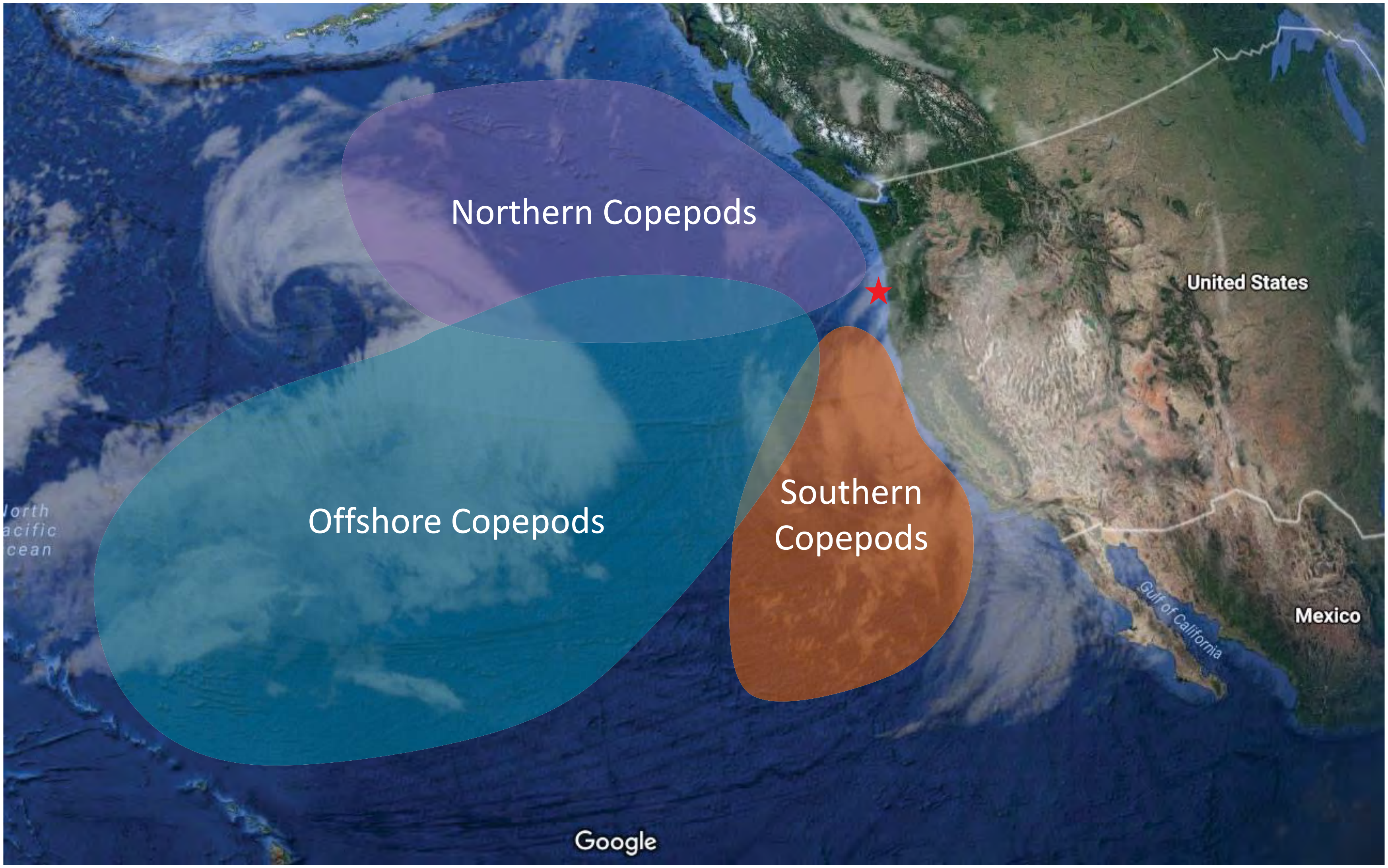


Data from Ric Brodeur, NOAA Fisheries

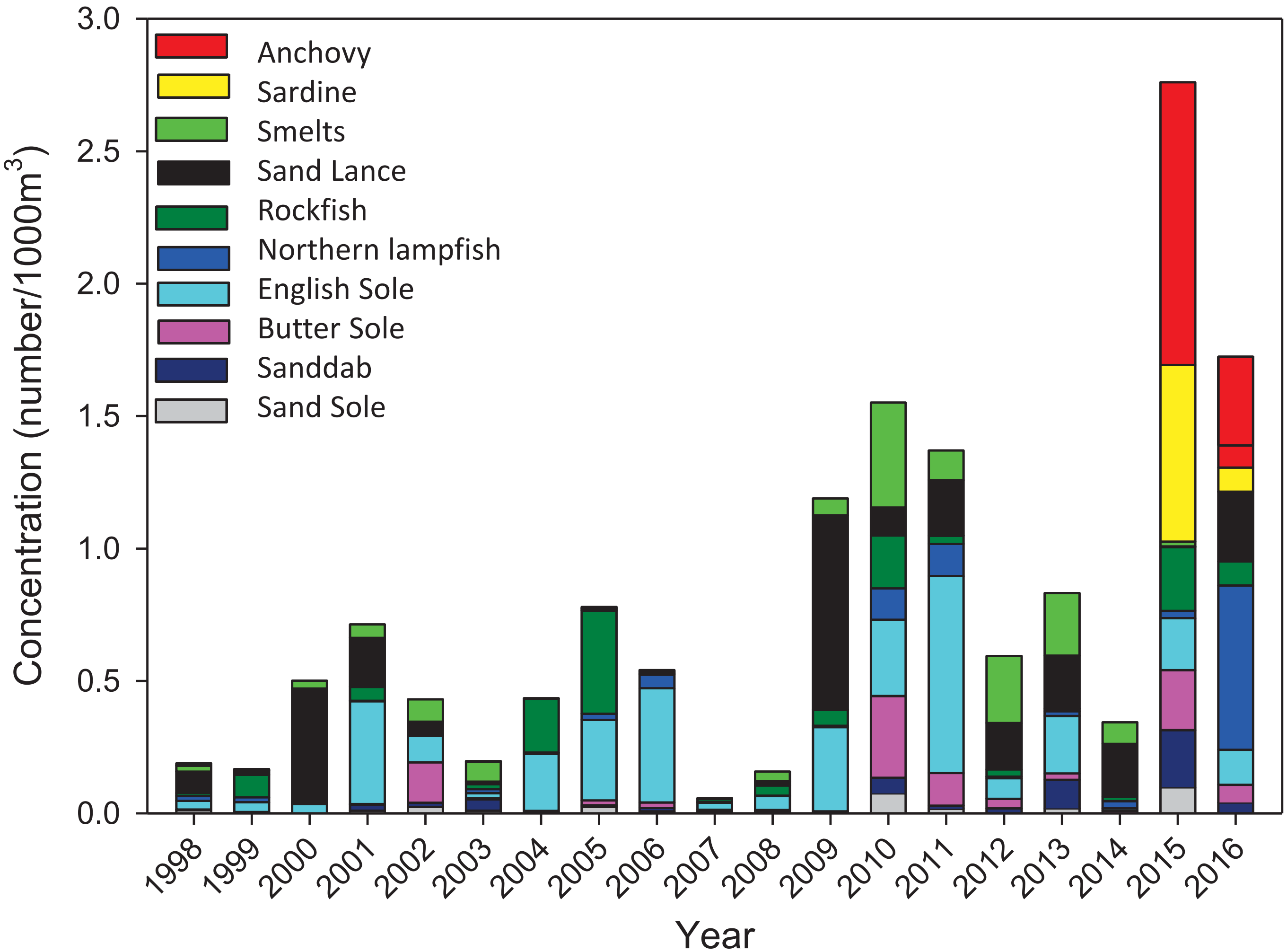


Data courtesy of Bill Peterson

Copepod Species Indicate Source Waters for Transport



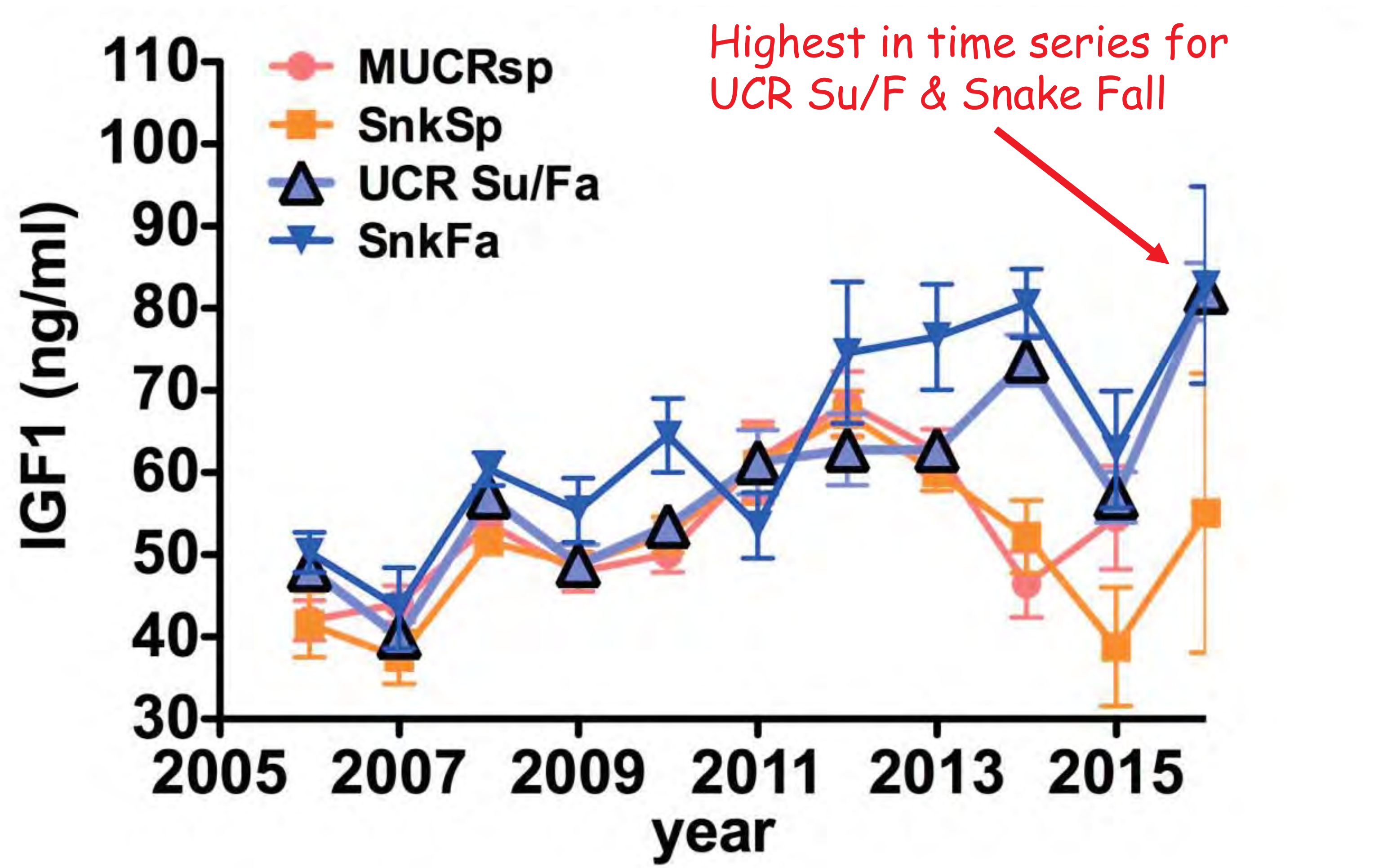
Winter (Jan – March) Ichthyoplankton



- Earliest (by three months) and most widespread spawning of anchovies and sardines in NCC
- Also found Pacific hake and jack mackerel eggs and larvae off Newport
- Both years had a diversity of larvae represented in the winter samples

Auth et al. (In prep.)

June Chinook Yearling IGF (growth hormone)



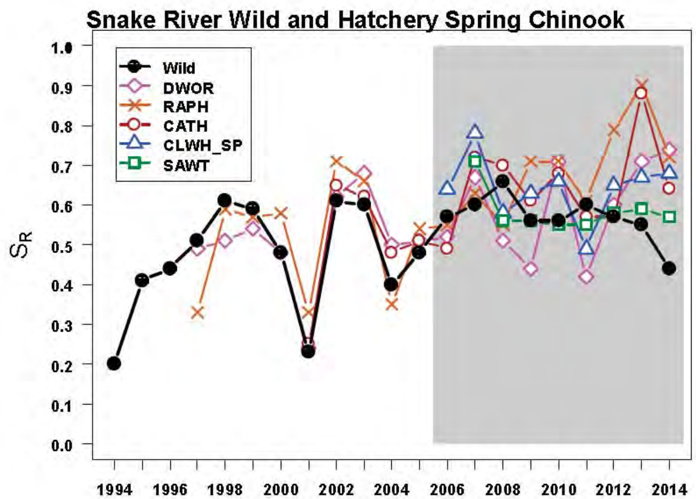
Data from Brian Beckman (NOAA Fisheries)

- Field Sampling / Data Sources
- Large-scale Oceanographic Patterns

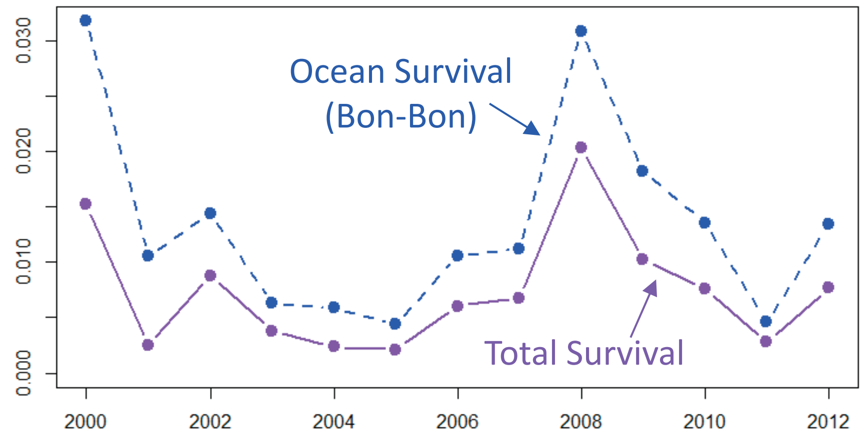
  (The blob and El Niño)
- Altered Ecology
- **Models**

Where is the source of variability?

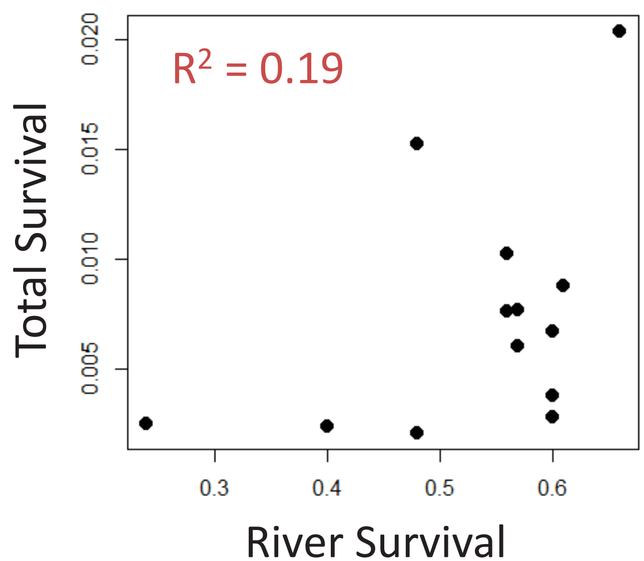
Wild and hatchery Chinook

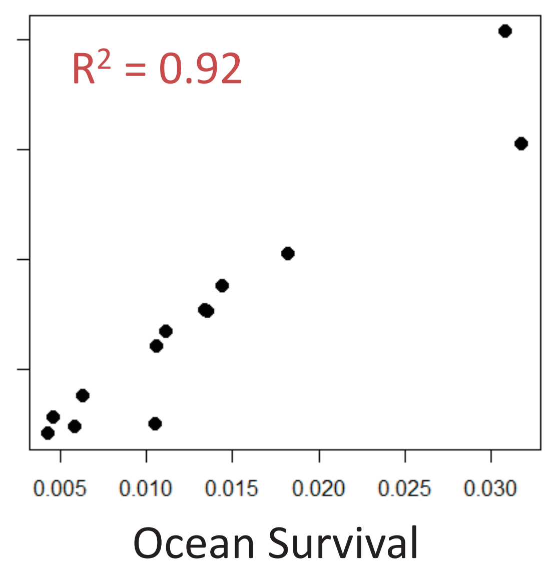


Obtained from CSS – 2015 Annual Report



Raw data from PTAGIS, survival estimated by B. Burke





		Year																		
	Ecosystem Indicators	*1998*	*1999*	*2000*	*2001*	*2002*	*2003*	*2004*	*2005*	*2006*	*2007*	*2008*	*2009*	*2010*	*2011*	*2012*	*2013*	*2014*	*2015*	*2016*
Basin-scale physical indices	PDO (Sum Dec-March)	16	6	3	12	7	18	11	15	13	9	5	1	14	4	2	8	10	19	17
	PDO (Sum May-Sept)	10	4	6	5	11	15	14	16	12	13	2	9	7	3	1	8	17	19	18
	ONI (Average Jan-June)	18	1	1	6	12	14	13	15	8	11	3	10	16	4	5	7	9	17	19
Regional physical indices	46050 SST (°C; May-Sept)	15	8	3	4	1	7	19	14	5	16	2	9	6	10	11	12	13	18	17
	Upper 20 m T (°C; Nov-Mar)	18	11	8	10	6	14	15	12	13	5	1	9	16	4	3	7	2	19	17
	Upper 20 m T (°C; May-Sept)	15	11	13	4	1	3	19	17	7	8	2	5	12	10	6	16	18	9	14
	Deep temperature (°C; May-Sept)	19	6	8	4	1	10	12	16	11	5	2	7	14	9	3	15	18	17	13
	Deep salinity (May-Sept)	18	3	8	4	5	15	16	9	6	1	2	13	17	12	11	10	19	14	7
Regional biological indices	Copepod richness anom. (no. species; May-Sept)	17	2	1	7	6	13	12	16	14	10	8	9	15	4	5	3	11	18	19
	N. copepod biomass anom. (mg C m^{-3}; May-Sept)	17	13	9	10	3	15	12	18	14	11	6	8	7	1	2	4	5	16	19
	S. copepod biomass anom. (mg C m^{-3}; May-Sept)	19	2	5	4	3	13	14	18	12	10	1	7	15	9	8	6	11	16	17
	Biological transition (day of year)	17	11	6	7	8	12	10	16	15	3	1	2	14	4	9	5	13	19	19
	Ichthyoplankton biomass (log (mg C 1000 m^{-3}); Jan-Mar)	19	10	2	6	8	17	16	12	15	14	1	11	3	13	9	7	18	4	5
	Ichthyoplankton community index (PCO axis 1 scores; Jan-Mar)	9	13	1	6	4	10	18	16	3	12	2	14	15	11	5	7	8	17	19
	Chinook salmon juvenile catches (no. km^{-1}; June)	18	4	5	16	10	13	17	19	12	8	1	6	7	15	3	2	9	14	11
	Coho salmon juvenile catches (no. km^{-1}; June)	18	7	12	5	6	2	15	19	16	3	4	9	10	14	17	1	11	8	13
	Mean of ranks	16.4	7.0	5.7	6.9	5.8	11.9	14.6	15.5	11.0	8.7	2.7	8.1	11.8	7.9	6.3	7.4	12.0	15.3	15.3
	Rank of the mean rank	19	6	2	5	3	13	15	18	11	10	1	9	12	8	4	7	14	16	16

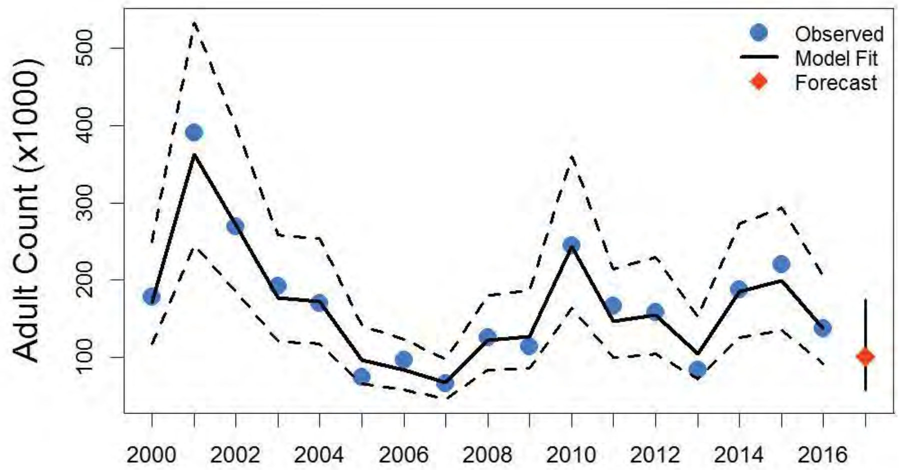
Spring Chinook at Bonneville Dam

Dynamic Linear Models

With jack counts and the first Principal Component of the stoplight chart variables

Spring Chinook

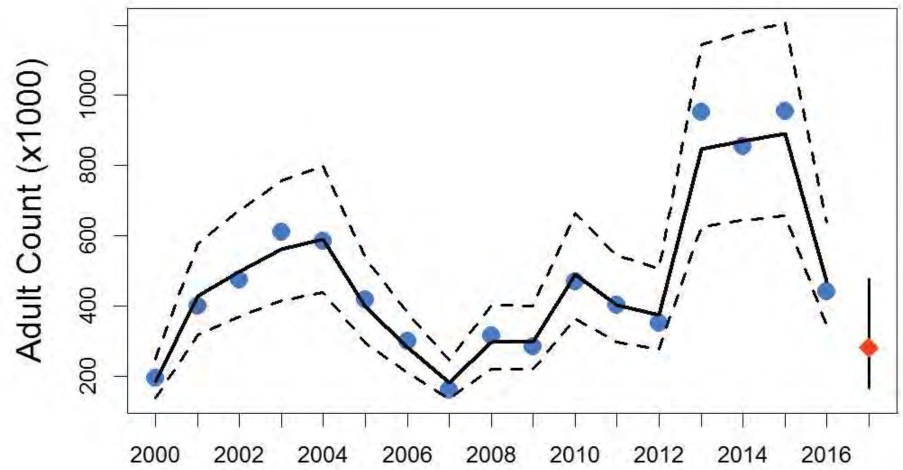
March 15 – May 31



Outlook for 2017: 101K (58-174)

Fall Chinook

Aug 1 – Nov 15

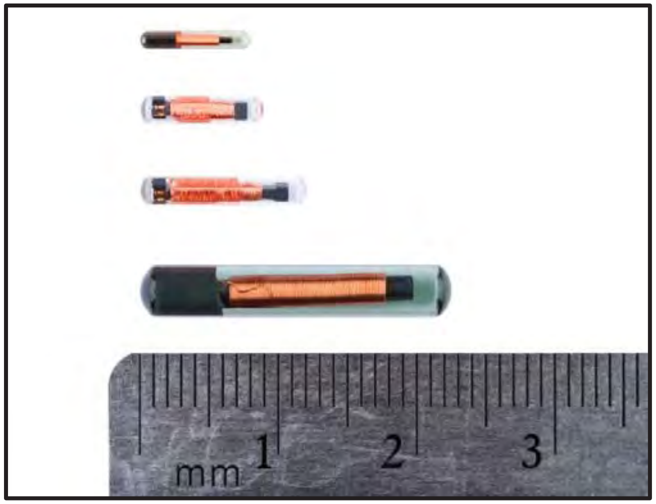


Outlook for 2017: 266K (158-450)

Data from Columbia Basin Research, DART

Logistic Model with PIT Tag Data

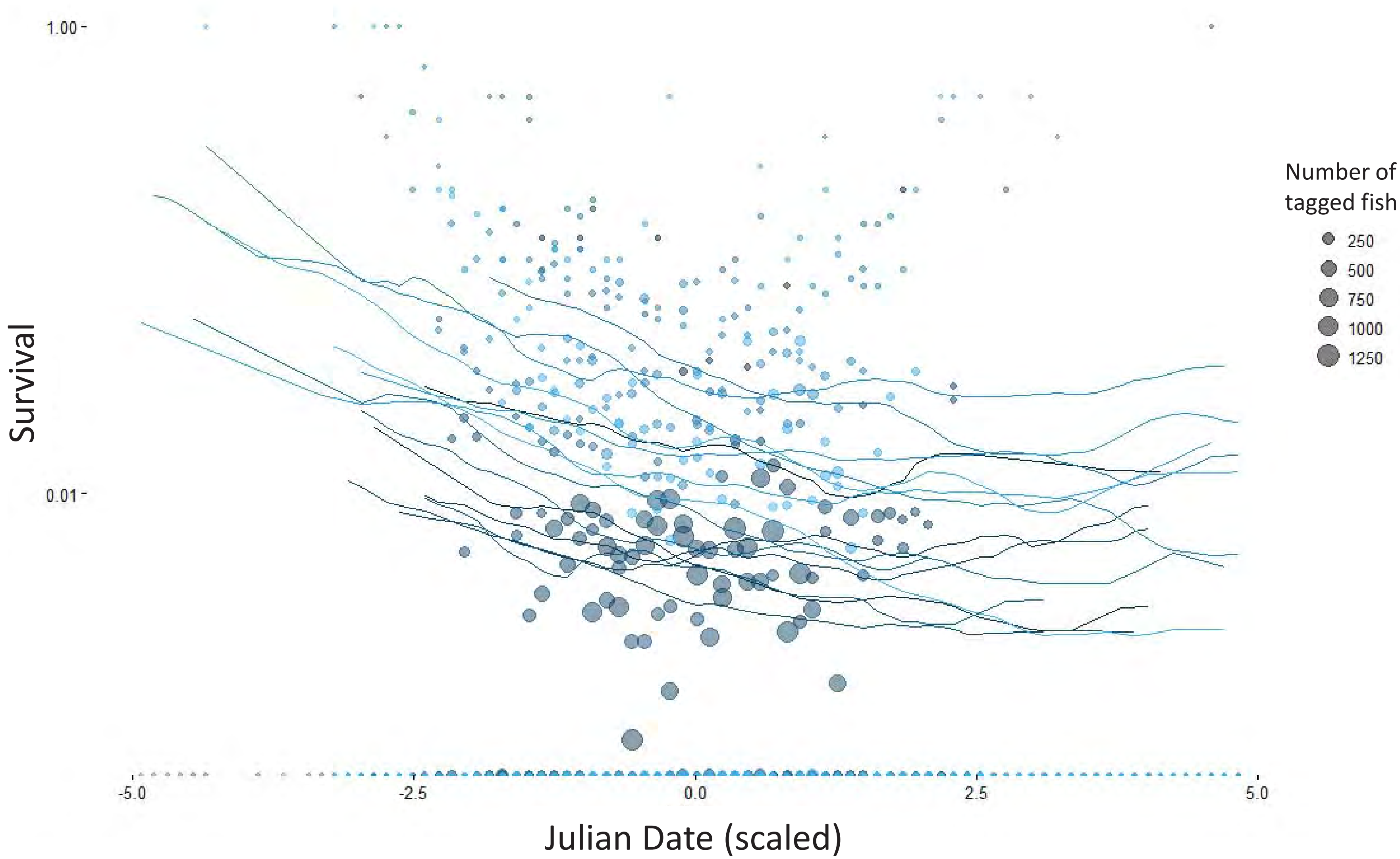
- Data
  - Individual PIT-tagged fish
  - Chinook and Steelhead
  - Wild and Hatchery
  - Run-of-river and transported
  - Outmigration years 1999-2013
  - Returns through 2016



- Focus on individual-level covariates

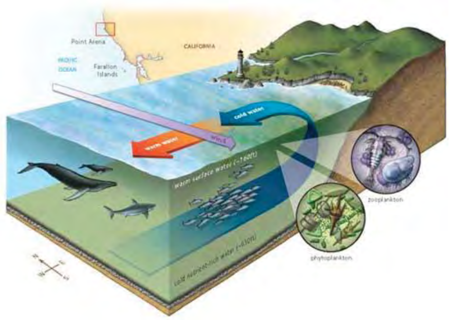
Wenatchee

Outmigration years 2000-2014



Individual-specific metrics

Coastal Upwelling

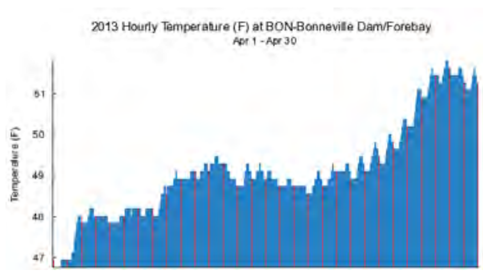


	df	AIC
7-day mean	**6**	**0.00**
spring mean	6	5.99

River Flow

	df	AIC
7-day mean	6	0.34
spring mean	6	0.00

River Temperature



	df	AIC
7-day mean	6	4.31
spring mean	**6**	**0.00**

FINAL

720 Olive Way, Suite 1900
Seattle, Washington 98101
206.287.9130

ANCHOR QEA

Memorandum

To: Wells, Rocky Reach, and Rock Island HCP Coordinating Committees

Date: May 15, 2017

From: John Ferguson, HCP Coordinating Committees Chairman

cc: Kristi Geris

Re: Revised Minutes of the March 28, 2017, HCP Coordinating Committees Meeting

The Wells, Rocky Reach, and Rock Island Hydroelectric Projects Habitat Conservation Plan (HCP) Coordinating Committees met at the Grant PUD Office in Wenatchee, Washington, on Tuesday March 28, 2017, from 10:00 a.m. to 12:40 p.m. Attendees are listed in Attachment A to these meeting minutes.

Action Item Summary

- Alene Underwood (Chelan PUD Fish and Wildlife Program Manager) will provide Chelan PUD's comments on the Federal Columbia River Power System (FCRPS) National Environmental Policy Act (NEPA) Scoping Process to Kristi Geris for distribution to the HCP Coordinating Committees (Item I-C). *(Note: Underwood provided these comments to Geris following the meeting on March 28, 2017, which Geris distributed to the HCP Coordinating Committees on March 29, 2017.)*
- Tom Kahler will provide fish passage count data for winter months at Wells Dam for review regarding timing of winter maintenance at Wells Dam to Kristi Geris for distribution to the HCP Coordinating Committees (Item I-C).
- John Ferguson will coordinate with Tracy Hillman (HCP Hatchery Committees Chairman) to obtain HCP Hatchery Committees and Wells HCP Coordinating Committee approval of the 2017 Broodstock Collection Protocols prior to the April 15, 2017 deadline to the National Marine Fisheries Service (NMFS; Item II-A). *(Note: Ferguson discussed the timeline with Hillman following the meeting on March 28, 2017, who coordinated with the HCP Hatchery Committees to deliver the protocols by approximately April 7, 2017.)*
- Douglas PUD will provide the Draft 2016 Douglas PUD Pikeminnow Removal Program Annual Report for review to Kristi Geris for distribution to the HCP Coordinating Committees (Item III-A). *(Note: Tom Kahler provided the draft report for review to Geris following the meeting on March 28, 2017, which Geris distributed to the HCP Coordinating Committees on March 29, 2017.)*
- Douglas PUD will provide an electronic copy of the 2017 Trapping Activities at Wells Dam Gantt Chart to Kristi Geris for distribution to the HCP Coordinating Committees (Item III-E). *(Note: Tom Kahler provided the chart to Geris following the meeting on March 28, 2017, which Geris distributed to the HCP Coordinating Committees on March 29, 2017.)*

- Chelan PUD will complete edits to the Revised Draft Rock Island and Rocky Reach Coho Phase Designation Statement of Agreement (SOA), as discussed, and will provide a final SOA to Kristi Geris for distribution to the HCP Coordinating Committees (Item IV-A). *(Note: Lance Keller provided the final SOA to Geris on March 29, 2017, which Geris distributed to the HCP Coordinating Committees that same day.)*
- Anchor QEA, LLC, will communicate to Washington Department of Fish and Wildlife (WDFW) what discussions took place during today's HCP Coordinating Committees meeting regarding the Revised Draft Rock Island and Rocky Reach Coho Phase Designation SOA, and will request that WDFW submit a vote via email by close of business Thursday, March 30, 2017 (Item IV-A). *(Note: Kristi Geris coordinated with WDFW, as discussed, and WDFW submitted their approval of the SOA on March 30, 2017.)*
- Anchor QEA will notify the HCP Hatchery Committees that the HCP Coordinating Committees approved the Rock Island and Rocky Reach Coho Phase Designation SOA, so the HCP Hatchery Committees may move forward with hatchery compensation planning (Item IV-A). *(Note: Kristi Geris notified Sarah Montgomery [HCP Hatchery Committees Support Staff] about the approval, as discussed, on March 30, 2017.)*
- Chelan PUD will incorporate gate sequence details into the 2017 Rock Island and Rocky Reach Fish Spill Plan and will provide the final plan to Kristi Geris for distribution to the HCP Coordinating Committees (Item IV-B).
- The Yakama Nation (YN) will provide the report, "Translocation of Adult Pacific Lamprey within the Wenatchee Subbasin (2015-2016 Broodstock)," to Kristi Geris for distribution to the HCP Coordinating Committees (Item IV-C). *(Note: Bob Rose provided the report to Geris during the meeting on March 28, 2017, which Geris distributed to the HCP Coordinating Committees on March 29, 2017.)*
- Kristi Geris will add Catherine Willard (Chelan PUD HCP Hatchery Committees Alternate) to the HCP Coordinating Committees email distribution list, as approved by the HCP Coordinating Committees (Item IV-F). *(Note: Geris added Willard to the list on March 29, 2017.)*
- Chelan PUD will provide the Revised Draft 2017 Rock Island and Rocky Reach HCP Action Plan for vote via email to Kristi Geris for distribution to the HCP Coordinating Committees (Item IV-G). *(Note: Lance Keller provided the revised plan to Geris on March 29, 2017, which Geris distributed to the HCP Coordinating Committees on March 30, 2017.)*
- Chelan PUD will address comments received on the Draft 2016 Rock Island and Rocky Reach HCP Annual Reports and will provide the revised reports to Kristi Geris for final production (Item VI-H). *(Note: Lance Keller provided the revised reports to Geris on March 29, 2017.)*
- Chelan PUD will provide the Final 2016 Rocky Reach Juvenile Fish Bypass System Report to Kristi Geris for distribution to the HCP Coordinating Committees (Item IV-I).

- **The HCP Coordinating Committees meeting on April 25, 2017, will be held in-person at the Grant PUD office in Wenatchee, Washington (Item V-A).**

Decision Summary

- The Wells HCP Coordinating Committee representatives present approved the 2017 Wells HCP Action Plan (Item III-C). *(Note: Carmen Andonaegui provided the Washington Department of Fish and Wildlife's [WDFW's] approval of the plan via email prior to the meeting on March 28, 2017.)*
- The Rock Island and Rocky Reach HCP Coordinating Committees representatives present approved the Rock Island and Rocky Reach Coho Phase Designation SOA, as revised (Item IV-A). *(Note: Carmen Andonaegui provided WDFW's approval of the SOA via email on March 30, 2017.)*
- The HCP Coordinating Committees representatives present approved adding Catherine Willard to the HCP Coordinating Committees email distribution list (Item IV-F).
- The Rock Island and Rocky Reach HCP Coordinating Committees representatives approved the 2017 Rock Island and Rocky Reach HCP Action Plan, as revised, via email as follows: Chelan PUD and U.S. Fish and Wildlife Service (USFWS) approved on March 30, 2017; NMFS approved on April 4, 2017; and WDFW, the Colville Confederated Tribes (CCT) and the YN approved on April 5, 2017 (Item IV-G).
- The Wells HCP Coordinating Committee approved the 2017 Broodstock Collection Protocols, as revised, via email as follows: Douglas PUD approved on April 10, 2017; and NMFS, USFWS, WDFW, the CCT, and the YN approved on April 11, 2017.

Agreements

- The HCP Coordinating Committees representatives present agreed to vote via email on the Revised Draft 2017 Rock Island and Rocky Reach HCP Action Plan (Item IV-G).
- HCP Coordinating Committees representatives agreed via email to add Alf Haukenes (WDFW Hatchery/Wildlife Interactions Unit leader) to select HCP Hatchery Committees email distribution lists, per a request by Mike Tonseth (WDFW HCP Hatchery Committees Representative), as follows: WDFW, Douglas PUD, NMFS, and USFWS approved on April 17, 2017; Chelan PUD and the YN approved on April 18, 2017; and the CCT approved on April 19, 2017.

Review Items

- Kristi Geris sent an email to the HCP Coordinating Committees on March 1, 2017, notifying them the Draft Rocky Reach Total Dissolved Gas Alternative Analysis Report is available for review with edits and comments due to Marcie Clement (Chelan PUD) by Friday, March 31, 2017 (Item IV-D).

- Kristi Geris sent an email to the HCP Coordinating Committees on March 29, 2017, notifying them the Draft 2016 Douglas PUD Pikeminnow Removal Program Annual Report is available for a 60-day review period, with edits and comments due to Tom Kahler by Monday, May 29, 2017 (Item III-A).
- Kristi Geris sent an email to the HCP Coordinating Committees on March 30, 2017, notifying them the Revised Draft 2017 Rock Island and Rocky Reach HCP Action Plan is available for review with votes via email due to Lance Keller (with Geris copied) by Wednesday, April 5, 2017 (Item IV-G). *(Note: votes were submitted, and the plan was approved as described under the Decision Summary.)*
- Kristi Geris sent an email to the HCP Coordinating Committees on April 17, 2017, notifying them a Wells Project Land-use Permit Application (Small Block LLC) was available for a 60-day review period, with edits and comments due to Tom Kahler by Friday, June 16, 2017.
- Kristi Geris sent an email to the HCP Coordinating Committees on April 27, 2017, notifying them a Wells Project Land-use Permit Application (City of Pateros) was available for a 60-day review period, with edits and comments due to Tom Kahler by Monday, June 26, 2017.

Finalized Documents

- The Final 2017 Wells HCP Action Plan was distributed to the HCP Coordinating Committees by Kristi Geris on March 29, 2017 (Item III-C).
- The Final 2016 Rock Island and Rocky Reach HCP Annual Reports were distributed to the HCP Coordinating Committees by Kristi Geris on April 6, 2017 (Item IV-H).

I. Welcome

A. Review Agenda (John Ferguson)

John Ferguson welcomed the HCP Coordinating Committees and reviewed the agenda. Ferguson asked for any additions or changes to the agenda. The following revisions were requested:

- Lance Keller added: 1) Draft Rocky Reach Total Dissolved Gas Alternative Analysis Report; 2) Rocky Reach Juvenile Fish Bypass System (RRJFBS) marked fish release; 3) request to add Catherine Willard to the HCP Coordinating Committees email distribution list; 4) Draft 2017 Rock Island and Rocky Reach HCP Action Plan; 5) Draft 2016 Rock Island and Rocky Reach HCP Annual Reports; and 6) Draft 2016 Rocky Reach Juvenile Fish Bypass System Report.
- Tom Kahler removed the 2017 Broodstock Collection Protocols, and added: 1) Draft 2016 Douglas PUD Pikeminnow Removal Program Annual Report; and 2) Twisp Pond update.

B. Meeting Minutes Approval (John Ferguson)

The HCP Coordinating Committees reviewed the revised draft February 28, 2017, meeting minutes. Kristi Geris said she added under the Decision Summary that the Wells HCP Coordinating Committee approved the 2016 Wells HCP Annual Report after no disapprovals were received prior to the 30-day review period deadline. She said she also noted distribution of the Final 2016 Wells HCP Annual Report and Final 2015 Douglas PUD Pikeminnow Program Annual Report under the Finalized Documents. She said all comments and revisions received from members of the Committees were incorporated into the revised minutes. HCP Coordinating Committees members present approved the February 28, 2017, meeting minutes, as revised.

C. Last Meeting Action Items (John Ferguson)

Action items from the HCP Coordinating Committees meeting on February 28, 2017, and follow-up discussions, were as follows. *(Note: italicized text corresponds to agenda items from the meeting on February 28, 2017):*

- *Alene Underwood (Chelan PUD Fish and Wildlife Program Manager) will provide Chelan PUD's comments on the FCRPS NEPA Scoping Process to Kristi Geris for distribution to the HCP Coordinating Committees (Item I-C).*
  This action item will be carried forward.
- *Tom Kahler will provide fish passage count data for winter months at Wells Dam for review regarding timing of winter maintenance at Wells Dam to Kristi Geris for distribution to the HCP Coordinating Committees (Item I-C).*
  This action item will be carried forward.
- *John Ferguson will request from Michelle Rub (National Marine Fisheries Service [NMFS]) an estimation of survival of adult spring/summer Chinook salmon from the Columbia River estuary to Bonneville Dam in 2016 (Item I-C).*
  Rub indicated via email she does not yet have a final estimate for 2016, as distributed to the HCP Coordinating Committees by Kristi Geris on March 13, 2017.
- *Lance Keller will discuss internally proposals regarding the Rock Island and Rocky Reach Coho Salmon Phase Designation and report back to the HCP Coordinating Committees with a recommended path forward that will be discussed during the meeting on March 28, 2017 (Item III-A).*
  This will be discussed during today's meeting.
- *Lance Keller will inquire internally about the basis for the fish spill patterns implemented at Rock Island and Rocky Reach dams, as well as how these patterns are evaluated for efficacy (Item III-C).*
  This will be discussed during today's meeting.

- *Tom Kahler will finalize the 2015 Douglas PUD Pikeminnow Program Annual Report and provide the final report to Kristi Geris for distribution to the HCP Coordinating Committees (Item IV-A).*
  Kahler provided the final report to Geris prior to the meeting on March 28, 2017, which Geris distributed to the HCP Coordinating Committees that same day.

II. HCP Tributary and Hatchery Committees Update

A. HCP Tributary and Hatchery Committees Update (Tracy Hillman)

Tracy Hillman updated the HCP Coordinating Committees on the following actions and discussions that occurred during the HCP Tributary Committees meeting on March 9, 2017:

- *Methow Valley Irrigation District Instream Flow Improvement Project*: Trout Unlimited submitted a time extension request on the Methow Valley Irrigation District (MVID) Instream Flow Improvement Project, requesting to extend the period of their contracts from March to November 2017. The HCP Tributary Committees approved this request.
- *Entiat Stillwaters Gray Reach Acquisition*: The Chelan-Douglas Land Trust (CDLT) submitted a time extension and amendment request on the Entiat Stillwaters Gray Reach Acquisition Project, requesting to extend the period of the contract and to use part of the remaining balance of this project to help cover expenses associated with lot sales and the purchase of additional properties, which were not part of the original proposal. Because the amendment represented a significant departure in the scope of the original project, the Rocky Reach HCP Tributary Committee denied the amendment and time extension, and indicated if CDLT wants to use funding for additional properties they will need to submit a new proposal. This project will be terminated at the end of March 2017.
- *Similkameen River Mile 3.8 Rehabilitation Project*: The Okanogan Conservation District submitted a budget amendment request on the Similkameen River Mile (RM) 3.8 Rehabilitation Project, requesting an additional $24,851 to be added to their budget resulting in an increase from $67,370 to $92,221. The Rocky Reach HCP Tributary Committee approved the budget amendment.
- *Beaver Fever: Restoring Ecosystem Function Project*: Trout Unlimited submitted a budget amendment request on the Beaver Fever: Restoring Ecosystem Function Project, requesting to shift funds among different budget line items. The Rock Island HCP Tributary Committee approved the budget amendment. The total budget will not change as a result of this amendment.
- *General Salmon Habitat Program Proposal*: Cascade Columbia Fisheries Enhancement Group (CCFEG) submitted a General Salmon Habitat Program Proposal titled, Derby Creek Fish Passage – Collins Project. The purpose of the project is to remove the lowermost fish passage

barrier culvert on Derby Creek, to provide access to spawning and rearing habitat for steelhead. CCFEG requested $90,000 from HCP Tributary Funds; however, the HCP Tributary Committees were unable to make a funding decision because they need more information on the passability of a possible barrier farther downstream of the barrier proposed for removal. The HCP Tributary Committees requested additional information.

- *Draft HCP Tributary Committees Action Plans*: The Wells, Rock Island, and Rock Reach HCP Tributary Committees reviewed their respective draft action plans for 2017 and approved the tributary sections of their respective draft action plans.
- *Review of Tributary Committees' Policies and Procedures*: The HCP Tributary Committees rearranged certain sections of the Tributary Committees' Policies and Procedures document to highlight the importance of allowing public access on properties acquired with Plan Species Account funds and also to reflect a more logical order. The HCP Tributary Committees are also drafting language to add to the document regarding limiting the amount of time between when a project is approved for funding and when the sponsor signs a contract. Hillman said, for example, one project still has no signed contract 5 years after it was approved for funding.
- *Contributions to Plan Species Accounts*: The PUDs deposited funds into each of the Plan Species Accounts at the end of January 2017. Chelan PUD deposited $737,452 into the Rock Island Account and $349,271 into the Rocky Reach Account. Douglas PUD deposited $267,771 into the Wells Account. As of March 2017, the unallocated balances within each account were $5,559,653 in the Rock Island Account, $2,378,263 in the Rocky Reach Account, and $1,331,318 in the Wells Account. This totals about $8,269,234 for restoration/protection efforts.
- *Middle Entiat Restoration Project Presentation*: The Bureau of Reclamation (Reclamation) provided a status update on the Middle Entiat Restoration Project to the HCP Tributary Committees and the Priest Rapids Coordinating Committee (PRCC) Habitat Subcommittee. Hillman recalled this is the restoration project in the Middle Entiat Basin the Bonneville Power Administration (BPA) was going to fund, but were unable to reach agreement with CDLT regarding liability. Ultimately, Reclamation will be able to fund much of the project, and the status update included an overview of the scope of the project and the current landowner-project sponsor relationship. Chelan County was able to reach an agreement with CDLT on liability. Chelan County will assume responsibility for projects above the ordinary high-water mark, and Washington Department of Natural Resources will be responsible for projects below the ordinary high-water mark. In terms of funding, Reclamation will fall short by about $1 to 1.5 million to complete the project. Reclamation asked the HCP Tributary Committees and the PRCC Habitat Subcommittee about their interest in funding specific components of the restoration project. The HCP Tributary Committees will review this request during the HCP

Tributary Committees meeting on April 13, 2017. Jim Craig asked, considering that the liability issue has been resolved, will Reclamation ask BPA to cover the shortfall. Hillman said no, BPA has made it clear they no longer will be involved with this project. John Ferguson asked if there has been any indication why BPA is not willing to come back to the project. Hillman said he is not certain, but it is likely because BPA has reallocated their funds to other projects in the Methow and Wenatchee basins. Craig questioned if this has implications regarding funding of intensively monitored watershed evaluations being conducted in the basin. Hillman said he heard BPA is still considering this, but has not yet made a decision.

- *Next Steps*: The next meeting of the HCP Tributary Committees will be on Thursday, April 13, 2017.

Hillman updated the HCP Coordinating Committees on the following actions and discussions that occurred during the HCP Hatchery Committees meeting on March 13, 2017:

- *DECISION: Wells HCP 2017 Action Plan*: The Wells HCP Hatchery Committee approved the hatchery section of the Wells HCP 2017 Action Plan.
- *DECISION: Hatchery Monitoring and Evaluation Reporting Schedule*: Douglas PUD presented an SOA memorializing the hatchery monitoring and evaluation (M&E) reporting schedule, as discussed in previous HCP Hatchery Committees meetings. The Wells HCP Hatchery Committee approved the SOA.
- *Methow Fish Hatchery Pond 13*: Douglas PUD noted a high level of bird predation in Pond 13 at the Methow Fish Hatchery (FH) last winter. In summer 2016, about 80,000 spring Chinook salmon were stocked in outdoor Pond 13 at Methow FH. Despite installing wiring and conducting bird hazing efforts, more than 40,000 spring Chinook salmon were removed by mergansers, cormorants, herons, and other avian predators. Douglas PUD speculated this is likely because Pond 13 at Methow FH was the only waterbody that did not freeze over last winter. Fish managers estimated approximately 35,000 spring Chinook salmon remain in the pond. Despite this large loss, there will be no impact on the release goal for the program. Douglas PUD plans to install additional fencing. Craig asked if installing bird netting is not possible because of snow load, and Tom Kahler said he believes that is the reason.
- *DECISION: Hatchery Monitoring and Evaluation Reporting Schedule*: Chelan PUD presented an SOA memorializing the hatchery M&E reporting schedule, as discussed in previous HCP Hatchery Committees meetings. The Rock Island and Rocky Reach HCP Hatchery Committees approved the SOA.
- *DECISION: Draft 2017 Steelhead Release Plan*: Chelan PUD presented the Draft 2017 Steelhead Release Plan. In short, the plan is similar to the 2016 Steelhead Release Plan, and the Rock Island and Rocky Reach HCP Hatchery Committees approved the plan.

- *USFWS Bull Trout Consultation Update*: USFWS is moving forward with finalizing the draft Biological Opinion (BiOp) covering hatchery programs in the Wenatchee basin. Comments are due Friday, March 31, 2017. USFWS will address comments received and plans to complete the BiOp by mid-May 2017. Next, USFWS will work on either the Methow steelhead BiOp or the Columbia River mainstem unlisted programs, pending a decision on a path forward by NMFS.
- *NMFS Consultation Update*: The signed permits for Methow spring Chinook salmon are with the applicants. NMFS is now working on the Methow steelhead consultation, with no known completion date. Kahler said he spoke with Charlene Hurst (NMFS HCP Hatchery Committees Alternate) who indicated she does not believe the permit for Methow steelhead will be ready in 2017.
- *Draft 2017 Broodstock Collection Protocols:* WDFW presented the draft protocols and reviewed the new items. The HCP Hatchery Committees reviewed the protocols and provided comments to WDFW by March 16, 2017. Hillman said he understands Mike Tonseth (WDFW HCP Hatchery Committees Representative) is currently addressing the comments and will revise the protocols or will schedule a conference call to discuss difficult comments, as needed. Hillman said he believes Tonseth will request a vote via email this week or in early April 2017. Bob Rose asked if the technical issues were resolved with fish health, regarding transferring steelhead to Wells FH due to live spawning. Hillman said he will discuss this under the next topic. Ferguson asked how HCP Hatchery Committees and Wells HCP Coordinating Committee approval of the protocols will be coordinated. Hillman said the HCP Hatchery Committees are aware the protocols need to be approved by the HCP Hatchery Committees and then by the Wells HCP Coordinating Committee before submitting to NMFS on April 15, 2017. He said he has not heard from Tonseth, so he hopes this means a conference call will not be needed. Ferguson said he will coordinate with Hillman to obtain HCP Hatchery Committees and Wells HCP Coordinating Committee approval of the 2017 Broodstock Collection Protocols prior to the April 15, 2017 deadline to NMFS. Kahler said Douglas PUD provided Tonseth with extensive comments on the steelhead program, and Kahler believes Douglas PUD and Tonseth will convene a call today. *(Note: Ferguson discussed the timeline with Hillman following the meeting on March 28, 2017, who coordinated with the HCP Hatchery Committees to deliver the protocols by approximately April 7, 2017.)*
- *Brood Year 2017 Twisp River Steelhead*: WDFW discussed two recommended revisions to brood year (BY) 2017 Twisp River Steelhead in the 2017 Broodstock Collection Protocols. First, rather than acclimating and releasing BY 2017 smolts (S1s) at the Twisp Acclimation Pond, WDFW recommended releasing the 48,000 S1s at Buttermilk Bridge, to encourage the juveniles to return farther upstream into the Twisp River, resulting in better distribution. The Wells HCP Hatchery Committee representatives present agreed to this revision. Second,

WDFW proposed collecting BY 2017 steelhead at the Twisp Weir in the spring and then transferring them to Winthrop National Fish Hatchery (NFH) to be spawned as part of the aggregate composite population. The eggs or fry would then be transferred to Wells FH to be reared as S1s. The Wells HCP Hatchery Committee is still considering this request with regard to aspects such as fish health, live-spawning, sampling schemes, tagging, and hatchery space, among other things. Hillman said he believes a vote via email will be requested by the end of March 2017. Kahler said he believes the YN are interested in this because of the kelt reconditioning issue. He explained that the YN had been conducting live spawning of the Twisp portion of Methow basin releases and holding progeny at Methow FH; however, since those fish were live-spawned, organ and tissue samples could not be collected to examine for viruses. Kahler said to deal with this lack of parental screening, the WDFW fish health protocols developed by Bob Rogers (WDFW), required the sampling of progeny of the live-spawned females prior to their transfer from Methow FH to Wells FH, and this protocol differs from that implemented for the Winthrop NFH steelhead program. Kahler said there were some questions about what would become of that WDFW protocol. He said if all adults are transferred to Winthrop NFH for spawning, there were questions about whether the WDFW disease-screening protocol would be implemented prior to transferring the fish to Wells FH, or whether WDFW would accept the USFWS protocol as adequate screening. Regardless, this issue will not affect the kelt program because the females from the programs would be live-spawned in any case; but spawning all the fish at WNFH and following the USFWS screening protocols would simplify everything, including the kelt-reconditioning program. Bob Rose noted that Keely Murdoch (YN HCP Hatchery Committees Alternate) was not expressing concern; rather, this was a technical discussion she brought up that WDFW is working on.

- *Spring Chinook Salmon Outplanting in the Chewuch River*: Recall the HCP Hatchery Committees developed a draft plan for outplanting surplus, passive integrated transponder (PIT)-tagged MetComp fish in the Chewuch River, with the goal of monitoring movement and spawning. Chelan PUD revised the draft plan and following discussions, a few more edits were identified. Chelan PUD will address those comments and will redistribute a second revised draft plan for approval.
- *Brood Year Stray Rate Targets*: The HCP Hatchery Committees continued discussing BY stray rate targets for their programs and requested Hillman write up a suggestion he discussed during the meeting. Hillman explained the idea is to keep stray rate targets for recipient populations and spawning aggregates because those are linked directly with extinction risk. He said a BY stray rate target, on the other hand, is not linked directly to extinction risk and it is not easily justified biologically. He said if the HCP Hatchery Committees agree that a BY stray target is necessary, the HCP Hatchery Committees will need to identify targets for each program, which will be a difficult task. Rose asked what the need is to establish a target, and

asked if stray rates are alarmingly high. Hillman said there is a need to have targets for recipient populations and spawning aggregates because those are biologically justified (i.e., they are linked with extinction risk). In contrast, according to Todd Pearson's (Grant PUD) research, a BY stray rate target is not well founded biologically and no other hatchery program has a BY stray rate target. Hillman said it is important to measure it, because it informs the other stray rate metrics (i.e., recipient stray rate metrics), but assigning a target to BY stray rate may be less important. Hillman added that yes, in some years, BY stray rates are high, but when BY stray rates are high, recipient population or spawning aggregate rates are also high. Thus, there appears to be a correlation between BY stray rates and recipient stray rates, suggesting some redundancy in the metrics. Hillman stated the HCP Hatchery Committees have reviewed Mike Ford's (NMFS)[1] work, and it is clear selecting a unique BY stray rate target for each hatchery program would be difficult. Hillman said he is unsure if everyone agrees there should not be a BY stray rate target; however, there is agreement that BY stray rates need to be measured, because they inform other stray rate metrics that do have targets. He added that the BY stray rate target for Chiwawa spring Chinook salmon has not been met in any year since monitoring began in the early 1990s.

- *Maturation Sampling for Methow and Chiwawa Spring Chinook Salmon 2017 Releases*: The Rock Island HCP Hatchery Committee approved Chelan PUD's request to perform the third year of maturation sampling with USFWS. The plan includes sampling 300 Chiwawa spring Chinook salmon to determine maturation. The Wells HCP Hatchery Committee also approved Douglas PUD's request to sample 300 Methow spring Chinook salmon to determine maturation.
- *Next Steps*: The next meeting of the HCP Hatchery Committees will be on Wednesday, April 19, 2017.

III.Douglas PUD

A. Draft 2016 Douglas PUD Pikeminnow Removal Program Annual Report (Tom Kahler)

Tom Kahler said when Douglas PUD received the Final 2015 Douglas PUD Pikeminnow Removal Program Annual Report from the contractor, the Draft 2016 Douglas PUD Pikeminnow Removal Program Annual Report was also provided. Kahler said he plans to review the draft 2016 report and will provide the draft report for review to Kristi Geris for distribution to the HCP Coordinating Committees. *(Note: Kahler provided the draft report for review to Geris following the meeting on March 28, 2017, which Geris distributed to the HCP Coordinating Committees on March 29, 2017.)*

Geris sent an email to the HCP Coordinating Committees on March 29, 2017, notifying them the Draft 2016 Douglas PUD Pikeminnow Removal Program Annual Report is available for a 60-day review period, with edits and comments due to Kahler by Monday, May 29, 2017.

B. Twisp Pond Update (Tom Kahler)

Tom Kahler said, this winter, a massive pile of ice accumulated in front of the Twisp Pond intake. He said crews were finally able to install the traps last Thursday, March 23, 2017, and fish are now in the pond as of yesterday, March 27, 2017. Kirk Truscott asked about the release date for spring Chinook salmon from the Twisp Pond. Kahler said it largely depends on the weather and fish growth. He said it's still quite cold and river flow has not yet increased. He said, in past years, fish were typically released out of the Twisp Pond by mid-April; however, if the weather remains cool and wet, the release date could be delayed a few weeks.

C. DECISION: 2017 Wells HCP Action Plan (Tom Kahler)

Tom Kahler said Kristi Geris sent an email to the HCP Coordinating Committees on February 23, 2017, notifying them the Draft 2017 Wells HCP Action Plan is available for review. John Ferguson noted the HCP Tributary and Hatchery Committees already approved their respective sections, and now the plan is ready for Wells HCP Coordinating Committee approval.

Ferguson asked about the 2020 survival verification study, noting the time gap between defining the study design and conducting the study. Kahler said the timing is based on broodstock collection. He said broodstock needs to be collected in 2018 for the study, and Douglas PUD decided to start designing the study in late 2017 because the 2018 broodstock collection protocols (developed early in 2018) would need to include brood collection for study fish. Ferguson asked if Douglas PUD and Chelan PUD are on the same schedule for a survival verification study, just not the design portion, and Kahler said that is correct.

The Wells HCP Coordinating Committee representatives present approved the 2017 Wells HCP Action Plan. *(Note: Carmen Andonaegui provided WDFW's approval of the plan via email prior to the meeting on March 28, 2017.)*

The Final 2017 Wells HCP Action Plan was distributed to the HCP Coordinating Committees by Geris on March 29, 2017.

D. Wells Dam Bypass PIT-detection System (Tom Kahler)

Tom Kahler said bypass operations are scheduled to start at midnight on April 9, 2017; however, Wells Dam is receiving such high river flow, the bypass barriers have not all been installed. He said according to our bypass operating plan, some of the barriers are pulled once river flow reaches a certain level, and the current river flow is already exceeding that level. John Ferguson asked if these operations affect the expanded PIT-tag detector system in Bypass Bay 2. Kahler said part of the system is already installed (barriers in slots A and B, antennas in some of the baffles). He said the goal is to have all antennas installed in the baffles by the end of this week and also have the baffles ready to be installed, so they can be trucked onto the dam and ready for installation next week. Ferguson asked if the system will be operational by April 9, 2017. Kahler said it should be operational by April 6, 2017, because they want to ensure everything is functioning properly. He noted the lowest antenna will be installed 70 feet below the water surface. He also noted permission was granted to leave the system installed, so crews do not need to pull the baffles each year.

E. 2017 Trapping Activities at Wells Dam (Tom Kahler)

Tom Kahler distributed a hard copy of a 2017 Trapping Activities at Wells Dam Gantt Chart, and said he will provide an electronic copy of the chart to Kristi Geris for distribution to the HCP Coordinating Committees. *(Note: Kahler provided the chart to Geris following the meeting on March 28, 2017, which Geris distributed to the HCP Coordinating Committees on March 29, 2017.)*

Kahler said the YN coho salmon trapping activities at the Wells Dam fish ladders and Methow outfall were incorporated into the chart. He also said Douglas PUD is still waiting to hear from Jeff Fryer (Columbia River Tribal Fish Commission) regarding on which fish ladder Fryer will conduct sockeye salmon trapping activities. Kahler said, per usual, Douglas PUD will convene a trapping coordination meeting in April 2017.

Kirk Truscott said he spoke with Casey Baldwin about broodstock protocols and the potential for a low spring Chinook salmon return this year, and the CCT's ability to trap spring Chinook salmon at the Chief Joseph Dam fish ladder, depending on river flow. Truscott said there may be an option included in the 2017 Broodstock Collection Protocols for the CCT to trap adipose fin (ad)-clipped non-wired spring Chinook salmon at Wells Dam if the return pans out as low as expected.
John Ferguson asked if the low forecast came from the Technical Advisory Committee, and Truscott said it came from the Fishery Resource Office. He added there have only been 12 Chinook salmon counted at Bonneville Dam, whereas at this time last year there had been 90 Chinook salmon counted, and the 10-year average is 170 Chinook salmon. He said, if the CCT trapped at Wells Dam, those fish would go toward the segregated program at Chief Joseph Dam, and the CCT would trap within the confines of the trapping schedule.

Ferguson asked if there are any issues with the trap itself. Kahler said Douglas PUD plans to cover the west fish ladder trap upwell holding area, similar to the east fish ladder trap holding area, as originally proposed in 2014. He explained the east fish ladder trap is covered and has grating and padding, but the west fish ladder currently does not. He also noted that there should not be any constraints (like last year) related to the Wells FH Modernization project. Lastly, he said Douglas PUD contractors are fixing the section of the transport pipe from the west fish ladder to the hatchery that was unintentionally designed such that, if the pipe flow is not turned down at the trap, it discharges water and fish from the pipe exit at such high velocities, the fish could hit the raceway wall opposite the pipe mouth.

IV. Chelan PUD

A. DECISION: Rock Island and Rocky Reach Coho Salmon Phase Designation (Lance Keller, Alene Underwood, and Catherine Willard)

Lance Keller recalled that during the last HCP Coordinating Committees meeting on February 28, 2017, the HCP Coordinating Committees had a lengthy discussion about the proposed Rock Island and Rocky Reach Coho Phase Designation SOA, which was distributed to the HCP Coordinating Committees by Kristi Geris on February 15, 2017. Keller said the discussion ended with an action item for Chelan PUD to discuss internally recommendations provided by the HCP Coordinating Committees regarding the proposed SOA and a path forward. Keller said Chelan PUD also spoke again with the YN. Keller reiterated what Steve Hemstrom touched on last meeting, that John Skalski and Richard Townsend (Columbia Basin Research) initially conducted the analysis using only 2 years of acoustic and PIT-tag data (2010 and 2011) for the Rocky Reach Project. Keller said, during that time, Chelan PUD was concerned the dataset was not using all of the available information and requested that Skalski and Townsend conduct a more robust study. He said the 2010 projected survival was 95.94% and the 2011 projected survival was 94.35%, averaging to 95.15% for the 2-year average. He said, if Chelan PUD accepted those 2 years of data and added 1 additional year to obtain 3 years of data, as stipulated in the HCP, a survival level of only 88.71% would be needed during the third year of study to achieve Phase III (Standards Achieved). Keller said Chelan PUD chose not to accept those numbers because of the interest in a more robust dataset. Keller also noted the adult component contained in the 2010 yearling Chinook SOA, and said he told Bob Rose Chelan PUD would review adult data for the Rocky Reach Project. Keller said there was variability in those data, noting that from 2010 to 2016, estimated adult survival for coho salmon ranged from 86.6% to 100.0%; however, the total average was still 94.58%. Keller also discussed data from 2014, noting all of these data contribute to a positive story about coho salmon. Keller recalled the SOA, "HCP Phase III Standards Achieved Designation for Steelhead at Rock Island with two years of survival testing at a 10% spill level," which was approved by the Rock Island HCP Coordinating Committee on November 16, 2010, was based on less than 3 years of valid survival data (2 years). He said this is one example from the past where the HCP Coordinating Committees were satisfied with making a decision based on the available data. He and John Ferguson also noted the SOA, "Phase III Standards Achieved for 91% Combined Adult and Juvenile Spring Chinook Survival at the Rocky Reach Project," which was approved by the Rocky Reach HCP Coordinating Committee on August 30, 2011. Keller and Ferguson said aspects of this SOA are also similar to the currently proposed SOA for coho salmon, and in the 2011 SOA, the HCP Coordinating Committees accepted juvenile survival levels that were less than the

93% standard (92.37%) and comprised of four years of juvenile survival studies. Therefore, Ferguson said the concern that incorporating a level of estimated survival in the current coho phase designation SOA for Rocky Reach (92.94%) that is slightly less than the 93% standard would establish an unwanted precedent does not seem to be an issue. He did note, however, the 2011 SOA was based on the combined survival of juvenile and adult spring Chinook salmon, whereas the current SOA is based just on juvenile survival data.

Rose said, in general, the YN are comfortable with Chelan PUD's currently proposed SOA. Rose thanked Chelan PUD and the HCP Coordinating Committees for taking the time to thoroughly vet this decision. He said he agrees there is a high level of confidence that the number is sufficient to meet or exceed the standard. He said, however, the YN are still interested in paying attention to and tracking precedence. He said he does not want the HCP Coordinating Committees to begin accepting lower and lower standards. He said the YN are not so concerned about one or two SOAs; rather, he was only making points. He said, while discussing this with Keely Murdoch, she made an interesting comment, which Rose said he agrees with. Rose said Murdoch noted that when the coho salmon program is set up for the next several years, the program will be successful and will contribute many more fish than the 0.06% under discussion. Ferguson said the HCP Coordinating Committees appreciate Rose's comments, which encouraged everyone to review past decisions and governing documents.

Ferguson asked about edits to the SOA before voting. Geris noted that Carmen Andonaegui requested via email to postpone WDFW's vote until Jeff Korth is available on Thursday, March 30, 2017. Ferguson suggested voting with representatives present, and following up with WDFW afterwards. Keller clarified it was not Chelan PUD's intention when drafting one SOA for both projects to imply that survival values through the Rock Island and Rocky Reach projects can be combined or averaged. Rose said he believes his comments will be adequately captured in the meeting minutes, and no revisions to the SOA are needed for the YN. Kirk Truscott requested that the SOA be updated to be consistent with past nomenclature (e.g., "yearling spring Chinook" versus "yearling Chinook," etc.). Jim Craig requested that "Projects" be added to the title of the SOA.

The Rock Island and Rocky Reach HCP Coordinating Committees representatives present approved the Rock Island and Rocky Reach Coho Phase Designation SOA, as revised.

Keller said Chelan PUD will complete edits to the Revised Draft Rock Island and Rocky Reach Coho Phase Designation SOA, as discussed, and will provide a final SOA to Geris for distribution to the HCP Coordinating Committees. *(Note: Keller provided the final SOA to Geris on March 29, 2017, which Geris distributed to the HCP Coordinating Committees that same day.)*

Anchor QEA will communicate to WDFW what discussions took place during today's HCP Coordinating Committees meeting regarding the Revised Draft Rock Island and Rocky Reach Coho Phase Designation SOA, and will request that WDFW submit a vote via email by close of business Thursday, March 30, 2017. *(Note: Geris coordinated with WDFW, as discussed, and WDFW submitted approval of the SOA on March 30, 2017.)*

Anchor QEA will notify the HCP Hatchery Committees that the HCP Coordinating Committees approved the Rock Island and Rocky Reach Coho Phase Designation SOA, so the HCP Hatchery Committees may move forward with hatchery compensation planning. *(Note: Geris notified Sarah Montgomery about the approval, as discussed, on March 30, 2017.)*

B. Draft 2017 Rock Island and Rocky Reach Fish Spill Plan (Lance Keller)

Lance Keller said Kristi Geris sent an email to the HCP Coordinating Committees on February 22, 2017, notifying them the Draft 2017 Rock Island and Rocky Reach Fish Spill Plan is available for a 30-day review with edits and comments due to Keller by Friday, March 24, 2017. Keller said no edits were requested by the HCP Coordinating Committees on the draft plan. He recalled a question from Bob Rose about the shape of the daily spill (the gate opening pattern across the spillway). Keller said, during the early years of operation, hydroacoustic data provided some guidance, and acoustic tag survival data were also used to provide shape for spring and summer spill at Rocky Reach Dam and summer spill at Rock Island Dam. Keller also noted spill shape at both projects is the same as when the HCP survival studies were conducted.

Keller said Thad Mosey (Chelan PUD Fish Biologist and Spill Coordinator) obtains river flow estimates from Chief Joseph Dam, and based on those estimates plus tributary flows, Mosey distributes a memorandum to spill operators outlining spill shape 2 days in advance. Keller said Mosey can also monitor all spill programs in real-time, so if inaccuracies due to inaccurate flow estimates occur he can make a real-time adjustment.

Jim Craig asked if a general shape is targeted or is the shape adjusted, as needed. Keller said generally, a particular shape is targeted. Bob Rose said the YN are interested in understanding that the current spill shape is achieving what it is meant to do, as outlined in the spill plan. Kirk Truscott asked about the proposed spill pattern or gate sequence, throughout the 2017 season, along with outages. Keller explained that unit outages reduce turbine capacity resulting in more spill. He said there is a prefered spill gate sequence at Rock Island and Rocky Reach dam to provide a crown shape and also a preference for over-under gates. Truscott suggested including this type of information in the spill plan. Keller said Chelan PUD will incorporate gate sequence details into the 2017 Rock Island and Rocky Reach Fish Spill Plan and will provide the final plan to Geris for distribution to the HCP Coordinating Committees.

John Ferguson said this discussion reminded him of the total dissolved gas (TDG) discussion, and asked how much information the HCP Coordinating Committees want to hear regarding TDG issues. Keller said TDG falls under Chelan PUD's Clean Water Act Section 401 Water Quality Certification, which is the purview of the fish forum. He said TDG will be an issue this year and added it really already is an issue. Truscott asked if the Fish Passage Center provides weekly reports on TDG, and Keller said it does. The HCP Coordinating Committees agreed that routine updates from Keller on TDG were not needed because members can look up TDG data on the Fish Passage Center website at any time. Keller added that Chelan PUD will conduct gas bubble trauma monitoring in 2017 at the Rock Island Juvenile Bypass Trap, per the Fish Passage Center Smolt Monitoring Program.

C. Tumwater Dam Pacific Lamprey Update (Lance Keller)

Lance Keller said USFWS requested to receive a progress update from Chelan PUD on the Tumwater Dam Pacific Lamprey Passage Feasibility Study, which includes the anticipated schedule for completion and a brief synopsis regarding the type of information the final report will contain. Keller recalled that Pacific lamprey discussions are germane to the HCP Coordinating Committees when Pacific lamprey activities have the potential to affect passage of HCP Plan species. He said Pacific lamprey discussions are germane to the HCP Hatchery Committees when Pacific lamprey activities affect brood collection of Plan species. He said Chelan PUD voluntarily drafted a feasibility report. He said the Rocky Reach Fish Forum (RRFF) discusses Pacific lamprey monthly, and the goal of the feasibility study was to determine what would be feasible from an engineering standpoint, should action to address Pacific lamprey passage be implemented at Tumwater Dam.

Jim Craig asked if efforts will focus on the fishway itself. Keller said several alternatives are being considered and noted the current status of the report is "draft for internal review." Keller said Chelan PUD will distribute the draft report for review to the RRFF following internal review. Craig said USFWS understands these discussions will occur in the RRFF; however, he requested periodic updates in the HCP Coordinating Committees. He added that his office is involved with designing lamprey passage structures. Keller said he believes R.D. Nelle (USFWS) has shared those designs in the RRFF. Bob Rose said the YN recently completed a Pacific lamprey study at Tumwater Dam, which is summarized in a report. He said he will provide the report, "Translocation of Adult Pacific Lamprey within the Wenatchee Subbasin (2015-2016 Broodstock)," to Kristi Geris for distribution to the HCP Coordinating Committees. *(Note: Rose provided the report to Geris during the meeting on March 28, 2017, which Geris distributed to the HCP Coordinating Committees on March 29, 2017.)*

D. Draft Rocky Reach Total Dissolved Gas Alternative Analysis Report (Lance Keller)

Lance Keller said Kristi Geris sent an email to the HCP Coordinating Committees on March 1, 2017, notifying them the Draft Rocky Reach Total Dissolved Gas Alternative Analysis Report is available for review, with edits and comments due to Marcie Clement by April 1, 2017. Keller clarified that edits and comments are due to Clement by Friday, March 31, 2017. Keller said this report is step two of a 401 Water Quality Certification requirement. He recalled step one was the Five-Year Compliance Report, which the Rocky Reach HCP Coordinating Committee approved on January 27, 2015. He said these reports serve as consultation with the RRFF and HCP Coordinating Committees to determine if any additional reasonable and feasible measures may exist to meet the TDG standards, as required by the certification.

Jim Craig asked how to address incoming water that is already in exceedance. Alene Underwood explained Chelan PUD is not held responsible for TDG levels in incoming water; however, the project cannot add TDG to any existing exceedances. Tom Kahler said this is difficult, because while running the bypass at Wells Dam, it is almost impossible to not add to TDG.

E. Rocky Reach Juvenile Fish Bypass System Marked Fish Release (Lance Keller)

Lance Keller said a preseason test of marked fish release was conducted at the RRJFBS to ensure the system is operating correctly ahead of the April 1, 2017, startup at midnight. He said, on Thursday, March 23, 2017, a total of 189 marked fish were released in the bypass channel. He said all fish were collected free of any descaling injury or mortal wounds. He said the intake diversion screens were also tested in Powerhouse Turbine Units C1 and C2. He said 100 fish were flushed through each unit (200 total), of which 198 were recaptured (typically 185 to 195 are recaptured). None of the recapture fish showed any signs of injury, and there were no mortalities.

Keller said, with the cold winter, the lower end of the bypass conduit filled with ice, and crews had to introduce water into the system to remove the ice. He said another full inspection was completed after the ice was removed and the results were good. He said the sampling screen also froze in the down position, and crews had to thaw the screen and then remove it. Jim Craig asked if the screen will be removed before the winter season in future years, and Keller said the screen was only there due to maintenance activities, so this should not be an issue in future years.

F. Request to Add Catherine Willard to the HCP Coordinating Committees Email Distribution List (Lance Keller)

Lance Keller requested that Catherine Willard (Chelan PUD HCP Hatchery Committees Alternate and future Representative) be added to the HCP Coordinating Committees email distribution list, mainly to track HCP Coordinating Committees meeting minutes and discussions pertaining to the HCP Hatchery Committees. The HCP Coordinating Committees representatives present approved adding Willard to the HCP Coordinating Committees email distribution list. Kristi Geris will add Willard to the HCP Coordinating Committees email distribution list, as approved by the HCP Coordinating Committees. *(Note: Geris added Willard to the list on March 29, 2017.)*

G. Draft 2017 Rock Island and Rocky Reach HCP Action Plan (Lance Keller)

Lance Keller said Kristi Geris sent an email to the HCP Coordinating Committees on January 23, 2017, notifying them the Draft 2017 Rock Island and Rocky Reach HCP Action Plan was available for a 30-day review with edits and comments due to Keller by Wednesday, February 22, 2017. A Revised Draft 2017 Rock Island and Rocky Reach HCP Action Plan was distributed for review on January 24, 2017. USFWS provided comments on the revised draft plan on March 9, 2017.

The HCP Coordinating Committees representatives present agreed to vote via email on the Revised Draft 2017 Rock Island and Rocky Reach HCP Action Plan. Chelan PUD will resend the Revised Draft 2017 Rock Island and Rocky Reach HCP Action Plan for vote via email to Geris for distribution to the HCP Coordinating Committees. *(Note: Keller provided the revised plan to Geris on March 29, 2017.)*

Geris sent an email to the HCP Coordinating Committees on March 30, 2017, notifying them the Revised Draft 2017 Rock Island and Rocky Reach HCP Action Plan is available for review, with votes via email due to Keller (and copy Geris) by Wednesday, April 5, 2017. The Rock Island and Rocky Reach HCP HCP Coordinating Committees representatives approved the 2017 Rock Island and Rocky Reach HCP Action Plan, as revised, via email as follows: Chelan PUD and USFWS approved on March 30, 2017; NMFS approved on April 4, 2017; and WDFW, the CCT, and the YN approved on April 5, 2017.

H. Draft 2016 Rock Island and Rocky Reach HCP Annual Reports (Lance Keller)

Lance Keller said Kristi Geris sent an email to the HCP Coordinating Committees on February 16, 2017, notifying them the Draft 2016 Rock Island and Rocky Reach HCP Annual Reports are available for a 30-day review with edits and comments due to Geris by Monday, March 20, 2017. Keller said Chelan PUD received a comment from USFWS about noting certain Pacific lamprey discussions were taking place in the RRFF. Chelan PUD will address comments received on the Draft 2016 Rock Island and Rocky Reach HCP Annual Reports and will provide the revised reports to Geris for final production. *(Note: Keller provided the revised reports to Geris on March 29, 2017.)*

The Final 2016 Rock Island and Rocky Reach HCP Annual Reports were distributed to the HCP Coordinating Committees by Geris on April 6, 2017.

I. Draft 2016 Rocky Reach Juvenile Fish Bypass System Report (Lance Keller)

Lance Keller said Kristi Geris sent an email to the HCP Coordinating Committees on February 17, 2017, notifying them the Draft 2016 RRJFBS Report is available for a 30-day review, with edits and comments due to Keller by Monday, March 20, 2017.

Chelan PUD will provide the Final 2016 Rocky Reach Juvenile Fish Bypass System Report to Geris for distribution to the HCP Coordinating Committees.

V. HCP Administration

A. Next Meetings

The next scheduled HCP Coordinating Committees meeting is on April 25, 2017, to be held in-person at the Grant PUD Wenatchee Office in Wenatchee, Washington.

The May 23 and June 27, 2017, meetings will be held by conference call or in-person at the Grant PUD Wenatchee Office in Wenatchee, Washington, as is yet to be determined.

VI. List of Attachments

Attachment A List of Attendees

Attachment A
List of Attendees

Name	Organization
John Ferguson	Anchor QEA, LLC
Kristi Geris	Anchor QEA, LLC
Tracy Hillman[1]†	BioAnalysts
Lance Keller*	Chelan PUD
Alene Underwood[2]†	Chelan PUD
Catherine Willard†[2]	Chelan PUD
Tom Kahler*	Douglas PUD
Scott Carlon*	National Marine Fisheries Service
Jim Craig*	U.S. Fish and Wildlife Service
Kirk Truscott*	Colville Confederated Tribes
Bob Rose*†	Yakama Nation

Notes:
* Denotes HCP Coordinating Committees member or alternate
† Joined by phone
[1] Joined for the HCP Tributary and Hatchery Committees Update
[2] Joined for select Chelan PUD items

FINAL

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ANCHOR QEA

Memorandum

To: Wells, Rocky Reach, and Rock Island HCP Coordinating Committees

Date: June 27, 2017

From: John Ferguson, HCP Coordinating Committees Chairman

cc: Kristi Geris

Re: Final Minutes of the May 23, 2017, HCP Coordinating Committees Conference Call

The Wells, Rocky Reach, and Rock Island Hydroelectric Projects Habitat Conservation Plan (HCP) Coordinating Committees met by conference call on Tuesday May 23, 2017, from 9:00 to 10:00 a.m. Attendees are listed in Attachment A to these conference call minutes.

Action Item Summary

- Tom Kahler will provide fish passage count data for winter months at Wells Dam for review regarding the timing of winter maintenance outages at Wells Dam to Kristi Geris for distribution to the Coordinating Committees (Item I-C).
- Chelan PUD will incorporate gate sequence details into the 2017 Rock Island and Rocky Reach Fish Spill Plan and will provide the final plan to Kristi Geris for distribution to the Coordinating Committees (Item I-C). *(Note: Lance Keller provided the final plan to Geris on June 26, 2017, which Geris distributed to the HCP Coordinating Committees that same day.)*
- Chelan PUD will provide the Final 2016 Rocky Reach Juvenile Fish Bypass System Report to Kristi Geris for distribution to the Coordinating Committees (Item I-C).
- Anchor QEA, LLC, will contact Mackenzie Gavery (Postdoctoral Research Associate, University of Washington/National Oceanic and Atmospheric Administration [NOAA] Northwest Fisheries Science Center) regarding possibly presenting her epigenetics research to the HCP Coordinating Committees during a future meeting (Item II-A).
- Lance Keller will inquire internally about the cause of losing the use of automated spill gates 7, 17, and 25 at Rock Island Dam, as well as the timeline for repairing the gates, and will report back to the HCP Coordinating Committees (Item IV-A).
- Bob Rose will coordinate internally to develop and provide a Yakama Nation (YN) HCP Representation Designation document for distribution to the HCP Coordinating Committees (Item V-A).
- Kristi Geris will add Keely Murdoch, the new YN HCP Coordinating Committees Representative, to the HCP Coordinating Committees email distribution lists and request access to the extranet site from Julene McGregor (Douglas PUD Information Systems Staff; Item V-A). *(Note: Geris added Murdoch to the email lists and requested access to the extranet site following the meeting on May 23, 2017.)*

- The HCP Coordinating Committees meeting on June 27, 2017, will be held in-person at the Grant PUD office in Wenatchee, Washington (Item VI-B).

Decision Summary

- The Wells HCP Coordinating Committee representatives present approved the Columbia River Inter-Tribal Fish Commission's (CRITFC's) annual request to tag sockeye salmon at Wells Dam in 2017 (Item III-A). *(Note: Kirk Truscott provided the Colville Confederated Tribes' [CCT's] approval of the request via phone call prior to the meeting on May 23, 2017.)*

Agreements

- There were no HCP Agreements discussed during today's conference call.

Review Items

- Kristi Geris sent an email to the HCP Coordinating Committees on March 29, 2017, notifying them the Draft 2016 Douglas PUD Pikeminnow Removal Program Annual Report was available for a 60-day review period, with edits and comments due to Tom Kahler by Monday, May 29, 2017.
- Kristi Geris sent an email to the HCP Coordinating Committees on April 17, 2017, notifying them a Wells Project Land-use Permit Application (Small Block LLC) was available for a 60-day review period, with edits and comments due to Tom Kahler by Friday, June 16, 2017.
- Kristi Geris sent an email to the HCP Coordinating Committees on April 27, 2017, notifying them a Wells Project Land-use Permit Application (City of Pateros) was available for a 60-day review period, with edits and comments due to Tom Kahler by Monday, June 26, 2017.

Finalized Documents

- The Final Rocky Reach Total Dissolved Gas Alternative Analysis Report was finalized following a 30-day HCP Coordinating Committees review, and was distributed to the HCP Coordinating Committees by Kristi Geris on May 23, 2017.
- The Final 2017 Rock Island and Rocky Reach Fish Spill Plan was distributed to the HCP Coordinating Committees by Kristi Geris on June 26, 2017.

I. Welcome

A. Review Agenda (John Ferguson)

John Ferguson welcomed the HCP Coordinating Committees and reviewed the agenda. Ferguson asked for any additions or changes to the agenda. Lance Keller added an update on the spill gate change at Rock Island Dam.

B. Meeting Minutes Approval (John Ferguson)

The HCP Coordinating Committees reviewed the revised draft March 28, 2017, meeting minutes. Kristi Geris said there is one outstanding edit to discuss under Chelan PUD's discussion on the Draft Rocky Reach Total Dissolved Gas Alternative Analysis Report. Lance Keller edited a statement made by Tom Kahler about the bypass at Wells Dam, and Keller requested that Kahler approve the edit. Kahler approved the edit.

Geris said all other comments and revisions received from members of the Committees were incorporated into the revised minutes. HCP Coordinating Committees members present approved the March 28, 2017, meeting minutes, as revised. *(Note: Kirk Truscott provided the CCT's approval of the minutes via phone call prior to the meeting on May 23, 2017.)*

C. Last Meeting Action Items (John Ferguson)

Action items from the HCP Coordinating Committees meeting on March 28, 2017, and follow-up discussions, were as follows. *(Note: italicized text corresponds to agenda items from the meeting on March 28, 2017):*

- *Alene Underwood (Chelan PUD Fish and Wildlife Program Manager) will provide Chelan PUD's comments on the Federal Columbia River Power System (FCRPS) National Environmental Policy Act (NEPA) Scoping Process to Kristi Geris for distribution to the HCP Coordinating Committees (Item I-C).*
  Underwood provided these comments to Geris following the meeting on March 28, 2017, which Geris distributed to the HCP Coordinating Committees on March 29, 2017.
- *Tom Kahler will provide fish passage count data for winter months at Wells Dam for review regarding timing of winter maintenance at Wells Dam to Kristi Geris for distribution to the HCP Coordinating Committees (Item I-C).*
  This action item will be carried forward.
- *John Ferguson will coordinate with Tracy Hillman (HCP Hatchery Committees Chairman) to obtain HCP Hatchery Committees and Wells HCP Coordinating Committee approval of the 2017 Broodstock Collection Protocols prior to the April 15, 2017 deadline to the National Marine Fisheries Service (NMFS; Item II-A).*

Ferguson discussed the timeline with Hillman following the meeting on March 28, 2017, who coordinated with the HCP Hatchery Committees to deliver the protocols by approximately April 7, 2017.

- *Douglas PUD will provide the Draft 2016 Douglas PUD Pikeminnow Removal Program Annual Report for review to Kristi Geris for distribution to the HCP Coordinating Committees (Item III-A).*
  Tom Kahler provided the draft report for review to Geris following the meeting on March 28, 2017, which Geris distributed to the HCP Coordinating Committees on March 29, 2017.
- *Douglas PUD will provide an electronic copy of the 2017 Trapping Activities at Wells Dam Gantt Chart to Kristi Geris for distribution to the HCP Coordinating Committees (Item III-E).*
  Tom Kahler provided the chart to Geris following the meeting on March 28, 2017, which Geris distributed to the HCP Coordinating Committees on March 29, 2017.
- *Chelan PUD will complete edits to the Revised Draft Rock Island and Rocky Reach Coho Phase Designation Statement of Agreement (SOA), as discussed, and will provide a final SOA to Kristi Geris for distribution to the HCP Coordinating Committees (Item IV-A).*
  Lance Keller provided the final SOA to Geris on March 29, 2017, which Geris distributed to the HCP Coordinating Committees that same day.
- *Anchor QEA, LLC, will communicate to Washington Department of Fish and Wildlife (WDFW) what discussions took place during today's HCP Coordinating Committees meeting regarding the Revised Draft Rock Island and Rocky Reach Coho Phase Designation SOA, and will request that WDFW submit a vote via email by close of business Thursday, March 30, 2017 (Item IV-A).*
  Kristi Geris coordinated with WDFW, as discussed, and WDFW submitted their approval of the SOA on March 30, 2017.
- *Anchor QEA will notify the HCP Hatchery Committees that the HCP Coordinating Committees approved the Rock Island and Rocky Reach Coho Phase Designation SOA, so the HCP Hatchery Committees may move forward with hatchery compensation planning (Item IV-A).*
  Kristi Geris notified Sarah Montgomery (HCP Hatchery Committees Support Staff) about the approval, as discussed, on March 30, 2017.
- *Chelan PUD will incorporate gate sequence details into the 2017 Rock Island and Rocky Reach Fish Spill Plan and will provide the final plan to Kristi Geris for distribution to the HCP Coordinating Committees (Item IV-B).*
  This action item will be carried forward.
- *The Yakama Nation (YN) will provide the report, "Translocation of Adult Pacific Lamprey within the Wenatchee Subbasin (2015-2016 Broodstock)," to Kristi Geris for distribution to the HCP Coordinating Committees (Item IV-C).*
  Bob Rose provided the report to Geris during the meeting on March 28, 2017, which Geris distributed to the HCP Coordinating Committees on March 29, 2017.

- *Kristi Geris will add Catherine Willard (Chelan PUD HCP Hatchery Committees Alternate) to the HCP Coordinating Committees email distribution list, as approved by the HCP Coordinating Committees (Item IV-F).*
  Geris added Willard to the list on March 29, 2017.
- *Chelan PUD will provide the Revised Draft 2017 Rock Island and Rocky Reach HCP Action Plan for vote via email to Kristi Geris for distribution to the HCP Coordinating Committees (Item IV-G).*
  Lance Keller provided the revised plan to Geris on March 29, 2017, which Geris distributed to the HCP Coordinating Committees on March 30, 2017.
- *Chelan PUD will address comments received on the Draft 2016 Rock Island and Rocky Reach HCP Annual Reports and will provide the revised reports to Kristi Geris for final production (Item VI-H).*
  Lance Keller provided the revised reports to Geris on March 29, 2017.
- *Chelan PUD will provide the Final 2016 Rocky Reach Juvenile Fish Bypass System Report to Kristi Geris for distribution to the HCP Coordinating Committees (Item IV-I).*
  Lance Keller said Chelan PUD is still addressing a few comments on this report. This action item will be carried forward.

II. HCP Tributary and Hatchery Committees Update

A. HCP Tributary and Hatchery Committees Update (Tracy Hillman)

Tracy Hillman said the HCP Tributary Committees did not officially meet in May 2017; rather, the Committees attended project tours on May 10, 2017, in the Wenatchee River basin; on May 11, 2017, in the Entiat River basin; and on May 18, 2017, in the Methow River basin. This year, the HCP Tributary Committees received nine General Salmon Habitat Program proposals. All projects are cost shares. Total funds requested from the HCP Tributary Committees Plan Species Accounts equal about $612,000. The HCP Tributary Committees will attend presentations in June 2017, and during the regular monthly meeting on June 8, 2017, the Committees will evaluate the proposals and decide which projects should be submitted as final proposals. John Ferguson asked about the overall quality of the proposals this year. Hillman said there are some good ones and also a couple the HCP Tributary Committees may not recommend for submitting a final proposal. He said, for example, reviewers liked a project that will improve instream flow in the lower Icicle Creek (titled, "Cascade Orchards Flow Restoration in Icicle Creek"), which will produce an important contribution to flow in the creek during late summer and early-fall (about 7 to 8 cubic feet per second). Other projects involve restoration work where the HCP Tributary Committees may recommend a slightly different approach. The next meeting of the HCP Tributary Committees will be on Thursday, June 8, 2017.

Hillman updated the HCP Coordinating Committees on the following actions and discussions that occurred during the HCP Hatchery Committees meeting on May 17, 2017:

- *PRESENTATION: Epigenetics*: Mackenzie Gavery shared a presentation titled, "Epigenetics: what is it and why is it relevant to hatchery practices?" The presentation included an overview of epigenetics, discussion of a specific epigenetic marks called deoxyribonucleic acid (DNA) methylation, and a presentation of results for the Methow River steelhead DNA methylation study. Epigenetics refers to heritable changes in trait or phenotype caused by a mechanism other than mutation to the DNA sequence. The epigenome of an organism can be affected by the environment, especially during early development, and even after the environmental signal is removed. In Gavery's research, she asked whether there are discernable epigenetic differences between hatchery- and natural-origin steelhead at Winthrop National Fish Hatchery. In 2014, blood and sperm samples were extracted from returning hatchery- and natural-origin adult steelhead, and a DNA methylation analysis was performed to evaluate somatic and germline cells (which are passed on to the next generation). The results showed steelhead have a heavily methylated genome compared to other species. Comparisons of differentially methylated regions between blood and sperm cells show sperm carry important epigenetic information regarding which genes are going to be turned on in the early embryo. Results also showed there are differences in DNA methylation between hatchery- and natural-origin steelhead in both somatic and germline-derived cell types. Epigenetics may play a role in the observed fitness loss of steelhead after a single generation of rearing. Epigenetics can help organisms retain and pass on information about their environment and the study of the epigenome is an emerging tool to help understand how the environment affects phenotype in hatchery fish. Gavery has a second study underway where offspring from natural-origin Methow steelhead families are divided into two groups and reared in a hatchery tank and an artificial stream. Hillman said Gavery provided an excellent presentation, recommended the HCP Coordinating Committees inquire about having Gavery present at a future meeting, and thanked USFWS for recommending Gavery to present to the HCP Hatchery Committees. Anchor QEA will contact Gavery regarding possibly presenting her epigenetics research to the HCP Coordinating Committees during a future meeting.
- *USFWS Bull Trout Consultation Update*: USFWS is currently revising the draft Biological Opinion (BiOp) for the Wenatchee subbasin programs and expects it will be finalized in mid-June 2017.
- *NMFS Consultation Update*: NMFS is working on consultation for the unlisted programs in the upper Columbia River. The proposed actions will likely be finished in June 2017. NMFS is also working on the Methow steelhead consultation. A consultation update meeting is scheduled for June 1, 2017.

- *Wells Fish Hatchery Power/Water Outage*: WDFW and Douglas PUD provided a recap and update about a power and water outage experienced at Wells Fish Hatchery. The power and water outage occurred on May 2, 2017, and water was restored overnight. Approximately 20,000 to 25,000 steelhead fry of unknown origin were lost. WDFW indicated the loss will not affect the overall production obligation for the program.
- *Wells Dam West Fish Ladder Trapping Contingencies*: Currently, WDFW is manually trapping spring Chinook salmon at the Wells Dam west fish ladder because the pipe that is used to transfer fish to the pond is under construction, which includes increasing the diameter of the pipe to 30 inches and installing a dewatering screen. Improvements are expected to be completed soon.
- *Review Hatchery Monitoring and Evaluation Plan Objectives*: The HCP Hatchery Committees are reviewing the objectives in the Hatchery Monitoring and Evaluation (M&E) Plan to verify they are consistent with the hatchery M&E timeline. The HCP Hatchery Committees have completed their review of the first few objectives with only a few changes. The review should be completed by June or July 2017.
- *Methow Steelhead Gene Flow Plan*: The HCP Hatchery Committees discussed the proportion of hatchery-origin spawners (pHOS) target for inclusion in the Methow steelhead BiOp. NMFS proposed achieving a pHOS of 0.3 for most run sizes. However, in 2013, there was also an agreement that pHOS should be closer to 0.5. The HCP Hatchery Committees are discussing how to identify a target and how to achieve it. The Committees are further discussing a phased approach, which was also discussed in 2013. These discussions are expected to continue.
- *Coho Salmon Recalculation:* The YN and Chelan PUD are coordinating on this and provided a presentation to the HCP Hatchery Committees. The goal is to use the same recalculation methods for coho salmon as were used for other species. The YN and Chelan PUD will include the final mitigation numbers in a SOA for review and approval in June 2017.
- *Update from the Upper Columbia Regional Technical Team*: The Independent Scientific Advisory Board (ISAB) is working with the Upper Columbia Salmon Recovery Board to review upper Columbia River spring Chinook salmon recovery analyses and strategies. ISAB is visiting the upper Columbia River on July 20 and 21, 2017, for presentations and site visits. Further updates will be available in June 2017. Ferguson asked about the ISAB review scope. Hillman said at this point, it is only for spring Chinook salmon, but may eventually change to steelhead.
- *Next Steps*: The next meeting of the HCP Hatchery Committees will be on Wednesday, June 21, 2017.

III. Douglas PUD

A. DECISION: CRITFC Annual Request for Sockeye Tagging at Wells Dam (Tom Kahler)

Tom Kahler said CRITFC's annual request to tag sockeye salmon at Wells Dam in 2017 (Attachment B) was distributed to the HCP Coordinating Committees by Kristi Geris on April 17, 2017. Kahler recalled this is the same request received from Jeff Fryer (CRITFC) each year.

John Ferguson said Kirk Truscott provided the CCT's approval of the request via phone call prior to the meeting on May 23, 2017, as long as the request is the same as last year's. Kahler said the only difference in this year's request from last year, is this year's letter specifies fin clips for genetic samples, which also occurred last year but was not included in the request letter. Kahler also noted that traditionally, CRITFC received assistance from the CCT and the YN; however, this year only the YN will provide assistance.

The Wells HCP Coordinating Committee representatives present approved CRITFC's annual request to tag sockeye salmon at Wells Dam in 2017. *(Note: Truscott provided the CCT's approval of the request via phone call prior to the meeting on May 23, 2017.)*

B. Trapping at Wells Dam (Tom Kahler)

Tom Kahler recalled discussing with the HCP Coordinating Committees during past meetings about the transport pipe from the west fish ladder trap to the Adult Handling Facility, where engineers had not included a dewatering section in the new pipe. Kahler said those repairs have been underway and the change order specified the repairs would be complete by mid-April 2017. He said, however, the sweep for the 30-inch pipe (the pipe turns approximately 30 degrees) needed to be custom fabricated and the manufacturer took longer than planned. He said once received, contractors discovered that the opening in the vault where the sweep is to be installed is 6 inches higher than necessary. He said a new hole was cut and the pipe flange grouted in place, to which the sweep was connected, and the whole pipe is being embedded in concrete which should be completed by today or tomorrow. He said the west ladder fish trap may be operational as early as tomorrow, depending on how long it takes for the concrete to cure. He said in the meantime, WDFW is proposing real-time trapping, where fish are conveyed from the trap chute across the ladder pool into a tote for processing. He recalled trapping for spring Chinook salmon may occur at the west fish ladder between May 1 and June 20, under a maximum 5 days per week (but no more than 3 consecutive days) at 16 hours per day.

Kahler said spring Chinook salmon numbers passing Wells Dam have been in the single digits until last Sunday, May 21, 2017, when there were 31 fish counted passing the dam. He said he expects numbers to increase moving forward.

IV. Chelan PUD

A. Spill Gate Change at Rock Island Dam (Lance Keller)

Lance Keller said a notification of spill gate changes at Rock Island Dam was distributed to the HCP Coordinating Committees by Kristi Geris on May 19, 2017. Keller said on May 18, 2017, Chelan PUD received notification that Rock Island Dam lost capability of operating one of the automated spill gates (spill gate 7). He said now, a total of three spill gates are out of service (spill gates 7, 17, and 25). Keller said it is his understanding there is no capability to manually raise an automated spill gate and hold it in an open position. He said there are 31 spill gates at Rock Island Dam, 11 of which are automated and 20 are operated manually. He said if a large spring runoff event suddenly occurs, it is expected that the functioning automated and manual gates can be opened. He said with the manual gates, staff need to remove gate sections and store the sections on either side of the dam. He said while staff are opening the manual gates, the spill capacity provided through the automated gates must be relied upon.

Keller said with having three automated gates out of operation and recently experiencing the highest river flow at Rocky Reach and Rock Island dams on record, Rock Island Dam engineers requested to convert two notch gates back to full gate operation. He said Thad Mosey (Chelan PUD Fish Biologist and Spill Coordinator) and Steve Hemstrom discussed which notch gates to convert back to full gate operation with regard to juvenile and adult fish passage and total dissolved gas (TDG) levels. Keller said Chelan PUD decided to convert notched spill gates 18 and 24 for the following reasons: 1) conversion of these gates to full gate operation is not expected to have negative impacts to juvenile fish passage; 2) gates 18 and 24 are located away from the left powerhouse entrance of the right bank adult fish ladder and should have no impact on adult fish passage; and 3) both of these gates are shallow spill gates so additional TDG from the gate conversions should be negligible. Keller said this is a temporary conversion until river flow subsides or until the automated spill gates return to service.

Bob Rose asked about tailwater egress (e.g., eddies). Keller said Rock Island Dam staff are conducting visual observations every other day and, to date, everything looks good (flow appears to be linear).

Scott Carlon asked about the cause of the failed automated spill gates, and John Ferguson asked about the timeline for fixing the failed gates. Keller said he is unsure but will inquire internally about the cause of losing the use of automated spill gates 7, 17, and 25 at Rock Island Dam, as well as the timeline for repairing the gates, and will report back to the HCP Coordinating Committees.

V. Yakama Nation

A. Yakama Nation HCP Representation Update (Bob Rose)

Bob Rose said Keely Murdoch will transition into the YN HCP Coordinating Committees Representative and Rose will become the YN HCP Coordinating Committees Alternate. Rose said Murdoch is familiar with the HCPs and has participated on the HCP Hatchery Committees for years. Rose will coordinate internally to develop and provide a YN HCP Representation Designation document for distribution to the HCP Coordinating Committees.

John Ferguson asked what to expect with the transition. Rose said he is unable to attend the HCP Coordinating Committees meeting on June 27, 2017; however, he hopes to have the designation document distributed by then. He said he anticipates participating in the July 2017 meeting, with the transition occurring by the August or September 2017 meetings.

Murdoch noted that she also cannot attend the HCP Coordinating Committees meeting on June 27, 2017. Rose said the purpose of today's discussion is to notify the HCP Coordinating Committees of the change and understand that Murdoch will now be added to the email distribution list and extranet site. Kristi Geris said she will add Murdoch to the HCP Coordinating Committees email distribution lists and request access to the extranet site from Julene McGregor. *(Note: Geris added Murdoch to the email lists and requested access to the extranet site following the meeting on May 23, 2017.)*

VI. HCP Administration

A. Chelan PUD HCP Representation Update (Kristi Geris)

Kristi Geris said a Chelan PUD HCP Representation Designation document (Attachment C) was distributed to the HCP Coordinating Committees by Kristi Geris on April 13, 2017. Geris said key changes included designating: Alene Underwood (Chelan PUD Fish and Wildlife Manager) as the new Chelan PUD HCP Policy Committees Representative; Jeff Smith (Chelan PUD Managing Director – District Services) as the new Chelan PUD HCP Policy Committees Alternate; and Catherine Willard (Chelan PUD Senior Fisheries Biologist) as the new Chelan PUD HCP Hatchery Committees Representative.

B. Next Meetings

The next scheduled HCP Coordinating Committees meeting is on June 27, 2017, to be held in-person at the Grant PUD Wenatchee Office in Wenatchee, Washington.

The July 25 and August 22, 2017, meetings will be held by conference call or in-person at the Grant PUD Wenatchee Office in Wenatchee, Washington, as is yet to be determined.

VII. List of Attachments

Attachment A	List of Attendees
Attachment B	CRITFC's annual request to tag sockeye salmon at Wells Dam in 2017
Attachment C	Chelan PUD HCP Representation Designation document

Attachment A
List of Attendees

Name	Organization
John Ferguson	Anchor QEA, LLC
Kristi Geris	Anchor QEA, LLC
Tracy Hillman[1]	BioAnalysts
Lance Keller*	Chelan PUD
Tom Kahler*	Douglas PUD
Scott Carlon*	National Marine Fisheries Service
Jim Craig*	U.S. Fish and Wildlife Service
Bob Rose*	Yakama Nation
Keely Murdoch*	Yakama Nation

Notes:
* Denotes HCP Coordinating Committees member or alternate
[1] Joined for the HCP Tributary and Hatchery Committees Update

Attachment B

COLUMBIA RIVER INTER-TRIBAL FISH COMMISSION

700 NE Multnomah Street, Suite 1200
Portland, Oregon 97232

(503) 238-0667
F (503) 235-4228
www.critfc.org

April 7, 2017

Tom Kahler
Fisheries Biologist
Public Utility District #1 of Douglas County
1151 Valley Mall Parkway
East Wenatchee, WA 98801

Dear Mr. Kahler:

Since 1995, the Columbia River Inter-Tribal Fish Commission (CRITFC) has conducted a scientific study near Wells Dam. The project is currently funded by the Bonneville Power Administration, and is entitled, "Studies into Factors Limiting the Abundance of Okanagan and Wenatchee Sockeye Salmon." CRITFC requests permission to access and conduct sampling activities at Wells Dam.

The purpose of this study is to determine the effect of temperature on the survival of sockeye salmon returning to their spawning grounds in the Okanagan Basin. It is anticipated that a maximum of 800 sockeye will be sampled for scales, fin clips for genetics samples, and tagged with PIT and Floy tags. We do not plan to do any acoustic tagging of sockeye in 2017. The sampling activity will take place daily, Monday-Friday, from late June 2017 through early August 2017, and will be coordinated with the Wells Hatchery brood stock collection programs.

The sampling team will consist of three to five individuals from two separate organizations, they are as follows: Dr. Jeff Fryer of CRITFC; Kraig Mott, Casey Heemsah, Clifford Smith, and Terri Benson of Confederated Tribes and Bands of the Yakama Nation.

Thank you for your consideration. If you have any questions or need further information, please contact Project Leader, Dr. Jeff Fryer at (503) 238-0667.

Sincerely,

Robert C. Lothrop
Interim Executive Director

NOTED
APR 17 2017
THK

NOTED
APR 17 2017
MEM

Attachment C



PUBLIC UTILITY DISTRICT NO. 1 of CHELAN COUNTY
P.O. Box 1231, Wenatchee, WA 98807-1231 • 327 N. Wenatchee Ave., Wenatchee, WA 98801
(509) 663-8121 • Toll free 1-888-663-8121 • www.chelanpud.org

Date: April 12, 2017

To: John Ferguson, Ph.D
Anchor QEA, LLC

From: Alene Underwood, Manger Fish and Wildlife
Chelan County Public Utility District

RE: HCP Committees Representatives

This memo is to inform you that Chelan PUD has made a change designating their representatives to the HCP Policy Committee, their representative to the Hatchery Committees and alternative representative to the Hatchery Committees. We respectfully request that your contact information is updated as appropriate. The delegate contact information is as follows:

Policy Committee	Policy Committee (Alternate)
Alene Underwood Fish and Wildlife Manager Chelan County Public Utility District PO Box 1231; Wenatchee, WA 98807 Phone: (509) 661-4364 Email: alene.underwood@chelanpud.org	Jeff Smith Managing Director – District Services Chelan County Public Utility District PO Box 1231; Wenatchee, WA 98807 Phone: (509) 661-4379 Email: jeff.smith@chelanpud.org

Hatchery Committees	Hatchery Committees (Alternate)
Catherine Willard Senior Fisheries Biologist Chelan County Public Utility District PO Box 1231; Wenatchee, WA 98807 Phone: (509) 661-4179 Email: catherine.willard@chelanpud.org	Vacant - TBD

The representatives for the Coordinating and Tributary Committees remain unchanged. Those representatives information are as follows:

Tributary Committees	Tributary Committees (Alternate)
Steve Hays Fish & Wildlife Senior Advisor Chelan County Public Utility District PO Box 1231; Wenatchee, WA 98807 Phone: (509) 661-4181 Email: steve.hays@chelanpud.org	Jeff Osborn License Compliance Supervisor Chelan County Public Utility District PO Box 1231; Wenatchee, WA 98807 Phone: (509) 661-4176 Email: jeff.osborn@chelanpud.org

Coordinating Committees	Coordinating Committees (Alternate)
Lance Keller Senior Fisheries Biologist Chelan County Public Utility District PO Box 1231; Wenatchee, WA 98807 Phone: (509) 661-4299 Email: lance.keller@chelanpud.org	Steve Hemstrom Senior Fisheries Biologist Chelan County Public Utility District PO Box 1231; Wenatchee, WA 98807 Phone: (509) 661-4281 Email: steven.hemstrom@chelanpud.org

FINAL

720 Olive Way, Suite 1900
Seattle, Washington 98101
206.287.9130

ANCHOR QEA

Memorandum

To: Wells, Rocky Reach, and Rock Island HCP Coordinating Committees

Date: August 23, 2017

From: John Ferguson, HCP Coordinating Committees Chairman

cc: Kristi Geris

Re: Final Minutes of the June 27, 2017, HCP Coordinating Committees Meeting

The Wells, Rocky Reach, and Rock Island Hydroelectric Projects Habitat Conservation Plan (HCP) Coordinating Committees met in-person at the Grant PUD Office in Wenatchee, Washington, on Tuesday June 27, 2017, from 10:00 to 11:45 a.m. Attendees are listed in Attachment A to these meeting minutes.

Action Item Summary

- Tom Kahler will provide fish passage count data for winter months at Wells Dam for review regarding timing of winter maintenance at Wells Dam to Kristi Geris for distribution to the Coordinating Committees (Item I-B).
- Chelan PUD will provide the Final 2016 Rocky Reach Juvenile Fish Bypass System Report to Kristi Geris for distribution to the Coordinating Committees (Item I-B). *(Note: Lance Keller provided the final report to Geris on June 28, 2017, which Geris distributed to the HCP Coordinating Committees that same day.)*
- Anchor QEA will contact Mackenzie Gavery (Postdoctoral Research Associate, University of Washington/National Oceanic and Atmospheric Administration [NOAA] Northwest Fisheries Science Center) regarding possibly presenting her epigenetics research to the HCP Coordinating Committees during a future meeting (Item I-B).
- Bob Rose will coordinate internally to develop and provide a Yakama Nation (YN) HCP Representation Designation document for distribution to the HCP Coordinating Committees (Item I-B).
- Kristi Geris will coordinate with Tracy Hillman (HCP Hatchery Committees Chairman) and Sarah Montgomery (HCP Hatchery Committees Support Staff) to obtain meeting and WebEx information for Jeff Jorgensen's (NOAA Northwest Fisheries Science Center) presentation to the HCP Hatchery Committees on August 16, 2017, on a life-cycle model for Wenatchee River spring Chinook salmon, which Geris will distribute to the HCP Coordinating Committees (Item II-A). *(Note: this presentation has been postponed to the HCP Hatchery Committees meeting on September 20, 2017.)*
- Chelan PUD will provide a Rocky Reach Dam large unit repair update during an HCP Coordinating Committees meeting in late-summer 2017 (Item III-B).

- Chelan PUD will provide a Rock Island Dam Powerhouse 1 maintenance update during the HCP Coordinating Committees conference call on July 25, 2017 (Item III-C).
- Kristi Geris will add Chad Jackson, potentially the new Washington Department of Fish and Wildlife (WDFW) HCP Coordinating Committees Representative, and Mike Tonseth, likely a new WDFW HCP Coordinating Committees Alternate, to the HCP Coordinating Committees email distribution lists and request access to the HCP Coordinating Committees extranet site from Julene McGregor (Douglas PUD Information Systems Staff; Item VI-A). *(Note: Geris added Jackson and Tonseth to the email lists and requested access to the extranet site following the meeting on June 27, 2017.)*
- The HCP Coordinating Committees meeting on July 25, 2017, will be held by conference call (Item VII-B). *(Note: due to lack of agenda items, the HCP Coordinating Committees meeting on July 25, 2017, has been canceled. The August 22, 2017, meeting will be held in-person at the Grant PUD Wenatchee Office in Wenatchee, Washington.)*

Decision Summary

- There were no HCP Decision Items approved during today's meeting.

Agreements

- HCP Coordinating Committees representatives present agreed to add Chad Jackson and Mike Tonseth to the HCP Coordinating Committees email distribution lists and provide them both with access to the HCP Coordinating Committees extranet site because Jackson will potentially become the WDFW HCP Coordinating Committees Representative and Tonseth will likely be a new WDFW HCP Coordinating Committees Alternate (Item VI-A).

Review Items

- There are no items that are currently out for review.

Finalized Documents

- There are no documents that have been recently finalized.

I. Welcome

A. Review Agenda (John Ferguson)

John Ferguson welcomed the HCP Coordinating Committees and reviewed the agenda. Ferguson asked for any additions or changes to the agenda. The following revisions were requested:

- Tom Kahler added updates on the Wells Hatchery Modernization and Wells Dam bypass.

- Jim Craig added a notification about subyearling spring Chinook salmon rearing in the Columbia River.
- Jeff Korth added an update on WDFW HCP Coordinating Committees representation.

B. Last Meeting Action Items (John Ferguson)

Action items from the HCP Coordinating Committees meeting on May 23, 2017, and follow-up discussions, were as follows. *(Note: italicized text corresponds to agenda items from the meeting on May 23, 2017):*

- *Tom Kahler will provide fish passage count data for winter months at Wells Dam for review regarding the timing of winter maintenance outages at Wells Dam to Kristi Geris for distribution to the Coordinating Committees (Item I-C).*
  This action item will be carried forward.
- *Chelan PUD will incorporate gate sequence details into the 2017 Rock Island and Rocky Reach Fish Spill Plan and will provide the final plan to Kristi Geris for distribution to the Coordinating Committees (Item I-C).*
  Lance Keller provided the final plan to Geris on June 26, 2017, which Geris distributed to the HCP Coordinating Committees that same day.
- *Chelan PUD will provide the Final 2016 Rocky Reach Juvenile Fish Bypass System Report to Kristi Geris for distribution to the Coordinating Committees (Item I-C).*
  This action item will be carried forward. *(Note: Lance Keller provided the final report to Geris on June 28, 2017, which Geris distributed to the HCP Coordinating Committees that same day.)*
- *Anchor QEA, LLC, will contact Mackenzie Gavery (Postdoctoral Research Associate, University of Washington/National Oceanic and Atmospheric Administration [NOAA] Northwest Fisheries Science Center) regarding possibly presenting her epigenetics research to the HCP Coordinating Committees during a future meeting (Item II-A).*
  This action item will be carried forward.
- *Lance Keller will inquire internally about the cause of losing the use of automated spill gates 7, 17, and 25 at Rock Island Dam, as well as the timeline for repairing the gates, and will report back to the HCP Coordinating Committees (Item IV-A).*
  This will be discussed during today's meeting.
- *Bob Rose will coordinate internally to develop and provide a Yakama Nation (YN) HCP Representation Designation document for distribution to the HCP Coordinating Committees (Item V-A).*
  This action item will be carried forward.
- *Kristi Geris will add Keely Murdoch, the new YN HCP Coordinating Committees Representative, to the HCP Coordinating Committees email distribution lists and request access to the extranet site from Julene McGregor (Douglas PUD Information Systems Staff; Item V-A).*

Geris added Murdoch to the email lists and requested access to the extranet site following the meeting on May 23, 2017.

C. Meeting Minutes Approval (John Ferguson)

The HCP Coordinating Committees reviewed the revised draft May 23, 2017, conference call minutes. Kristi Geris said she incorporated distribution of the Final 2017 Rock Island and Rocky Reach Fish Spill Plan into the action items and finalized documents sections of the minutes. She said all other comments and revisions received from members of the Committees were also incorporated into the revised minutes and there were no outstanding edits or questions to discuss. HCP Coordinating Committees members present approved the May 23, 2017, conference call minutes, as revised. WDFW abstained, because a WDFW representative was not present during the May 23, 2017, conference call.

II. HCP Tributary and Hatchery Committees Update

A. HCP Tributary and Hatchery Committees Update (Tracy Hillman)

Tracy Hillman updated the HCP Coordinating Committees on the following actions and discussions that occurred during the HCP Tributary Committees meeting on June 8, 2017:

- *Budget Amendment – Clear Creek Fish Passage Project*: The Rocky Reach HCP Tributary Committee received a budget amendment request from Trout Unlimited for the Clear Creek Fish Passage Project, requesting to move $2,000 from "Project Materials and Supplies" to "Professional Services and Permitting." The Rocky Reach HCP Tributary Committee approved the budget amendment. The amendment will not change the total budget amount.
- *Budget Amendment – Permitting Nutrient Enhancement in the Chiwawa River Basin Project*: The Rock Island HCP Tributary Committee received a budget amendment request from Cascade Columbia Fisheries Enhancement Group (CCFEG) for the Permitting Nutrient Enhancement in the Chiwawa River Basin Project, requesting to move $1,028 from "Professional Services" and "Indirect/Admin/Overhead" to "Sponsor Salaries and Benefits." The Rock Island HCP Tributary Committee approved the budget amendment. Jeff Korth said he thought this project was already completed. Hillman said the U.S. Fish and Wildlife Service (USFWS) expressed concern over placing nutrients on bull trout redds; however, after revising the treatment plan this is no longer an issue. John Ferguson asked if nutrient enhancement has started, and Hillman said not yet. Ferguson asked if nutrients are depleted in the Chiwawa River. Hillman said based on studies conducted by CCFEG and Pace Engineers, nutrients are low in the river. He added that macroinvertebrate species richness is relatively high, but abundance of each species is low.

- *Budget Amendment – White River Floodplain Connection (River Mile 3.4) Project*: The Rock Island HCP Tributary Committee received a budget amendment request from CCFEG for the White River Floodplain Connection (River Mile 3.4) Project, requesting to move all available funds from construction to other tasks. The Committee questioned how the project will be completed if all the money is taken out of construction; therefore, the Rock Island HCP Tributary Committee denied the request. Hillman said he contacted the project lead who indicated the rest of the funding is covered under another source. The HCP Coordinating Committees asked who owns the land where the project is taking place, and Hillman said part of the land is owned by WDFW and some is privately owned.
- *Time Extension*: The Rock Island HCP Tributary Committee received a time extension request from Trout Unlimited for the Barkley Irrigation Project. The sponsor indicated that construction on the project is unlikely to begin until fall 2017; therefore, the sponsor asked to extend the project end date from May 31, 2017, to December 31, 2018. The Rock Island HCP Tributary Committee approved the time extension.
- *General Salmon Habitat Program Draft Proposals*: The HCP Tributary Committees received nine draft proposals. Among those nine proposals, four were selected for final proposals. The other five projects may submit final proposals; however, it is unlikely they would be approved for funding. Full proposals are due on June 30, 2017. The proposed projects are in the Wenatchee, Entiat, and Methow River basins.
- *Small Projects Program Proposal*: The HCP Tributary Committees received a Small Projects Program application from Chelan County Natural Resources Department (CCNRD) titled, "Poison Canyon Restoration." Poison Canyon has a highly entrenched stream and is a tributary to Sand Creek, which is a tributary to Mission Creek. CCNRD proposed to install 20 wood structures to help aggrade the channel. The total cost of the project is $73,330, and the sponsor requested $38,160 from the HCP Tributary Committees, but they declined the opportunity to fund the project. Hillman explained, the issue is that several HCP Tributary Committees representatives have completed similar projects and such highly designed structures are unnecessary to achieve the project's purposes. He said the project is over-engineered and too expensive. CCNRD also proposed installing game cameras and piezometers, which the HCP Tributary Committees do not agree are needed. CCNRD proposed installing one structure per day, when the HCP Tributary Committees believe two or more structures can be constructed per day. CCNRD also needs to consider anchoring, so the wood does not get flushed out of the canyon. The HCP Tributary Committees are working with the sponsor to develop a cheaper, more effective proposal, and CCNRD will likely resubmit. Tom Kahler noted that Poison Canyon has a lot of erodible soils. Hillman agreed and said the sponsor just lacked the technical background on how to aggrade a small stream; however, he added that the proposal was very well-written.

- *Independent Scientific Advisory Board Visit*: The Independent Scientific Advisory Board will be visiting Wenatchee, Washington, from July 19 to 21, 2017. One day is for visiting the Wenatchee River basin, one day is for visiting the Methow River basin, and one day is for presentations. Kahler said he believes the plan now is to visit the Methow River basin at a later date, because all three components were too much to cover in a 3-day period.
- *Next Steps*: The next meeting of the HCP Tributary Committees will be on July 13, 2017, when the HCP Tributary Committees will be evaluating the final General Salmon Habitat Program proposals.

Hillman updated the HCP Coordinating Committees on the following actions and discussions that occurred during the HCP Hatchery Committees meeting on June 21, 2017:

- *Tumwater Dam Pacific Lamprey Passage Feasibility Study Update*: In the Rocky Reach Fish Forum, concerns were raised about Pacific lamprey passage issues at Tumwater Dam. The way the fish ladder is currently designed is not conducive to Pacific lamprey passage. The question is whether improvements can be made to improve Pacific lamprey passage. To address this question, Chelan PUD has funded a feasibility study. In the HCP Hatchery Committees, Alene Underwood (Chelan PUD HCP Policy Representative) provided an update on the status of the feasibility study. During the HCP Hatchery Committees meeting, Underwood indicated that technical staff at the District have been expecting to receive the feasibility study report for the past few months; however, the report is still under review by Chelan PUD's upper management. Chelan PUD is evaluating what their legal requirement is regarding Pacific lamprey passage at Tumwater Dam and the biological benefit that a passage structure at the dam will provide. Specifically, Chelan PUD is working on three items: 1) distributing the feasibility study as soon as possible; 2) determining regulatory nexus and requirements including off-license mitigation; and 3) preparing a biological benefit assessment to determine how passage improvements will influence future abundance. The report should be available in the next couple of months. Jim Craig recalled that when Bryan Nordlund (National Marine Fisheries Service [NMFS], retired) served on the HCP Coordinating Committees, Nordlund expressed concern that the denil structure could potentially exclude the largest of the Chinook salmon species (i.e., it was a caudal tail amplitude issue). Mike Tonseth (WDFW HCP Hatchery Committees Representative) noted that the structure was designed for sockeye salmon. Hillman also noted that Steve Rainey (USFWS consultant) designed the current fishway.
- *USFWS Bull Trout Consultation Update*: USFWS has made little progress on bull trout consultations due to other pressing issues.
- *NMFS Consultation Update*: NMFS provided an update on consultation for the six unlisted programs in the upper Columbia River, including: Wenatchee summer Chinook salmon,

Chelan Falls summer Chinook salmon, Wells summer Chinook salmon, Methow summer Chinook salmon, Priest Rapids fall Chinook salmon, and Ringold upriver bright fall Chinook salmon. The Ringold program will likely be a direct Section 7 consultation with the U.S. Army Corps of Engineers. The NMFS General Counsel prefers using the Section 4(d) process for Endangered Species Act (ESA) coverage for the other five programs rather than a Section 10 incidental take permit. Section 4(d) has a more flexible timeline, provides a wider range of actions under which a program can operate, and provides a continuing form of coverage. Section 10 is very specific, it has an expiring form of coverage, and operation changes could result in re-consultation. However, the language in the HCP stipulates Section 10 for ESA coverage. The PUDs are talking to their respective attorneys to determine if Section 4(d) is a workable alternative.

- *Review Hatchery Monitoring and Evaluation Plan Objectives*: The HCP Hatchery Committees have been reviewing the objectives in the Hatchery Monitoring and Evaluation (M&E) Plan to verify they are consistent with the updates made to the hatchery M&E timeline. The review is complete. Language will be added to the plan, mostly in the section on straying. Hillman explained that stray rates for within population and among populations are related to ESA criteria defined by the Upper Columbia Technical Recovery Team (UCTRT) and included in the Upper Columbia Spring Chinook Salmon and Steelhead Recovery Plan. Brood year stray rate, on the other hand, is not described in the Recovery Plan or UCTRT document and therefore those documents did not provide a criterion for brood year stray rate. Consequently, the HCP Hatchery Committees are discussing whether they need to have a target for brood year stray rate. The current brood year stray rate target in the Hatchery M&E Plan is 5%. There is no literature supporting a specific brood year stray rate target; however, some literature indicates stray rates of natural-origin fish can range anywhere from 1 to 100% depending on what spawning aggregate is considered. Hillman noted that changes can be made to programs that could affect the stray rates; however, complete brood year returns have to be reported years after any changes because fish from those brood years have not yet returned, so this is always being evaluated retrospectively. The HCP Hatchery Committees will continue to measure and evaluate a target for brood year stray rates in light of other metrics. The genetics component is also still under review. Kirk Truscott asked how the HCP Hatchery Committees can make changes if there is no target to apply it against. Tonseth said it comes down to accountability.
- *Methow Steelhead Gene Flow:* The Wells HCP Hatchery Committee continued their discussion on steelhead gene flow in the Methow River basin. The Wells HCP Hatchery Committee is working toward a proportionate natural influence (PNI) target of 0.67 or greater for in-basin. Depending on steelhead escapement levels, a basin-wide PNI can be achieved by setting percent hatchery-origin spawners (pHOS) targets for specific areas (i.e., some areas have low pHOS and others have high or fluctuating pHOS, so long as PNI can be achieved basin-wide).

Korth asked what a low pHOS is, and Tonseth said 0.25. Hillman added that the pHOS in the conservation zone would be divided between programs such that conservation programs would have a pHOS target of 0.20 and the safety-net program would have a pHOS target of 0.05. Tonseth clarified this is for run escapements larger than 500 fish. He also added this is modeled similarly to Methow spring Chinook salmon. Hillman said discussions are ongoing.

- *Hatcheries and Life Cycle Modeling*: The NOAA Northwest Fisheries Science Center is modeling effects of hatchery programs on the Wenatchee spring Chinook salmon life cycle. Hillman invited the senior modeler, Jeff Jorgensen, to present these studies to the HCP Hatchery Committees during their meeting on August 16, 2017. Hillman suggested the HCP Coordinating Committees also attend the presentation. Kristi Geris will coordinate with Hillman and Sarah Montgomery to obtain meeting and WebEx information for Jorgensen's presentation to the HCP Hatchery Committees, which Geris will distribute to the HCP Coordinating Committees. *(Note: this presentation has been postponed to the HCP Hatchery Committees meeting on September 20, 2017.)*
- *Draft Hatchery M&E Annual report*: The HCP Hatchery Committees are currently reviewing the Draft 2016 Chelan PUD and Grant PUD Hatchery M&E Annual Report. Comments are due by July 15, 2017.
- *Next Steps*: The next meeting of the HCP Hatchery Committees will be on July 19, 2017.

III. Chelan PUD

A. Tumwater Dam Pacific Lamprey Passage Feasibility Study Progress Update (Lance Keller)

Lance Keller said Jim Craig requested that Chelan PUD provide an update on the Tumwater Dam Pacific Lamprey Passage Feasibility Study; however, Tracy Hillman covered this under the HCP Hatchery Committees update. Keller asked Craig if he had further questions at this time, and Craig said Hillman's update was adequate.

B. Rocky Reach Large Unit Repair Update (Lance Keller)

Lance Keller said Rocky Reach Dam has four large turbine units, C8, C9, C10, and C11, which are the northern-most units and were built in 1961. Keller said in 2013, one unit (C10) started leaking oil and metal particles were found in an oil strainer. He said mechanic crews investigated this and discovered the stainless steel rod that delivers oil to the servo motor was machined too thin and had developed a hairline crack. He said Chelan PUD determined this crack could lead to catastrophic failure and because all large units were designed similarly, Chelan PUD decided to take the four large units out of service. Keller said Chelan PUD then worked with the Rocky Reach HCP Coordinating Committee and Bryan Nordlund and ultimately welded blocks to fix the blades on the large units at a specific angle, which was selected to be the most hydraulically efficient (and best for fish passage) at full turbine flow.

Keller said Chelan PUD last provided a Rocky Reach large unit repair update to the HCP Coordinating Committees in 2014 that included the following timeline for repairing the units assuming no further issues developed:

Schedule for Rocky Reach Large Unit Repair, 2014

Turbine Unit	Return to Service
C8	December 2017
C9	October 2016
C10	December 2020
C11	November 2019

Keller said after providing this timeline during the HCP Coordinating Committees meeting on May 24, 2016, Chelan PUD notified the HCP Coordinating Committees that cracks were identified in the wheels of the bridge crane required to hoist the turbines for repair. He recalled that the repair of the bridge crane was fast tracked internally by making an emergency declaration and is scheduled to be back in service in 2017. He said with the bridge crane back in service this year, the updated timeline for repairing the large units is as follows:

Schedule for Rocky Reach Large Unit Repair, 2017

Turbine Unit	Return to Service
C8	Fourth Quarter 2017
C9	First Quarter 2019
C10	First Quarter 2020
C11	First Quarter 2021

Keller noted that the return-to-service date for C11 is the same year Chelan PUD will conduct the HCP 10-year check-in survival study for Rocky Reach Dam. He said if the unit repairs cannot be completed on schedule, Chelan PUD determined C11 is the preferred unit to be offline during a survival study. He explained that given C11 is the northern-most unit, being offline will not cause a shift in flow nor provide a calm, central area for predators to stage in the immediate tailrace.

Jim Craig asked if the servo rods will be completely replaced, and Keller said yes. John Ferguson said with C8 scheduled to be back in service this fall, he suggested that Chelan PUD provide another Rocky Reach Dam large unit repair update during an HCP Coordinating Committees meeting in late-summer 2017. Keller agreed. Jeff Korth asked if the large units will remain in a fixed position once the new servo rods are installed. Keller said no, the units will be restored to their Kaplan configuration.

C. Rock Island Powerhouse 1 Maintenance Update (Lance Keller)

Lance Keller said he was unable to obtain a Rock Island Powerhouse 1 maintenance update in time for today's meeting; therefore, Chelan PUD will provide this update during the HCP Coordinating Committees conference call on July 25, 2017.

D. Spill Gate Change at Rock Island Dam (Lance Keller)

Lance Keller recalled providing an update during the HCP Coordinating Committees conference call on May 23, 2017, about the notification from May 18, 2017, that Rock Island Dam lost capability of operating automated spill gate 7. Keller said the issue with spill gate 7, coupled with two other spill gates being out of service, resulted in reduced capacity to respond to a significant flow event; therefore, two notch gates were converted back to full gate operation. He said this discussion resulted in an action item for Chelan PUD to explain the cause of losing the use of automated spill gates 7, 17, and 25 at Rock Island Dam, as well as the timeline for repairing the gates.

Keller explained that the spill gates at Rock Island Dam are suspended on large cables. He said on spill gate 7, one cable became unattached; therefore, when one end of the gate raised up, the other end did not, damaging the gate and guiderails. He said river flow needs to decrease in order to deploy divers for repairs. He said currently, spill gate 7 is jammed in place.

Keller said spill gates 17 and 25 are in a similar condition. He said spill gate 17, during operation, had the gear shaft twisted in half in the gear box, causing one end of the gate to raise and the other end not. He said again, the gate was damaged and the gear box needs to be replaced. He said replacement parts are 20 weeks out. Keller said after the spill gate 17 failure, mechanics observed the same cracks in spill gate 25 and removed that gate from service. Keller added, however, that spill gate 25 has not yet failed. Upon review it was also discovered that the gear box was undersized for the operation, and engineers are looking into replacement with a new gear box. He said Chelan PUD is hopeful the spill gates will be equipped with new gear boxes and back in service by spring 2018.

John Ferguson asked about the other automated spill gates. Keller said all other gates have been inspected and they are in good condition. He added that anytime a failure such as this occurs, Chelan PUD inspects all other similar structures.

Jeff Korth asked how the gates are replaced. Keller said the gates are removed in sections, and each section is held in place using a crane.

Kirk Truscott asked how often inspections are conducted on the spill gates, because there seems to be a trend of aging parts failing at the project. He said it may behoove Chelan PUD to inspect and replace parts before they fail. Keller agreed there have been some opportunities for better planning and to be more proactive. He added, however, it is still difficult with Rock Island Dam because once it is determined parts are at the end of their lifespan, repairs still take a long time because the parts are so old, typically a redesign is needed and parts need to be located.

Keller said Chelan PUD is hoping for a modern-day fix for the gear boxes, and have extra parts on hand for when the others gates show signs of possible failure.

IV. Douglas PUD

A. Wells Hatchery Modernization Update (Tom Kahler)

Tom Kahler said the modernization is expected to be complete by the end of August 2017. John Ferguson suggested convening an HCP Coordinating Committees meeting at the dam after the modernization is complete, including a tour of the upgrades. Kahler agreed this is a good idea and noted there is a conference room at the hatchery.

B. Wells Dam Bypass Update (Tom Kahler)

Tom Kahler recalled that bypass barriers have been pulled from spill bay 6 nearly all spring 2017. He said river flow out of Grand Coulee Dam is diminishing and barriers will likely be reinstalled in spill bay 6 in the next week.

Kahler said the newly installed passive integrated transponder (PIT)-tag detection system in spill bay 2 is operating well. He said when spill is high, detections are low; however, when spill is low, detections increase. He noted there were a few orphan PIT tag detections on June 23, 2017.

Jeff Korth asked about total dissolved gas out of Chief Joseph Dam. Kahler said he does not have those data available at this time and the Douglas PUD biologist who monitors those data has been in the field for the past couple of weeks.

V. USFWS

A. Subyearling Spring Chinook Salmon Rearing in the Columbia River (Jim Craig)

Jim Craig said USFWS now has genetic data from their M&E program in the Entiat River basin which indicate that subyearling ESA-listed spring Chinook salmon are outmigrating, residing, and rearing in the mainstem Columbia River. Craig said to date, fisheries managers believed the only subyearling Chinook salmon rearing in the Columbia River were of the non-listed summer Chinook salmon variety. He added that subyearling spring Chinook salmon have a life history which is difficult to monitor. He said follow-up emails with Scott Carlon also revealed this life history trait in the Deschutes River (i.e., subyearling spring Chinook salmon leave the tributaries in the fall and overwinter in the mainstem Deschutes River).

Kirk Truscott asked if USFWS is PIT-tagging fish out of the Entiat River basin, and Craig said yes. Craig said he is concerned there is no juvenile monitoring during the fall when a lot of subyearlings emigrate from the Entiat River basin.

VI. WDFW

A. WDFW HCP Coordinating Committees Representation (Jeff Korth)

Jeff Korth said his last day before retirement is Friday, June 30, 2017. Korth said WDFW opened the position for Northcentral Regional Fish Program Manager. He said there were three applicants, including Chad Jackson. Korth said Jackson is the front runner, because of his extensive management experience. Korth said interviews for his replacement will be conducted July 13, 2017. He said WDFW has also been considering Mike Tonseth to serve as a WDFW HCP Coordinating Committees Alternate, particularly to keep close connections to HCP Hatchery Committees topics. *(Note: Tonseth is also the WDFW HCP Hatchery Committees Representative.)*

Korth requested to add Jackson and Tonseth to the HCP Coordinating Committees email distribution lists and provide them both with access to the HCP Coordinating Committees extranet site, because Jackson will potentially become the WDFW HCP Coordinating Committees Representative and Tonseth will likely be a new WDFW HCP Coordinating Committees Alternate. HCP Coordinating Committees representatives present agreed to Korth's request.

Kristi Geris will add Jackson and Tonseth to the HCP Coordinating Committees email distribution lists and request access to the HCP Coordinating Committees extranet site from Julene McGregor. *(Note: Geris added Jackson and Tonseth to the email lists and requested access to the extranet site following the meeting on June 27, 2017.)*

VII. HCP Administration

A. Jeff Korth Farewell (All)

The HCP Coordinating Committees and Tracy Hillman thanked Jeff Korth for his contributions to the HCPs and fisheries world and said it has been a pleasure to work with Korth over the years.

A farewell lunch was planned for Korth at McGlinn's at 12:00 p.m.

B. Next Meetings

The next scheduled HCP Coordinating Committees meeting is on July 25, 2017, to be held by conference call. *(Note: due to lack of agenda items, the HCP Coordinating Committees meeting on July 25, 2017, has been canceled.)*

The August 22, 2017, meeting will be held in-person at the Grant PUD Wenatchee Office in Wenatchee, Washington.

The September 26, 2017, meeting will be held by conference call or in-person at the Grant PUD Wenatchee Office in Wenatchee, Washington, as is yet to be determined.

VIII. List of Attachments

Attachment A List of Attendees

Attachment A
List of Attendees

Name	Organization
John Ferguson	Anchor QEA, LLC
Kristi Geris	Anchor QEA, LLC
Tracy Hillman	BioAnalysts
Lance Keller*	Chelan PUD
Tom Kahler*	Douglas PUD
Scott Carlon*†	National Marine Fisheries Service
Jim Craig*	U.S. Fish and Wildlife Service
Jeff Korth*	Washington Department of Fish and Wildlife
Mike Tonseth	Washington Department of Fish and Wildlife
Kirk Truscott*	Colville Confederated Tribes

Notes:
* Denotes HCP Coordinating Committees member or alternate
† Joined by phone

FINAL

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ANCHOR QEA

Memorandum

To: Wells, Rocky Reach, and Rock Island HCP Coordinating Committees

Date: September 27, 2017

From: John Ferguson, HCP Coordinating Committees Chairman

cc: Kristi Geris

Re: Final Minutes of the August 22, 2017, HCP Coordinating Committees Meeting

The Wells, Rocky Reach, and Rock Island Hydroelectric Projects Habitat Conservation Plan (HCP) Coordinating Committees met in-person at the Grant PUD Office in Wenatchee, Washington, on Tuesday August 22, 2017, from 10:00 a.m. to 12:15 p.m. Attendees are listed in Attachment A to these meeting minutes.

Action Item Summary

- Bob Rose will coordinate internally to develop and provide a Yakama Nation (YN) HCP Representation Designation document for distribution to the HCP Coordinating Committees (Item I-C). *(Note: Rose provided a designation letter [Attachment B] to Kristi Geris following the HCP Coordinating Committees meeting on August 22, 2017, which Geris distributed to the HCP Coordinating Committees on August 23, 2017.)*
- Kristi Geris will coordinate with Tracy Hillman (HCP Hatchery Committees Chairman) and Sarah Montgomery (HCP Hatchery Committees Support Staff) to obtain meeting and WebEx information for Jeff Jorgensen's (National Oceanic and Atmospheric Administration [NOAA] Northwest Fisheries Science Center) presentation to the HCP Hatchery Committees on September 20, 2017, on a life-cycle model for Wenatchee River spring Chinook salmon, which Geris will distribute to the HCP Coordinating Committees (Item I-C). *(Note: Montgomery provided the HCP Hatchery Committees September 20, 2017, agenda with this information to the HCP Coordinating Committees on September 19, 2017.)*
- Chelan PUD will provide a Rocky Reach Dam large unit repair update during an HCP Coordinating Committees meeting in late-summer 2017 (Item I-C).
- John Ferguson will provide the paper, "The evolutionary basis of premature migration in Pacific salmon highlights the utility of genomics for informing conservation," by Daniel Prince et al., to Kristi Geris and Tracy Hillman for distribution to the HCP Coordinating and Hatchery Committees (Item II-A). *(Note: Ferguson provided the paper [Attachment C] to Geris and Hillman following the HCP Coordinating Committees meeting on August 22, 2017, which Hillman distributed to the HCP Hatchery Committees that same day, and Geris distributed to the HCP Coordinating Committees on August 23, 2017.)*
- Tom Kahler will discuss internally the feasibility to implement a temporary 1.0-foot fishway-entrance head differential from 22:00 to 04:00 daily during September 2017 to improve Pacific

Lamprey passage at Wells Dam ("lamprey operations"), in 1- or 2-day blocks (Item IV-A). *(Note: Kahler confirmed Wells Dam can accommodate the 2-day block design for head differentials at the fishway entrances, as distributed to the HCP Coordinating Committees by Kristi Geris on August 25, 2017.)*

- Anchor QEA will coordinate with Douglas PUD and the Aquatic Settlement Work Group (Aquatic SWG) regarding the Wells HCP Coordinating Committee discussion and HCP Decision about the Aquatic SWG Lamprey Operations Statement of Agreement (SOA; Item IV-A). *(Note: the Aquatic SWG convened a conference call on August 28, 2017, to discuss the HCP Decision about the Aquatic SWG Lamprey Operations SOA.)*
- Chelan PUD will provide a Rock Island Dam Powerhouse 1 Turbine Units B1 to B4 Rehabilitation Fact Sheet to Kristi Geris for distribution to the HCP Coordinating Committees (Item V-A). *(Note: Lance Keller provided the rehabilitation work submittal [Attachment H] to Geris on August 23, 2017, which Geris distributed to the HCP Coordinating Committees that same day.)*
- Anchor QEA will contact Mackenzie Gavery (Postdoctoral Research Associate, University of Washington/NOAA Northwest Fisheries Science Center) regarding possibly presenting her epigenetics research during the HCP Coordinating Committees meeting on October 24, 2017 (Item VI-B). *(Note: Gavery confirmed she can present her research in-person during the HCP Coordinating Committees meeting on October 24, 2017.)*
- The HCP Coordinating Committees meeting on September 26, 2017, will be held by conference call (Item VI-B).

Decision Summary

- Wells HCP Coordinating Committee representatives present approved the Aquatic SWG Lamprey Operations SOA, contingent upon: 1) Aquatic SWG review of 2013 radio-telemetry data regarding changes in fishway approach and ladder passage behavior of Pacific Lamprey when the fishway entrances are operated at a head differential of 1.0 foot; 2) change in hours of operation to 22:00 to 04:00; 3) consideration of 1- or 2-day block operations (the Wells HCP Coordinating Committee prefers 2-day blocks); 4) Aquatic SWG in-season management of operations based on analysis of daily fish counts, including discontinuing operations if negative impacts from the operation are observed; and 5) a post-season report being provided to the Wells HCP Coordinating Committee, which reviews results of the operation based on fish counts (Item IV-A).
- Wells HCP Coordinating Committee representatives approved via email the Wells HCP Coordinating Committee SOA, "To implement temporary fishway 'lamprey operations' in alternating 3-day blocks with normal operations during the 2017 Pacific Lamprey migration at Wells Dam," as follows: Douglas PUD approved on August 30, 2017, and the National Marine

Fisheries Service (NMFS), U.S. Fish and Wildlife Service (USFWS), Washington Department of Fish and Wildlife (WDFW), the YN, and the Colville Confederated Tribes (CCT) approved on August 31, 2017 (Item IV-A).

Agreements

- There were no HCP Agreements discussed during today's meeting.

Review Items

- There are no items that are currently out for review.

Finalized Documents

- There are no documents that have been recently finalized.

I. Welcome

A. Review Agenda (John Ferguson)

John Ferguson welcomed the HCP Coordinating Committees and reviewed the agenda. Ferguson asked for any additions or changes to the agenda. The following revisions were requested:

- Tom Kahler explained that Douglas PUD did not develop the Aquatic SWG Lamprey Operations SOA and was not a party advocating the operations; rather, Douglas PUD approved requesting Wells HCP Coordinating Committee concurrence with the proposed modified operations at Wells Dam. Kahler said, therefore, he does not believe Douglas PUD should lead this HCP Decision Item. Patrick Verhey said WDFW will take the lead on this discussion.
- Ferguson added notification of a recent paper by Prince et al., which may be of interest to the HCP Hatchery and Coordinating Committees.

B. Meeting Minutes Approval (John Ferguson)

The HCP Coordinating Committees reviewed the revised draft June 27, 2017, meeting minutes. Kristi Geris said all comments and revisions received from members of the Committees were incorporated into the revised minutes and there were no outstanding edits or questions to discuss. HCP Coordinating Committees members present approved the June 27, 2017, meeting minutes, as revised. The YN abstained, because a YN representative was not present during the June 27, 2017, meeting.

C. Last Meeting Action Items (John Ferguson)

Action items from the HCP Coordinating Committees meeting on June 27, 2017, and follow-up discussions, were as follows. *(Note: italicized text corresponds to agenda items from the meeting on June 27, 2017):*

- *Tom Kahler will provide fish passage count data for winter months at Wells Dam for review regarding timing of winter maintenance at Wells Dam to Kristi Geris for distribution to the Coordinating Committees (Item I-B).*
  Kahler recalled the initial impetus for this action item was regarding potentially starting the annual winter maintenance at Wells Dam in mid-November before the Thanksgiving holiday, rather than late-November or early December (in the interest of accommodating time off associated with the holiday season and avoiding freezing temperatures). He said this year, maintenance crews determined it is not feasible to start the necessary work before Thanksgiving; therefore, Kahler suggested removing this action item for now and revisiting it later, if needed. *(Note: Kahler later clarified that the current schedule is to begin winter maintenance starting the week of November 27, 2017, and it seems the first time this topic may resurface is in 2019, when the Thanksgiving holiday falls on the last week in November.)*
- *Chelan PUD will provide the Final 2016 Rocky Reach Juvenile Fish Bypass System Report to Kristi Geris for distribution to the Coordinating Committees (Item I-B).*
  Lance Keller provided the final report to Geris on June 28, 2017, which Geris distributed to the HCP Coordinating Committees that same day.
- *Anchor QEA will contact Mackenzie Gavery regarding possibly presenting her epigenetics research to the HCP Coordinating Committees during a future meeting (Item I-B).*
  Anchor QEA contacted Gavery, who indicated she is available to provide her presentation during the HCP Coordinating Committees meetings on September 26, October 24, or November 28, 2017. This will be further discussed during today's meeting.
- *Bob Rose will coordinate internally to develop and provide a YN HCP Representation Designation document for distribution to the HCP Coordinating Committees (Item I-B).*
  Rose said a designation letter was provided to the Priest Rapids Coordinating Committee and he will contact Paul Ward (YN) to obtain a letter for the HCP Coordinating Committees. This action item will be carried forward. *(Note: Rose provided a designation letter [Attachment B] to Kristi Geris following the HCP Coordinating Committees meeting on August 22, 2017, which Geris distributed to the HCP Coordinating Committees on August 23, 2017.)*

- *Kristi Geris will coordinate with Tracy Hillman and Sarah Montgomery to obtain meeting and WebEx information for Jeff Jorgensen's presentation to the HCP Hatchery Committees on August 16, 2017, on a life-cycle model for Wenatchee River spring Chinook salmon, which Geris will distribute to the HCP Coordinating Committees (Item II-A).*
  This presentation has been postponed until the HCP Hatchery Committees meeting on September 20, 2017. This action item will be carried forward.
- *Chelan PUD will provide a Rocky Reach Dam large unit repair update during an HCP Coordinating Committees meeting in late-summer 2017 (Item III-B).*
  This action item will be carried forward.
- *Chelan PUD will provide a Rock Island Dam Powerhouse 1 maintenance update during the HCP Coordinating Committees conference call on July 25, 2017 (Item III-C).*
  This will be discussed during today's meeting.
- *Kristi Geris will add Chad Jackson, potentially the new WDFW HCP Coordinating Committees Representative, and Mike Tonseth, likely a new WDFW HCP Coordinating Committees Alternate, to the HCP Coordinating Committees email distribution lists and request access to the HCP Coordinating Committees extranet site from Julene McGregor (Douglas PUD Information Systems Staff; Item VI-A).*
  Geris added Jackson and Tonseth to the email lists and requested access to the extranet site following the meeting on June 27, 2017.
- *The HCP Coordinating Committees meeting on July 25, 2017, will be held by conference call (Item VII B).*
  Due to lack of agenda items, the HCP Coordinating Committees meeting on July 25, 2017, was canceled.

II. HCP Tributary and Hatchery Committees Update

A. HCP Tributary and Hatchery Committees Update (Tracy Hillman)

Tracy Hillman reported that the HCP Tributary Committees did not meet in August 2017; however, he updated the HCP Coordinating Committees on select actions and discussions that occurred during the HCP Tributary Committees meeting on July 13, 2017, as follows:

- *Beaver Fever: Restoring Ecosystem Function Project*: The Rock Island HCP Tributary Committee received a budget amendment request from Trout Unlimited requesting to use $10,000 under Construction and Permitting to purchase a hydraulic post driver to install beaver-dam analogs. The request was denied because equipment purchased by a project sponsor with Plan Species Account funds becomes the property of the Committee. The HCP Tributary Committees prefer not to get involved in equipment storage, maintenance, and liability. Hillman said one exception is when the Wells HCP Tributary Committee purchased and stored piezometers, which are easy to store and have little to no risk for injury. He said the HCP Tributary Committees reviewed four budget amendment requests during the meeting on July 13, 2017, and this was the only request that was denied.

- *Clear Creek Fish Passage and Instream Flow Enhancement Project*: Hillman said this budget amendment request was approved in August 2017. The Rocky Reach HCP Tributary Committee received a scope change and budget amendment request from Trout Unlimited to add activities to the deliverables and for an additional $77,174.40 to complete the project. Hillman said the sponsor is helping facilitate water supply system upgrades to the Thousand Trails Leavenworth campground resort, which currently draws water from Clear Creek to supply irrigation and potable water to the resort. He said the work involves drilling a domestic well, which requires a lot of permitting. He said the sponsor has already invested about the same amount of money that is being requested. He noted that budget amendment requests typically involve moving money from one line item to another, and do not usually involve requesting more money; however, the request was approved because the upgrades will provide a lot of benefit, notably to two Endangered Species Act (ESA)-listed salmonids. He said this project was originally a Small Projects Program Proposal; it is now a General Salmon Habitat Program Proposal, with a total Rocky Reach HCP Tributary Committee contribution of $146,674.40. Jim Craig asked about the flow through Clear Creek in this area, and Hillman said he did not know the base flow, but the project would increase base flows by about 0.5 cubic feet per second. Hillman said the sponsor also received funding from the Upper Columbia Salmon Recovery Board to remove the existing water diversion structure.
- *Poison Canyon Restoration Project*: Hillman recalled this Small Projects Program Proposal, which was submitted to the Rock Island HCP Tributary Committee in June 2017 from the Chelan County Natural Resources Department (CCNRD). The purpose of the project was to aggrade incised reaches within Poison Canyon by installing wood jams to improve instream flows and water quality. Poison Canyon is a tributary in the Mission Creek watershed. The original proposal was declined because the project was overly engineered and too expensive. CCNRD resubmitted the application, which addressed the Committees' concerns and reduced costs by almost half. The total cost of the project is $37,918, the sponsor requested $21,600 from HCP Tributary Funds, and the Rock Island HCP Tributary Committee approved the request.
- *Cottonwood Bridge Removal Project*: The Rocky Reach HCP Tributary Committee received a Small Projects Program application from Chelan-Douglas Land Trust to remove an illegally built bridge. The funding would be used to remove the steel and creosoted railroad ties that make up the Cottonwood Bridge; however, would not include removing the abutments. The total cost of the project is $95,000, the sponsor requested $21,000 from HCP Tributary Funds, and the Rocky Reach HCP Tributary Committee approved the request. Removal of the bridge

is the beginning of a restoration effort for floodplain enhancement on the Cottonwood property located adjacent to the Entiat River.

- *M2 WDFW Flow Connection Project*: Hillman noted that "M2" represents the middle reach of the Methow River. He said the purpose of this project is to remove a small levee, which blocks off floodplain habitat, located at river mile 46.8 on the Methow River. The total cost of the project is $78,828, the sponsor requested $11,824 from HCP Tributary Funds, and the Wells HCP Tributary Committee approved the request. Hillman said most of the affected land is owned by WDFW. In order for the adjacent landowner to support the project, the sponsor will install a fence between the WDFW property and the adjacent landowner.
- *M2 Mid-Sugar Acquisition Project*: The purpose of this project is to acquire 17.3 acres of riparian and floodplain habitat including about 1,300 feet of stream bank and 550 feet of side channel near river mile 42.2 on the Methow River. The total cost of the project is $291,268, the sponsor requested $43,690 from HCP Tributary Funds, and the Wells HCP Tributary Committee approved the request.
- *Piscine Passage Design for Brush and Minnow Creeks Project*: Cascade Columbia Fisheries Enhancement Group (CCFEG) requested funding to produce designs and submit permits for projects that will restore fish passage and connectivity within Minnow and Brush creeks, tributaries to the Chiwawa River. The total cost of the project is $162,500, the sponsor requested $52,500 from HCP Tributary Funds, and the HCP Tributary Committees elected not to fund this project, because: 1) Chinook salmon are only present in the lower 200 meters of Brush Creek; and 2) the Brush Creek culvert is about 1 mile upstream of the confluence with the Chiwawa River. Therefore, there is low biological benefit associated with the project. Additionally, beavers use the culverts for building beaver dams. Hillman noted that the USFWS will fund part of Minnow Creek design.
- *Methow Basin Barrier and Diversion Assessment Project*: CCFEG would like to complete a comprehensive and standardized assessment of all fish barriers in the Methow River basin, and prioritize barrier sites for restoration. The total cost of the project is $206,650, the sponsor requested $40,000 from HCP Tributary Funds, and the Wells HCP Tributary Committee approved the request. John Ferguson said he thought something like this would have already been completed in the Methow River basin. Hillman said there have been some piecemeal efforts; however, a comprehensive assessment has not yet been completed.

- *2017 General Salmon Habitat Program Project Summary:* Hillman projected the following summary table of 2017 General Salmon Habitat Program Projects:

Project Name	**Sponsor[1]**	**Total Cost**	**Request from HCP-TC**	**HCP-TC Contribution[2]**
M2 WDFW Flow Connection	MSRF	$78,828	$11,824	W: $11,824
M2 Mid-Sugar Acquisition	MSRF	$291,268	$43,690	W: $43,690
Piscine Passage Design for Brush and Minnow Creeks	CCFEG	$162,500	$52,500	$0
Methow Basin Barrier and Diversion Assessment	CCFEG	$206,650	$40,000	W: $40,000
	Total:	**$739,246**	**$148,014**	**$95,514**

[1] CCFEG = Cascade Columbia Fisheries Enhancement Group; MSRF = Methow Salmon Recovery Foundation.
[2] RI = Rock Island Plan Species Account; RR = Rocky Reach Plan Species Account; W = Wells Plan Species Account.

- *HCP Tributary Committees Logo*: The HCP Tributary Committees approved the following logo:

- *Next Steps*: The next meeting of the HCP Tributary Committees will be on September 14, 2017.

Hillman updated the HCP Coordinating Committees on the following actions and discussions that occurred during the HCP Hatchery Committees meeting on August 16, 2017:

- *Draft Chelan PUD Coho Salmon Mitigation SOA*: Chelan PUD submitted the Draft Chelan PUD Coho Salmon Mitigation SOA to the HCP Hatchery Committees for review. Recall, the HCP Coordinating Committees previously approved a 7 percent Coho salmon hatchery compensation rate. The SOA is available for a 30-day review, with comments due to Chelan PUD on September 14, 2017. Chelan PUD will request approval of this SOA during the HCP Hatchery Committees meeting on September 20, 2017.
- *Draft 2018 Chelan PUD Hatchery Monitoring and Evaluation (M&E) Implementation Plan*: The Rock Island and Rocky Reach HCP Hatchery Committees reviewed and approved the 2018 Chelan PUD Hatchery M&E Implementation Plan.
- *USFWS Bull Trout Consultation Update*: USFWS is working on the Methow steelhead consultation and plans to write a coverage memorandum similar to the one completed for spring Chinook salmon. USFWS is also working on finalizing the Biological Opinion for the Wenatchee subbasin programs.

- *NMFS Consultation Update*: NMFS is working on finalizing the proposed action for the unlisted programs in the upper Columbia River. Recall, Douglas and Chelan PUDs were discussing with their respective attorneys whether Section 4(d) was a workable alternative for ESA coverage rather than a Section 10 incidental take permit. The PUDs have now identified their preferred ESA pathway; Douglas PUD will use Section 10 coverage and Chelan PUD will use Section 4(d) coverage. Hillman said Ringold Hatchery, which is operated under the U.S. Army Corps of Engineers (USACE), is part of the consultation package. NMFS is initiating consultation with USACE, and Mike Tonseth added that coordination calls have now been arranged between WDFW, NMFS, USFWS, and USACE.
- *Wenatchee Spring Chinook Salmon Update*: WDFW reported that about 1,300 spring Chinook salmon have passed Tumwater Dam. WDFW surplused 302 male Chinook salmon, which were mostly jacks. The Chiwawa spring Chinook salmon program met its production obligation target; however, the natural-origin target was not met because: 1) there were few adult natural-origin fish and they were difficult to acquire; 2) the Chiwawa weir was not operational as early in the season as intended because of high flows; and 3) mechanical issues took the Chiwawa weir out of operation for 1 week at a critical point during the trapping effort. The program is four females short of its natural-origin target. Tonseth said four adult returns from the conservation program were used to make up the difference.
- *Chelan Falls Trap*: Chelan PUD reported that the Chelan Falls summer Chinook salmon program is 19 females short of its broodstock collection target. The trap is shutdown this week for habitat restoration work in the Chelan River. Trapping will continue next week and stop at the end of the month. Tonseth said, as of this morning, a decision was made to forego operating the trap for another week, and the program will acquire 19 females from the Entiat National Fish Hatchery.
- *Genetic Monitoring Update:* The HCP Hatchery Committees decided to ask the WDFW Genetics Laboratory to provide a short paper identifying appropriate objectives, questions, and analyses for evaluating the effects of hatchery programs on fish genetics.
- *Spring Chinook Salmon in the Methow Basin: Status of Adult Management and Translocation to the Chewuch River*: Hillman recalled the HCP Hatchery Committees' plan to translocate spring Chinook salmon from the Methow program to the Chewuch River to evaluate the efficacy of adult translocation as a surrogate to early-term imprinting in order to address homing fidelity issues in Methow spring Chinook salmon. WDFW reported that this year, the Methow spring Chinook salmon program may not meet the natural-origin target of 122 fish, which means the Chewuch translocation study will not occur this year.
- *M&E Plan for PUD Hatchery Programs 2017 Update*: The HCP Hatchery Committees have been updating their Hatchery M&E Plan. They are currently working on the genetics objectives, Non-target Taxa of Concern section, and Adaptive Management section. Over the next several

months, the HCP Hatchery Committees will identify important changes in each hatchery program. Hillman said in many cases there are data dating back to the 1970s; however, there have been changes throughout the years. He said, for example, for a given period of time there may have been no changes in operations (status quo), but during other periods, there may have been major changes in operations (e.g., change in release numbers). These changes will represent important interruptions in the data time series, and the HCP Hatchery Committees want to analyze these changes separately.

- *Next Steps*: The next meeting of the HCP Hatchery Committees will be on September 20, 2017, when Jeff Jorgensen will present on a life-cycle model for Wenatchee River spring Chinook salmon. Recall, Kristi Geris will provide the WebEx information to the HCP Coordinating Committees, for those interested in calling into the presentation.

B. Prince et al. Paper (John Ferguson)

John Ferguson notified the HCP Coordinating Committees that a paper was recently published, which could potentially have huge implications for spring Chinook salmon management in the basin. He said the HCP Hatchery Committees may also be interested in the paper. He said he will provide the paper, "The evolutionary basis of premature migration in Pacific salmon highlights the utility of genomics for informing conservation," by Daniel Prince et al., to Kristi Geris and Tracy Hillman for distribution to the HCP Coordinating and Hatchery Committees. *(Note: Ferguson provided the paper [Attachment C] to Geris and Hillman following the HCP Coordinating Committees meeting on August 22, 2017, which Hillman distributed to the HCP Hatchery Committees that same day, and Geris distributed to the HCP Coordinating Committees on August 23, 2017.)*

III. Douglas PUD

A. Wells Dam Bypass Operations Update (Tom Kahler)

Tom Kahler said, per the Douglas PUD 2017 Bypass Operating Plan, bypass operations at Wells Dam were terminated on August 19, 2017, at 24:00.

IV. WDFW

A. DECISION: Aquatic SWG Lamprey Operations SOA (Patrick Verhey)

John Ferguson said the Aquatic SWG has been discussing Pacific Lamprey passage at Wells Dam since January 2017 and during the last Aquatic SWG meeting on August 9, 2017, the Aquatic SWG agreed to request Wells HCP Coordinating Committee concurrence, "to implement a temporary 1.0-foot fishway-entrance head differential for Pacific Lamprey from 17:00 to 00:59 daily during the 2017 Pacific Lamprey migration at Wells Dam," as described in the Lamprey Operations SOA (approved August 16, 2017; Attachment D), which was distributed to the HCP Coordinating Committees by Kristi Geris on August 17, 2017.

Ferguson said the SOA, as written, is the same request approved by the Wells HCP Coordinating Committee in past years. He said, however, there was also some discussion about shifting the lamprey operations window. He said based on past radio-telemetry data, Ralph Lampman (YN) recommended 21:00 to 05:59 as the best timing for Pacific Lamprey passage with the least overlap with steelhead, and Chinook, coho, and sockeye salmon passage. Ferguson said Bob Rose suggested 22:00 to 03:59 as a possible operations window, based on existing Columbia and Snake rivers projects Pacific Lamprey passage data.

Patrick Verhey said results from past lamprey operations, as described in Attachment D, were inconclusive due to low sample sizes. He said this year, Pacific Lamprey passage numbers are much higher, which could provide more substantive results. He said considering this, USFWS initiated the discussion of implementing lamprey operations at Wells Dam in 2017, and WDFW drafted the SOA. Verhey said, Lampman and Rose then suggested different lamprey operations windows; however, considering the limited review time, the Aquatic SWG decided to submit the same request as approved in past years to increase the likelihood of Wells HCP Coordinating Committee approval this year. Verhey said perhaps after further analysis, implementing alternate time windows can be considered for future years.

Rose said he believes it is important to note that at all Columbia and Snake rivers dams, Pacific Lamprey passage times are the same. He said movement begins around sunset, is strong through about midnight, and then stops at 04:00. He said he understands Verhey's comment about conducting further analyses; however, he is uncertain about what a sufficient analysis would entail (i.e., to what degree of data are needed to present to the Wells HCP Coordinating Committee to approve moving the time window?). He said no one wants to slow progress, which is why the Aquatic SWG presented the same SOA as approved in past years, so as to at least have an agreement in place for 2017. Verhey agreed.

Tom Kahler said he is curious why everyone is convinced the lamprey operations described in the SOA will benefit Pacific Lamprey. He recalled, when Douglas PUD conducted Dual-Frequency Identification Sonar (DIDSON) and radio-telemetry studies at Wells Dam, these data indicated that fish swam more easily at the 1-foot versus 1.5-foot head differential; however, the DIDSON study could not provide information regarding Pacific Lamprey approach to the fishway entrances, which would require radio-telemetry or acoustic-telemetry studies to determine. Radio-telemetry studies indicate many fewer fish attempting to pass at the 1-foot head differential than at the 1.5-foot differential. He said if an operational change will be implemented at Wells Dam, he wants to be sure the Aquatic SWG and Wells HCP Coordinating Committee are sure the change is benefiting passage, not impeding it. He said currently, about 60 to 70 Pacific Lamprey have been counted passing Wells Dam this year. He said it seems these fish are passing the dam with no issues, and there is no evidence passage is being impeded.

Kirk Truscott said he has the same comments as Kahler. Truscott said he recalls the DIDSON study years had so few fish, the data were not significant. He said, however, the RT studies had a larger sample size, which indicated a roughly 16 percent improvement in passage once fish were in the fish ladder at a 1-foot head differential; however, there was about a 200 percent decrease in approaches under the 1.0-foot head differential. He said, therefore, while the lamprey operations may improve passage in the lower fish ladder, the overall numbers passing the dam do not improve as a whole.

Ferguson asked about the sample sizes. Truscott said he recalls about 35 fish approached at the 1.5-foot head differential and about 12 fish approached at the 1-foot head differential.

Rose said there are no substantive data, which is why he proposes installing more antennas at the fishway entrances at Wells Dam. He added that much larger projects have higher passage numbers, and he finds it hard to believe Pacific Lamprey have a hard time locating the entrances at Wells Dam. He said by the time Pacific Lamprey reach Wells Dam they are already tired, and he believes if there is a lower velocity passage route, fish will find it.

Ferguson asked for thoughts or concerns about lamprey operations effecting Plan species. Truscott said statistically, there was no significant difference in passage; however, steelhead and coho salmon overlap the most with the adult Pacific Lamprey migration. He said there was a consistent delay in steelhead passage; however, not significant. Ferguson asked how delay was measured. Kahler said delay was measured using passive integrated transponder (PIT) tag data only, because DIDSON was not capable of measuring delay. He said PIT-tag detections for steelhead migrating from Rocky Reach Dam to Wells Dam indicated travel time was a little slower.

Truscott said his biggest concern is not impacts to Plan species; rather, he wants to make sure a change in fish ladder passage will not hinder approach conditions for Pacific Lamprey. He suggested approving the Lamprey Operations SOA, contingent that the Aquatic SWG has reviewed and understands these radio-telemetry data. He asked if these data on differences in fishway approach were discussed within the Aquatic SWG, and Verhey said not to his recollection. Kahler expressed surprise at this, considering the Douglas PUD representatives on the Aquatic SWG stated they have attempted to discuss the differences in approach on multiple occasions, without generating any apparent interest from the rest of the SWG.

Ferguson asked about the reasoning behind a 17:00 start time, and Truscott noted this is a peak passage time for Chinook salmon. Kahler said, specifically, 16:00 to 17:00 is the second highest passage hour for Chinook salmon, based on Wells Dam window count data from 1998 to 2016.

Kahler distributed hard copies of Wells Dam count-window data for Pacific Lamprey, steelhead, and Chinook salmon (Attachment E), which Geris distributed electronically to the HCP Coordinating Committees on August 23, 2017. Kahler said for most salmonids, Wells Dam count window passage times from Pool 19 (lower fish ladder) to Pool 68 (near the fish ladder exit) is about 2 hours, plus about 28 minutes for gallery time. He said most salmonids travel back and forth between fishways before choosing a fishway to ascend, making it difficult to say when fish actually entered and exited the fish ladders. He said, however, in general it takes salmonids no more than 3 hours to travel from the fish ladder entrance to the count window.

Kahler said for Pacific Lamprey, based on the radio-telemetry studies, the maximum travel time was 38 hours, the minimum was 4 hours, and average was 5.5 hours. Truscott said if 17:00 is close to the peak passage time for Chinook salmon and it takes about 3 hours to travel through the Wells Dam fish ladders, those fish would be arriving to the entrances at about 14:00, which may be the reasoning behind a 17:00 start time for lamprey operations.

Truscott asked about lag time between changes in head differentials. Kahler said the fish pumps at Wells Dam are operated using a programmable logic controller, so changes happen automatically and the difference between head differentials is rapid (he guessed about 10 minutes).

Ferguson asked what the current average river flow is past Wells Dam during September, and Kahler said about 85,000 cubic feet per second.

Mike Tonseth asked about night lighting through the fish ladders. Kahler said the lights are always on in the fish ladders; however, there are no lights in the collection galleries. Tonseth noted that Pacific Lamprey are more darkness-oriented than Chinook salmon. Kahler said he wondered whether the ladder lighting could be set on a cycle, and he said this has never been implemented.

Verhey asked the Wells HCP Coordinating Committee about considering a shift in the time period to later in the evening, so the end time would capture the end of the Pacific Lamprey passage period but not affect steelhead passage. Truscott suggested 22:00 for the start time and 04:00 for the end time to accommodate Chinook salmon and steelhead passage.

Keely Murdoch suggested implementing lamprey operations on alternate dates (i.e., block operations). She said this way, Pacific Lamprey passage can be monitored and evaluated with and without the modified head differential. Rose agreed and suggested implementing 1- or 2-day blocks and asked if this is feasible. Ferguson asked how these blocks would be evaluated. Rose suggested keeping it simple, such as a passage count difference. Jim Craig said there does not seem to be much of difference between implementing 1- versus 2-day blocks. Scott Carlon questioned whether 1 day is enough. Murdoch said the advantage of a 1-day block is it results in the most replicates. Verhey suggested 2-day blocks may result in more expression, in case fish are waiting for higher flow. Kahler said he will discuss internally the feasibility to implement a temporary 1.0-foot fishway-entrance head differential from 22:00 to 04:00 daily during September 2017 to improve Pacific Lamprey passage at Wells Dam (lamprey operations), in 1- or 2-day blocks. *(Note: Kahler confirmed Wells Dam can accommodate the 2-day block design for head differentials at the fishway entrances, as distributed to the HCP Coordinating Committees by Geris on August 25, 2017.)*

Wells HCP Coordinating Committee representatives present approved the Aquatic SWG Lamprey Operations SOA (Attachment D), contingent upon: 1) Aquatic SWG review of 2013 radio-telemetry data regarding changes in fishway approach and ladder passage behavior of Pacific Lamprey when the fishway entrances are operated at a head differential of 1.0 foot; 2) change in hours of operation to 22:00 to 04:00; 3) consideration of 1- or 2-day block operations (the Wells HCP Coordinating Committee prefers 2-day blocks); 4) Aquatic SWG in-season management of operations based on analysis of daily fish counts, including discontinuing operations if negative impacts from the operation are observed; and 5) a post-season report being provided to the Wells HCP Coordinating Committee, which reviews results of the operation based on fish counts.

Anchor QEA will coordinate with Douglas PUD and the Aquatic SWG regarding the Wells HCP Coordinating Committee discussion and HCP Decision about the Aquatic SWG Lamprey Operations SOA (Attachment D).

Note—
The Aquatic SWG convened a conference call on August 28, 2017, to discuss the HCP Decision about the Aquatic SWG Lamprey Operations SOA (Attachment D). After discussing the contingencies of approval, the Aquatic SWG agreed to all contingencies; however, modified implementing the lamprey operations in 2-day blocks to 3-day blocks. The Aquatic SWG Lamprey Operations SOA was updated to incorporate the Wells HCP Coordinating Committees' contingencies, including the 3-day blocks, and was approved by the Aquatic SWG on August 28, 2017 (Attachment F). Douglas PUD also drafted a Wells HCP Coordinating Committee SOA to formalize approval of the new Aquatic SWG SOA, which was distributed to the Wells HCP Coordinating Committee for email approval by Geris on August 30, 2017. Wells HCP Coordinating Committee representatives approved via email the Wells HCP Coordinating Committee SOA, "To implement temporary fishway 'lamprey operations' in alternating 3-day blocks with normal operations during the 2017 Pacific Lamprey migration at Wells Dam," (Attachment G) as follows: Douglas PUD approved on August 30, 2017, and NMFS, USFWS, WDFW, the YN, and the CCT approved on August 31, 2017.

V. Chelan PUD

A. Rock Island Powerhouse 1 Maintenance Update (Lance Keller)

Lance Keller recalled staff noticed cracks in the turbine blades of Units B1 to B4 of Powerhouse 1, which is the original powerhouse at Rock Island Dam. He said the cracked areas were fixed and the blades were determined to be crack-free; however, during follow-up inspections, staff discovered that additional cracks had formed. Keller said pieces of the blades were sent out for metallurgic analysis and results indicated the blades were at the end of their lifespan. He said Chelan PUD then conducted an in-depth analysis and decided on a rehabilitation option, which was vetted with the Rock Island HCP Coordinating Committee before Chelan PUD provided the recommendation to the Federal Energy Regulatory Commission. Keller said Chelan PUD requested and received bids for the rehabilitation work in December 2016, and a company named Andritz Hydro (based in Austria, with a location in the United States) provided a bid for completing all needed work before the 10-year check-in scheduled for Rock Island Dam in 2020.

Keller said Andritz Hydro recently conducted a finite metal analysis and identified parts which have a high probability of failing in less than 50 years, including: 1) rotor poles; 2) generator shaft; and 3) wicket gate body and stems. Keller said Units B1, B3, and B4, each have 20 bodies and stems per unit. He said previously, in Unit B2, mechanics had identified that 14 of 20 wicket gate stems were failing, which were repaired at the time of discovery. Keller said Chelan PUD had to request a contract amendment from the Board of Commissioners. He said these repairs are within the scope of the contract; however, they will cost more.

Kirk Truscott asked if these additional repairs have any ramifications to the schedule. Keller said because the failing parts were caught early enough, the repairs should not impact the schedule. He added, if failing parts are discovered in one unit, those parts are ordered for all units so waiting on these same parts will not be an issue in the future.

Mike Tonseth asked if Powerhouse 1 Units B1 to B4 are all offline now. Keller said yes, all units were taken offline immediately for safety. Tonseth asked if the resulting change in flow affected adult fish passage. Keller said yes, a change in adult fish passage has been observed, as passage through the left fish ladder had decreased (located closest to Powerhouse 1 Units B1 to B4) and an increase has been observed through the right and center fish ladders.

Patrick Verhey asked if replacing the turbine blades includes replacing the runners. Keller said yes, the turbine blades and runners are being rehabilitated to be as fish friendly as possible. He said the number of blades will be decreased as well. Truscott asked if the units will remain in a fixed position. Keller said yes, the rehabilitated will be a fixed blade configuration. He added that the fact sheet previously distributed to the HCP Coordinating Committees summarizes the changes quite well. He said he will provide the Rock Island Dam Powerhouse 1 Turbine Units B1 to B4 Rehabilitation Fact Sheet to Kristi Geris for distribution to the HCP Coordinating Committees. *(Note: Keller provided the rehabilitation work submittal [Attachment H] to Geris on August 23, 2017, which Geris distributed to the HCP Coordinating Committees that same day.)*

B. Rocky Reach and Rock Island Summer Spill (Lance Keller)

Lance Keller reviewed summer spill updates, as follows:

Rock Island Dam

Keller recalled, on May 26, 2017, summer spill was initiated at Rock Island Dam, shifting from a daily average spill target of 10 percent (spring spill) to 20 percent of the daily average river flow at Rock Island Dam. Keller said given the water year, Rock Island Dam was already spilling well above 10 percent at that time.

Keller said a Rock Island Dam end of summer spill notification was distributed to the HCP Coordinating Committees by John Ferguson on August 18, 2017. Keller recalled the criteria to shutdown summer spill includes: 1) Data Access in Real Time (DART) must have estimated that 95 percent of the juvenile subyearling Chinook salmon run has passed the project; and 2) daily subyearling Chinook salmon index counts at the juvenile bypass system must be 0.3 percent or less of the cumulative subyearling index total for any 3 out of 5 consecutive-day period. Keller said, as of August 18, 2017, the total cumulative subyearling Chinook salmon index count was more than 62,000 smolts, with an estimated passage of 99.4 percent of the total run having passed Rock Island Dam. He said in the previous week, counts had been below 0.3 percent of the total index. He said based on these data, Chelan PUD ended summer spill at Rock Island Dam on August 18, 2017, at 00:00, per the Rock Island Fish Spill Plan.

Rocky Reach Dam

Keller said on May 26, 2017, summer spill was initiated at Rocky Reach Dam, shifting to a daily average spill target of 9 percent of the daily average river flow at Rocky Reach Dam.

Keller said on July 30, 2017, about 1,200 juvenile subyearling Chinook salmon passed Rocky Reach Dam, and since that time, daily fish counts lingered in the 100s, and recently dwindled below 100. He said yesterday, on August 21, 2017, the daily subyearling Chinook salmon index count was 0.15 percent of the total index, which was the first time this season the index count was below 0.3 percent. He said currently, DART is estimating more than 99 percent of the juvenile subyearling Chinook salmon run has passed the project. He said Chelan PUD suspects criteria will be met to end summer spill within the next couple of days. *(Note: a Rocky Reach Dam end of summer spill notification was distributed to the HCP Coordinating Committees by Kristi Geris on August 25, 2017.)*

VI. HCP Administration

A. WDFW HCP Coordinating Committees Representation Designation Update (John Ferguson)

John Ferguson said a WDFW HCP Coordinating Committees representation designation letter (Attachment I) was distributed to the HCP Coordinating Committees by Kristi Geris on August 14, 2017. Ferguson said Chad Jackson is the new technical representative, Patrick Verhey is the new alternate, and Mike Tonseth is support staff.

B. Next Meetings

The next scheduled HCP Coordinating Committees meeting is on September 26, 2017, to be held by conference call.

John Ferguson recalled Anchor QEA's action item to contact Mackenzie Gavery regarding possibly presenting her epigenetics research during a future HCP Coordinating Committees meeting. HCP Coordinating Committees representatives present requested that Gavery present her research during the HCP Coordinating Committees meeting on October 24, 2017. Ferguson said Anchor QEA will contact Gavery with this request. *(Note: Gavery confirmed she can present her research in-person during the HCP Coordinating Committees meeting on October 24, 2017.)*

The October 24, 2017, meeting will be held in-person at the Grant PUD Wenatchee Office in Wenatchee, Washington.

The November 28, and December 26, 2017, meetings will be held by conference call or in-person at the Grant PUD Wenatchee Office in Wenatchee, Washington, as is yet to be determined.

VII. List of Attachments

Attachment A	List of Attendees
Attachment B	YN HCP Representation Designation Letter
Attachment C	*The evolutionary basis of premature migration in Pacific salmon highlights the utility of genomics for informing conservation*, Prince et al.
Attachment D	Aquatic SWG Lamprey Operations SOA (approved August 16, 2017)
Attachment E	Wells Dam Count Window Data for Pacific Lamprey, Steelhead, and Chinook Salmon
Attachment F	Aquatic SWG Lamprey Operations SOA (approved August 28, 2017)
Attachment G	Wells HCP Coordinating Committees Lamprey Operations SOA
Attachment H	Rock Island Dam Powerhouse 1 Turbine Units B1 to B4 Rehabilitation Work Submittal
Attachment I	WDFW HCP Coordinating Committees Representation Designation Letter

Attachment A
List of Attendees

Name	Organization
John Ferguson	Anchor QEA, LLC
Kristi Geris	Anchor QEA, LLC
Tracy Hillman	BioAnalysts
Lance Keller*	Chelan PUD
Tom Kahler*	Douglas PUD
Scott Carlon*	National Marine Fisheries Service
Jim Craig*	U.S. Fish and Wildlife Service
Patrick Verhey*	Washington Department of Fish and Wildlife
Mike Tonseth	Washington Department of Fish and Wildlife
Bob Rose*†	Yakama Nation
Keely Murdoch*	Yakama Nation
Kirk Truscott*	Colville Confederated Tribes

Notes:
* Denotes HCP Coordinating Committees member or alternate
† Joined by phone

Attachment B

MEMORANDUM

Yakama Nation Fisheries

Columbia River
Honor. Protect. Restore.

OFFICE

PHONE

FAX

EMAIL

WEB

August 24, 2017

John Ferguson Ph. D.
Chairman, HCP Coordinating Committees
ANCHOR QEA, LLC
720 Olive Way, Suite 1900
Seattle WA. 98101

RE: Change of Voting Representation – Mid Columbia HCP's

Dear John,

By this letter we notify the Mid-Columbia Coordinating Committees (including the Wells, Rocky Reach and Rock Island Coordinating Committees) of an important change in our representation on these Committees. Henceforth, Keely Murdoch will serve as our voting member and Bob Rose will become the alternate voting member. We have found it necessary to assign Bob a larger workload in the upcoming FCRPS NEPA process and must make this change for that reason.

Please notify the HCP Coordinating Committee members of this change in personnel. Thank You.

Sincerely,

Paul Ward, Manager

Yakama Nation Fisheries

Attachment C

EVOLUTIONARY GENETICS

The evolutionary basis of premature migration in Pacific salmon highlights the utility of genomics for informing conservation

Daniel J. Prince,[1,2] Sean M. O'Rourke,[1]* Tasha Q. Thompson,[1]* Omar A. Ali,[1] Hannah S. Lyman,[1] Ismail K. Saglam,[1,3] Thomas J. Hotaling,[4] Adrian P. Spidle,[5] Michael R. Miller[1,2]†

The delineation of conservation units (CUs) is a challenging issue that has profound implications for minimizing the loss of biodiversity and ecosystem services. CU delineation typically seeks to prioritize evolutionary significance, and genetic methods play a pivotal role in the delineation process by quantifying overall differentiation between populations. Although CUs that primarily reflect overall genetic differentiation do protect adaptive differences between distant populations, they do not necessarily protect adaptive variation within highly connected populations. Advances in genomic methodology facilitate the characterization of adaptive genetic variation, but the potential utility of this information for CU delineation is unclear. We use genomic methods to investigate the evolutionary basis of premature migration in Pacific salmon, a complex behavioral and physiological phenotype that exists within highly connected populations and has experienced severe declines. Strikingly, we find that premature migration is associated with the same single locus across multiple populations in each of two different species. Patterns of variation at this locus suggest that the premature migration alleles arose from a single evolutionary event within each species and were subsequently spread to distant populations through straying and positive selection. Our results reveal that complex adaptive variation can depend on rare mutational events at a single locus, demonstrate that CUs reflecting overall genetic differentiation can fail to protect evolutionarily significant variation that has substantial ecological and societal benefits, and suggest that a supplemental framework for protecting specific adaptive variation will sometimes be necessary to prevent the loss of significant biodiversity and ecosystem services.

INTRODUCTION

Invaluable economic, ecological, and cultural benefits are being lost worldwide as biodiversity decreases due to human actions (*1*–*3*). Legislation that provides a framework to protect unique species and population segments below the species level exists in many countries throughout the world (*4*, *5*). Protection is achieved by assessing the health of a defined conservation unit (CU), and if the unit is at risk, attempts are made to preserve/restore critical habitat and restrict stressors until the risk is eliminated. Assessing risk and developing a protection strategy is not possible without first establishing unit boundaries. Because the number of units that can be effectively managed is resource-limited (*6*), the delineation of units should be strategic and should prioritize evolutionary significance (*4*, *7*–*11*). Several criteria, such as genetic and ecological exchangeability (*10*), have been proposed for assessing evolutionary significance for CU delineation, but directly evaluating these criteria in natural populations is difficult (*5*).

Genetic methods play a pivotal role in the process of delineating CUs (*10*, *12*). To this end, genetic data from different regions of the genome are combined to produce measurements of overall genetic differentiation between populations. These measurements represent typical regions of the genome and serve as a proxy for evolutionary significance (*13*, *14*). However, because most genomic regions are primarily influenced by gene flow and genetic drift as opposed to selection, these measurements may fail to account for important adaptive differences between populations (*12*). Recent advances in genetic methodology facilitate the identification and evolutionary analysis of adaptively important loci (*15*–*22*) and provide an alternative way to assess evolutionary significance, but the utility of these loci for CU delineation is unclear and disputed (*12*, *23*–*27*).

Pacific salmon (*Oncorhynchus* spp.) provide a unique opportunity to investigate the application of genetic tools to the conservation of biodiversity below the species level (*4*, *6*, *28*–*30*). Despite extensive conservation efforts, Pacific salmon have been extirpated from almost 40% of their historical range in the contiguous United States, and many remaining populations have experienced marked declines and face increasing challenges from climate change (*31*–*35*). Reintroduction attempts of extirpated populations are largely unsuccessful because precise natal homing across highly heterogeneous environments has resulted in divergent selection and abundant local adaptation (*19*, *36*–*38*). Thus, maintaining existing stocks is critical for preserving the species themselves as well as the communities and ecosystems that rely on their presence (*39*). Genetic methods have been used extensively in delineating CUs in Pacific salmon [referred to as evolutionarily significant units (ESUs) or distinct population segments (DPSs) depending on the species] and, as a consequence of patterns of gene flow, have resulted in units that primarily reflect geography (*40*–*43*). Although current ESUs and DPSs certainly protect adaptive differences between distant populations, adaptations within highly connected populations are not necessarily protected (*10*, *34*). However, the evolutionary significance of these adaptations and the potential long-term consequences of not independently protecting them are poorly understood.

Perhaps the most recognized example of differential adaptation within highly connected populations of Pacific salmon is variation in adult migration timing (also called run timing) (*44*–*46*). In contrast

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to typical adult salmon that mature sexually before freshwater migration, premature migrating individuals have a complex behavioral and physiological adaptation that allows them to access distinct habitats, distributing ocean-derived nutrients higher into watersheds, and spawn earlier in the season (*46*). Because of their distinct migration time and high fat content (*47*), premature migrating populations also provide additional, more-coveted, and culturally important harvest opportunities (*48*). For example, indigenous peoples in the Klamath Basin in northern California celebrated the return of premature migrating salmon with ceremonies that progressed upriver with the salmon migration (*49*).

Premature migrating populations have suffered grossly disproportionate impacts from human actions, such as dam building, mining, and logging, because of their extended time in freshwater and reliance on headwater habitat (*14*, *34*, *40*, *42*, *46*, *50*, *51*). With few exceptions (for example, some interior Columbia Basin locations), genetic analyses find little differentiation between proximate premature and mature migrating populations (*13*, *52*–*59*), and as a result, they are generally grouped into the same ESU or DPS (*40*, *42*). Therefore, despite the extirpation or substantial decline of premature migrating populations, the ESUs or DPSs to which they belong usually retain relatively healthy mature migrating populations and thus have low extinction risk overall (*14*, *40*, *42*). Here, we investigate the genetic and evolutionary basis of premature migration to explore potential consequences of not independently protecting this beneficial adaptation as well as the utility of genomics for informing conservation.

RESULTS

Initial genomic analysis consistent with current steelhead DPS delineations

Dramatic examples of premature migration are observed in coastal (noninterior) populations of steelhead (anadromous rainbow trout; *Oncorhynchus mykiss*) and Chinook salmon (*Oncorhynchus tshawytscha*). In these populations, premature migrating individuals (called summer steelhead or spring Chinook) use receding spring flows during freshwater migration to reach upstream habitat before hostile summer conditions in the lower watershed, hold for several months in deep cool pools while their gametes mature, then spawn at similar times to mature migrating individuals that have just entered freshwater (*44*, *46*). We began our investigation by compiling a set of 148 steelhead samples from five coastal locations across four DPSs in California and Oregon (Fig. 1A). Four of the locations (Eel, New, Siletz, and North Umpqua) represent the few remaining watersheds with significant wild premature migrating populations. The fifth location, Scott, contains only mature migrating individuals. Our sampling focused as much as possible on individuals that could be confidently categorized as premature or mature migrating based on collection date and location (Fig. 1B and table S1).

To collect high-resolution genomic information from these samples, we prepared individually barcoded restriction site associated DNA (RAD) libraries, sequenced them using paired-end Illumina technology, and aligned the sequence reads to a recent draft of the rainbow trout genome (tables S1 and S2) (*60*). We then used a probabilistic framework to discover SNPs and genotype them in each individual (*61*). A total of 9,864,960 genomic positions were interrogated in at least 50% of individuals, and 615,958 SNPs (that is, segregating sites) were identified ($P < 10^{-6}$). Of these SNPs, 215,345 had one genotype posterior greater than 0.8 in at least 50% of individuals. Population structure characterization and genome-wide analyses in nonmodel organisms are typically carried out with far fewer SNPs (*62*). We conclude that the sequence data obtained are appropriate for genome-wide measurements and high-resolution analyses of specific genomic regions.

To characterize the genetic structure of these populations, we performed PCA and estimated pairwise F_{ST} using genome-wide genotype data (*63*). The first two PCs revealed four distinct groups corresponding to the four current DPSs (Fig. 1C). Siletz and North Umpqua, which are two different locations within the Oregon Coast DPS, did not break into distinct groups until PC6 (Fig. 1D), indicating relatively low genetic differentiation between distinct locations within a DPS. In all cases, individuals with different migration phenotypes from the same location were in the same group. The pairwise F_{ST} estimates also revealed strong genetic differentiation between locations but little differentiation between migration phenotypes from the same location (Fig. 1E). The mean pairwise F_{ST} between migration groups from the same location was 0.032 (range, 0.018 to 0.039; $n = 3$), whereas the mean between groups from different locations was 0.125 (range, 0.049 to 0.205; $n = 25$). The combination of this genetic structure and observations of hybridization between premature and mature migrating individuals (*53*) suggests higher rates of gene flow between different migration groups from the same location than between groups from different locations. Thus, as found in previous analyses, the overall genetic structure among steelhead populations is predominantly influenced by geography, as opposed to migration phenotype. We conclude that measurements of overall genetic differentiation from genome-wide SNP data are consistent with current steelhead DPS delineations.

Premature migrating steelhead explained by a single allelic evolutionary event at a single locus

To identify genomic loci associated with premature migration, we performed association mapping of migration category. We used a likelihood ratio test (*64*) with λ correction for population stratification (*65*) to compare 181,954 SNPs between migration categories in North Umpqua and found 14 SNPs that were significant (Bonferroni-corrected α level: $P < 0.05$). Strikingly, all of these SNPs were located within a 211,251–base pair (bp) region (568,978 to 780,229) on a single 1.95-Mb scaffold (Fig. 2A; fig. S1, A and B; and table S3). Furthermore, when this analysis was repeated with Eel individuals using 170,678 SNPs, we obtained a similar pattern of association (Fig. 2B; fig. S1, C and D; and table S3). The strongest associated SNPs in both sample locations were flanking two restriction sites approximately 50 kb apart and located just upstream and within a gene identified as *GREB1L* (Fig. 2C; see Discussion for more information on *GREB1L*). The strength of these associations was unexpected given the phenotypic complexity of premature migration and the relatively low number of samples analyzed. We conclude that the same single locus is strongly associated with migration phenotype in at least two DPSs.

To investigate the evolutionary history of this locus, we sequenced three amplicons, each of approximately 500 bp, from the *GREB1L* region in all individuals from all populations (Fig. 2C and tables S1, S4, and S5) and used these sequences to construct a haplotype tree based on parsimony (*66*). Strikingly, the tree contained two distinct monophyletic groups corresponding to migration phenotype (Fig. 2D). For 123 of 129 individuals, both haplotypes separated into the appropriate migration category clade. The remaining six individuals (four Siletz and two North Umpqua samples originally classified as mature migrating) had one haplotype in each migration category clade (Fig. 2D), suggesting heterozygosity at the causative polymorphism(s). Furthermore, although there was little differentiation within the mature migration clade, premature migration haplotypes from Siletz and North Umpqua were

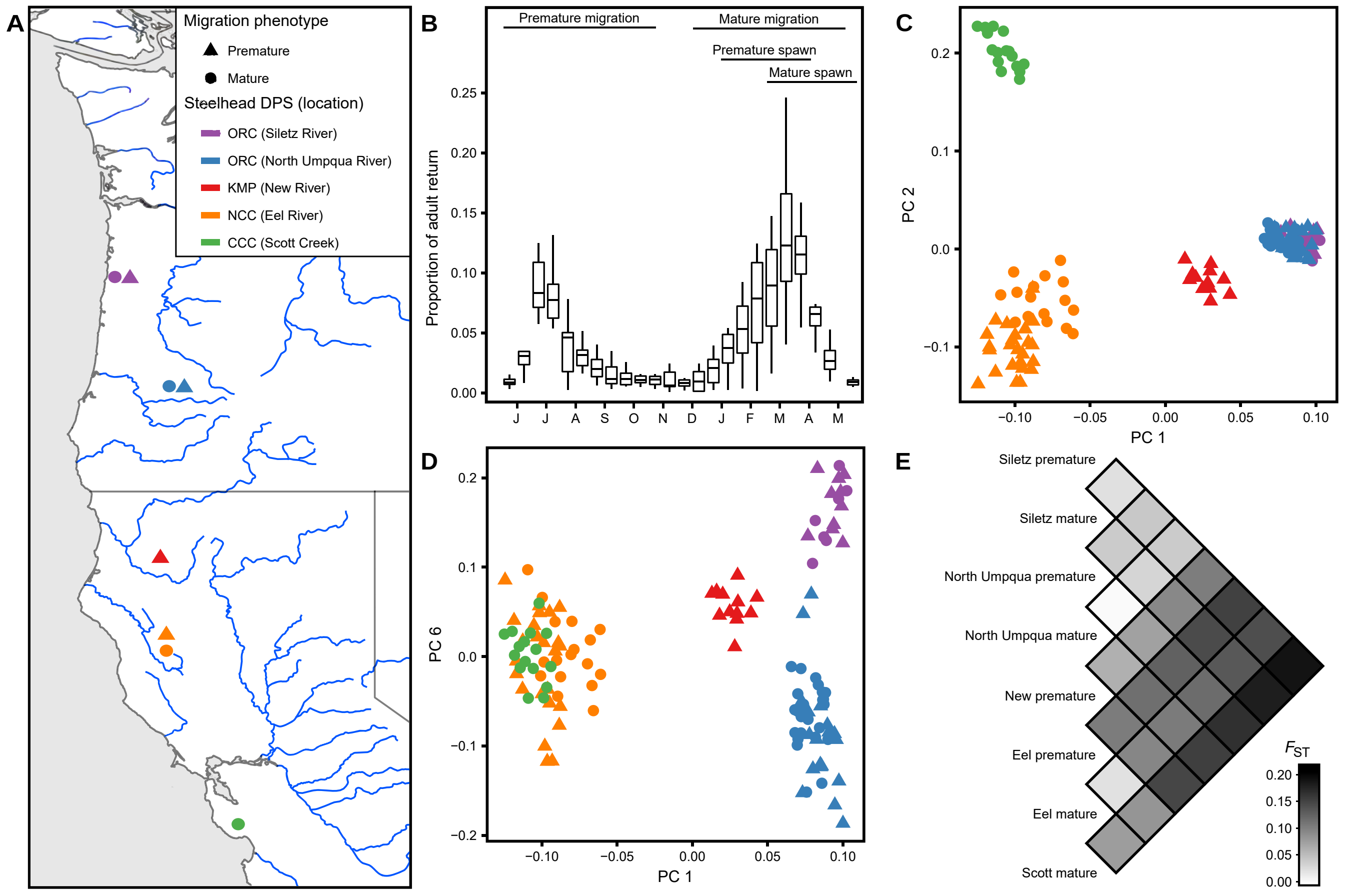

Fig. 1. Genetic structure of premature and mature migrating steelhead populations. (**A**) Map of steelhead sample locations and migration phenotypes; color indicates location, and shape indicates migration phenotype. (**B**) Bimonthly proportion of annual adult steelhead return over Winchester Dam on the North Umpqua River (2003 to 2013); horizontal bars depict migration and spawn timing of premature and mature migrating populations. (**C** and **D**) Principal component analysis (PCA) and (**E**) pairwise F_{ST} estimates using genome-wide single-nucleotide polymorphism (SNP) data.

more divergent from the mature migration clade than those from Eel and New (Fig. 2D; see Discussion for more information on heterozygotes and differentiation within the premature clade). The overall tree topology is inconsistent with premature migration alleles originating from independent evolutionary events in different locations because separate mutational events would be expected to occur on different haplotype backgrounds and result in premature migration alleles having a polyphyletic origin (*15*). We conclude that there is a nearly complete association between variation at this locus and migration category and that the premature migration alleles from all locations arose from a single evolutionary event.

To examine the evolutionary mechanisms leading to the dispersal of the premature migration allele as well as reconcile the difference between patterns of variation at the *GREB1L* locus and overall genetic structure, we summarized patterns of genetic variation using two estimators of θ ($4N\mu$). One estimator is based on average pairwise differences (θ_π) (*67*), and the other is based on the number of segregating sites (θ_S) (*68*). When genome-wide data were used, both estimators produced similar θ values for each migration category (Fig. 2E). The *GREB1L* region of mature migrating individuals also produced θ values similar to the genome-wide analysis. However, premature migrating individuals from North Umpqua had strikingly lower θ values (Fig. 2E) and a significantly skewed site frequency spectrum (SFS) (Tajima's $D = -2.08$; $P = 0.001$) (*69*) indicative of strong, recent positive selection in the *GREB1L* region. Premature migrating individuals from Eel also had reduced θ values in the *GREB1L* region (premature: $\theta_\pi/\text{kb} = 2.48$, $\theta_S/\text{kb} = 2.67$; mature: $\theta_\pi/\text{kb} = 3.59$, $\theta_S/\text{kb} = 4.00$), but the SFS was not significantly skewed, consistent with an older selection event. Although both demography and selection can reduce nucleotide diversity and skew the SFS, this pattern is specific to the *GREB1L* region as opposed to genome-wide, implicating selection as the cause. Furthermore, the combination of a stronger signature of selection and a more divergent sequence pattern in the northern premature migration haplotypes is consistent with a northward movement of the premature migration allele. We conclude that, upon entering new locations via straying, positive selection allowed the premature migration allele to persist despite ongoing hybridization with local mature migrating populations.

Premature migrating Chinook also explained by a single allelic evolutionary event in GREB1L region

To broaden our investigation into premature migration, we compiled a set of 250 Chinook samples from nine locations across five ESUs in California, Oregon, and Washington (Fig. 3A). Similar to steelhead, our sampling focused as much as possible on individuals that could be confidently categorized as premature or mature migrating based on collection time and location (table S6). We then prepared individually

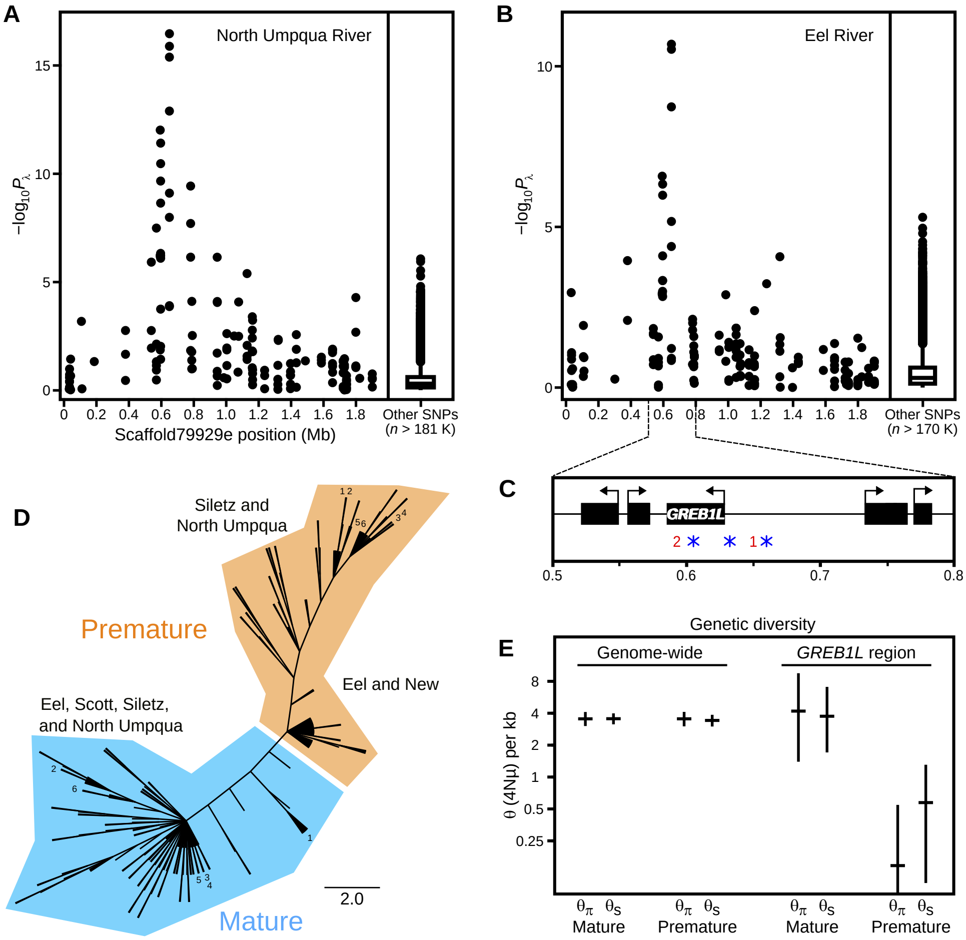

Fig. 2. Genetic and evolutionary basis of premature migration in steelhead. Association mapping of migration category in (**A**) North Umpqua River and (**B**) Eel River steelhead. (**C**) Gene annotation of region with strong association; red numbers indicate genomic positions of two restriction sites flanked by strongest associated SNPs, and blue asterisks indicate positions of amplicon sequencing. (**D**) Phylogenetic tree depicting maximum parsimony of phased amplicon sequences from all individuals; branch lengths, with the exception of terminal tips, reflect nucleotide differences between haplotypes; numbers identify individuals with one haplotype in each migration category clade. (**E**) Genome-wide and *GREB1L* region diversity estimates in North Umpqua for each migration category with 95% confidence intervals from coalescent simulations.

barcoded RAD libraries, sequenced them using paired-end Illumina technology, and aligned the sequence reads to the same rainbow trout reference assembly used above (tables S6 and S7). No reference genome is available for Chinook, and rainbow trout, which diverged from Chinook approximately 10 to 15 million years ago (*70*, *71*), is the closest relative with a draft genome assembly. With the methods described above, a total of 3,910,009 genomic positions were interrogated in at least 50% of individuals and 301,562 SNPs were identified ($P < 10^{-6}$). Of these SNPs, 55,797 had one genotype posterior greater than 0.8 in at least 50% of individuals. Although the alignment success was lower and subsequent SNP discovery and genotyping produced fewer SNPs compared to steelhead, the large number of SNPs discovered and genotyped should still be adequate for downstream analysis.

To characterize the genetic structure of these populations, we performed PCA and estimated pairwise F_{ST} using the genotype information described above. The first two PCs revealed four groups: the largest group contained all coastal ESUs, the second contained the two Puget Sound ESU locations, and the last two groups corresponded to the two locations within the Upper Klamath–Trinity Rivers ESU and were only differentiated by the second axis (Fig. 3B). In all cases, individuals from the same location but with different migration phenotypes were in the same group, and locations within groups became differentiated as additional PCs were examined. The mean pairwise F_{ST} between migration categories from the same location was 0.037 (range, 0.009 to 0.093; $n = 7$), and the mean between groups from different locations was 0.097 (range, 0.021 to 0.199; $n = 113$) (Fig. 3C). Thus, similar to what we found in steelhead, the overall genetic structure is strongly influenced by geography, as opposed to migration phenotype. We conclude that measurements of overall genetic differentiation from genome-wide SNP data are consistent with current Chinook ESUs.

To investigate the genetic architecture and evolutionary basis of premature migration in Chinook, we conducted association mapping with 114,036 SNPs using a generalized linear framework with covariate correction for population stratification (*65*, *72*). Strikingly, we again found a single significant peak of association (Bonferroni-corrected α level: $P < 0.05$) that contained five SNPs within 57,380 bp (537,741 to 595,121) in the same *GREB1L* region identified in steelhead (Fig. 3D and table S8). We next examined allele frequencies at these five SNPs and found a strong and consistent shift between all premature and mature migrating populations independent of location (Fig. 3E). Thus,

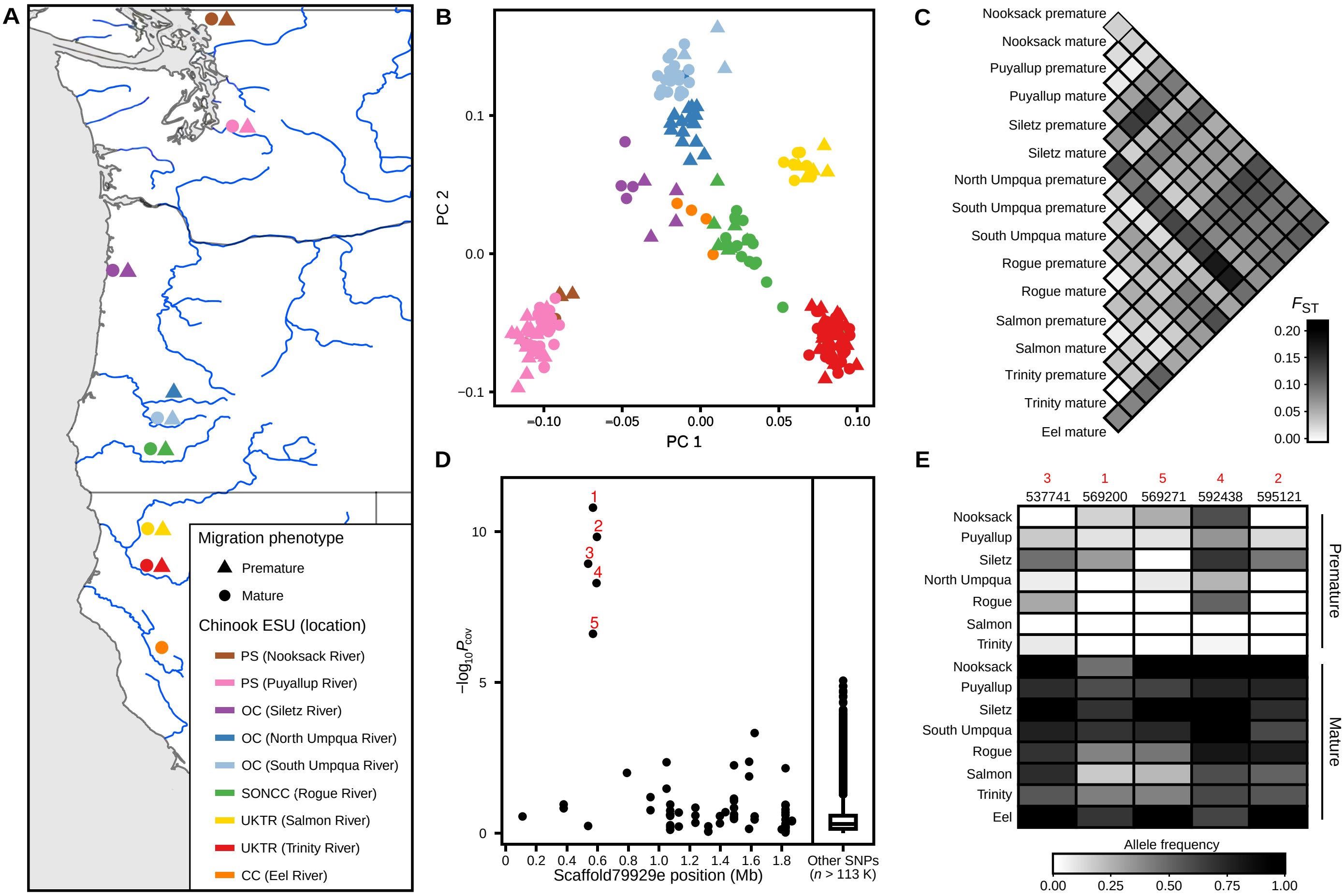

Fig. 3. Genetic and evolutionary basis of premature migration in Chinook. (**A**) Map of Chinook sample locations and migration phenotypes; color indicates location, and shape indicates migration category. (**B**) PCA and (**C**) pairwise F_{ST} estimates using genome-wide SNP data. (**D**) Association mapping of migration category in Chinook; red numbers indicate significant SNPs. (**E**) Allele frequency shift at significant SNPs between premature and mature migrating populations. Black numbers indicate SNP position on scaffold79929e.

despite having a lower genomic resolution and fewer samples per location, these results demonstrate that the *GREB1L* region is also the primary locus associated with premature migration in Chinook. Furthermore, the shift of allele frequencies in the same direction between premature and mature migrating populations across all locations is inconsistent with the premature migration alleles in Chinook being a product of multiple independent evolutionary events. Although the genomic region was consistent between species, the SNPs identified in Chinook were distinct from those in steelhead (tables S3 and S8). That is, the premature and mature migrating Chinook haplotypes are more similar to each other than to either of the steelhead haplotypes and vice versa, suggesting independent allelic evolutionary events in each species. We conclude that the same evolutionary mechanism used in steelhead, with a single allelic evolutionary event in the *GREB1L* region that subsequently spread to different locations, also explains premature migration in Chinook.

DISCUSSION

Our association analysis across multiple populations in each of two different species, as well as an independent analysis on Klickitat River steelhead (*73*), suggests that either the function or the regulation of *GREB1L* is modified in premature migrating individuals. Both *GREB1L* and its paralog *GREB1* are ubiquitous in and highly conserved across vertebrates. Although *GREB1* is known to encode a nuclear hormone receptor coactivator (*74*) and has been implicated in diverse biological processes (*75–80*), relatively little is known about *GREB1L*. However, a recent study found that *GREB1L* is differentially regulated by feeding and fasting in AgRP (agouti-related protein) neurons of the hypothalamic arcuate nucleus in mice (*81*). The strength of the associations, as well as the known role of AgRP neurons in modulating diverse behavior and metabolic processes such as foraging and fat storage (*81*, *82*), provides evidence for and an explanation of how the complex premature migration phenotype could be controlled by this single locus. An alternative explanation is that the *GREB1L* region only influences a subset of the phenotypic components of premature migration and that other important loci were not identified because of technical or biological reasons. Regardless, our results indicate that an appropriate genotype at this locus is necessary for successful premature migration.

Given that premature migration alleles at this locus are critical for premature migration, our results on the evolutionary history of these alleles provide important insights into the potential for premature migration to persist during declines and reemerge if lost. Finding

Attachment C

that the same locus is associated with premature migration in both steelhead and Chinook indicates that genetic mechanisms capable of producing this phenotype are very limited. Although some loci can be predisposed to functionally equivalent mutations in relatively short evolutionary time scales (*83*, *84*), this does not appear to be the case with the *GREB1L* region. In predisposed loci, several independent mutations with the same phenotypic effect are observed in different populations of a single species (*83*, *84*). In contrast, our survey of many populations revealed only one evolutionary event that produced a premature migration allele in each species despite the 10 to 15 million years since they diverged (*70*, *71*). Regardless of whether or not additional allelic evolutionary events have occurred (for example, in the interior Columbia Basin), our finding that a broad array of populations shares alleles from a single evolutionary event suggests that mutational events that create new premature migration alleles are rare. Thus, if current premature migration alleles are lost, new premature migration alleles and the phenotype they promote cannot be expected to reevolve in time frames relevant to conservation planning (for example, tens to hundreds of years).

The rarity of mutational events that produce premature migration alleles at this locus highlights the importance of existing premature migration alleles. Unlike alleles with a small effect on phenotype, alleles with a large effect on phenotype are expected to be rapidly lost from a population when there is strong selection against the phenotype they promote (*85*). An important exception to this is when an allele is recessive and therefore masked in the heterozygous state (*15*, *85*). Thus, the inheritance pattern of the *GREB1L* locus has critical implications for the persistence of premature migration alleles during declines of the premature migration phenotype. Although our sampling focused on migration peaks (Fig. 1B) and was not designed to investigate the migration phenotype of heterozygotes, the recently published Klickitat data (*73*) included samples collected outside the migration peaks. Strikingly, a reanalysis of these data suggests that the same haplotype is associated with premature migration (Fig. 4A and table S3) and that heterozygotes display an intermediate phenotype (Fig. 4B and fig. S2). This explains the high frequency of heterozygotes in our Siletz mature migrating samples (4 of 10), which were collected before the peak of mature migration and far upstream in the watershed (table S1). Thus, the premature migration allele does not appear to be masked in the heterozygous state and cannot be expected to be maintained as standing variation in populations that lack the premature migration phenotype.

Two additional lines of evidence suggest that the premature migration allele will not be maintained as standing variation in mature migrating populations. First, the combination of the strong bimodal phenotypic distribution that is usually observed (for example, Fig. 1B) and the ecology of premature migration (see Introduction) (*44*, *46*) suggests a general pattern of disruptive selection against individuals with an intermediate phenotype (for example, heterozygotes). Although heterozygotes are expected to be produced by hybridization in locations where both migration categories exist (for example, we observed two heterozygotes in North Umpqua, which has the lowest genetic differentiation between migration groups; Fig. 1E), their presence does not suggest that the premature migration allele will be maintained by mature migrating populations. Second, the genetic differentiation between premature migration haplotypes from California and Oregon steelhead (Fig. 2D) indicates that, unlike mature migration alleles, premature migration alleles are not freely moving across this area. This result reveals that mature migrating populations do not act as an influential source or conduit of premature migration alleles despite being abundant and broadly distributed. Therefore, premature migrating populations appear ultimately necessary for both the maintenance and spread of these alleles.

Previously, studies revealing that overall genetic structure among populations of steelhead and Chinook primarily reflects geography (as opposed to migration phenotype) suggested that premature migration evolved independently in many locations within each species (*13*, *54*, *59*). This implied that premature migration is evolutionarily replaceable over time frames relevant to conservation planning (*13*) and is not an important component in the evolutionary legacy of the species (*14*). Although these interpretations were logical given the data available at that time, our results demonstrate that the evolution was not independent in each location but instead relied on preexisting genetic variation. Thus, although evolving the premature migration phenotype in new locations could be rapid if robust premature migrating populations are present in proximate locations, the widespread extirpation and decline of premature migrating populations (*14*, *34*, *40*, *42*, *46*, *50*, *51*) has greatly diminished the potential restoration and expansion (for example, into new habitats that become available with climate

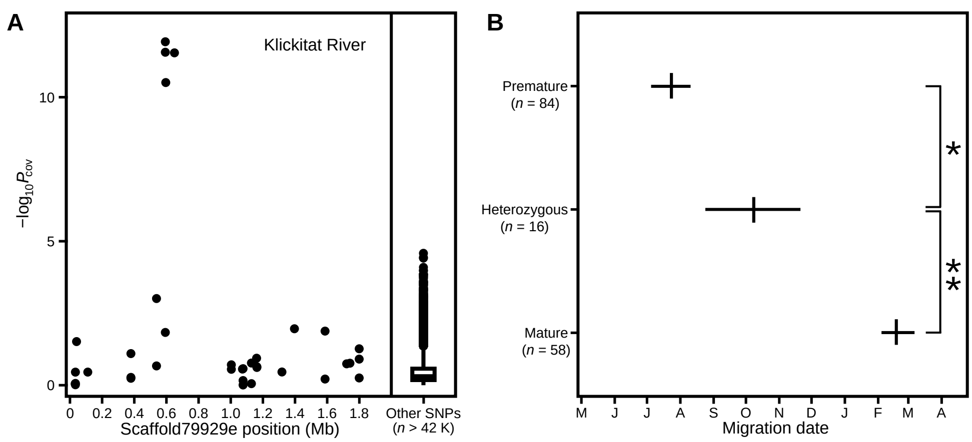

Fig. 4. Inheritance pattern of *GREB1L* locus. (**A**) Association mapping of migration date in Klickitat River steelhead. (**B**) Mean migration date and 95% confidence interval of the mean in Klickitat River steelhead categorized as homozygous for the premature migration allele, heterozygous, and homozygous mature. $*P = 0.00574$; $**P = 2.95 \times 10^{-5}$.

change) of premature migration across at least a substantial proportion of the range for both species (*19*).

Future work characterizing the distribution of premature migration alleles would improve our understanding of the extent to which the potential restoration and expansion of the premature migration phenotype has been diminished. For example, testing for the presence of premature migration alleles in locations where the phenotype has recently been extirpated would reveal how quickly these alleles are lost and potential restoration options. One possibility is that some heterozygotes still exist in these locations and could be used to restore the premature migration phenotype. The alternative is that the premature migration allele has already been lost and restoration of the phenotype would require introducing the allele from an outside population. Regardless, the results presented here will serve as a foundation for future work to determine optimal strategies for the conservation and restoration of premature migrating populations. Additionally, given the complex premature migration phenotype and evolutionary importance of premature migration alleles, future work that provides mechanistic insight into the *GREB1L* locus [for example, identifying the causative polymorphism(s) and characterizing expression profiles] could have important implications for areas ranging from conservation to biomedicine.

The combination of three key results from this study has broad conservation implications, which highlight the utility of genomics for informing conservation. First, we present an example of how a single allele at a single locus can have economic, ecological, and cultural importance. Second, we show that mutations producing an important allele can be very rare from an evolutionary perspective, suggesting that the allele will not readily reevolve if lost. Last, we observe that patterns of significant adaptive allelic variation can be completely opposite from patterns of overall genetic differentiation. Together, our results demonstrate that CUs reflecting overall genetic differentiation can fail to protect evolutionarily significant variation that has substantial ecological and societal benefits, and suggest that a supplemental framework for protecting specific adaptive variation will sometimes be necessary to prevent the loss of significant biodiversity and ecosystem services.

MATERIALS AND METHODS

Sample collection and molecular biology

Fin clips were taken from live adults or post-spawn carcasses (tables S1 and S6), dried on Whatman qualitative filter paper (grade 1), and stored at room temperature. DNA was extracted with either the DNeasy Blood and Tissue Kit (Qiagen) or a magnetic bead–based protocol (*22*) and quantified using Quant-iT PicoGreen dsDNA Reagent (Thermo Fisher Scientific) with an FLx800 Fluorescence Reader (BioTek Instruments).

SbfI RAD libraries were prepared with well and plate (when applicable) barcodes using either the traditional or new RAD protocol (*22*) and sequenced with paired-end 100-bp reads on an Illumina HiSeq 2500 (tables S2 and S7). In some cases, the same sample was included in multiple libraries to improve sequencing coverage.

For amplicon sequencing, genomic DNA extractions were rearrayed into 96-well plates and diluted 1:40 with low TE buffer (pH 8.0; 10 mM tris-HCl and 0.1 mM EDTA). Two microliters of this diluted sample was used as polymerase chain reaction (PCR) template for each of the three amplicons in the *GREB1L* region (Fig. 2 and table S4). Multiple forward primers were synthesized for each amplicon. Each forward primer contained a partial Illumina adapter sequence, a unique inline plate barcode, and the amplicon-specific sequence (tables S4 and S5). Initial PCRs were performed in 96-well plates using OneTaq DNA polymerase (New England Biolabs) at the recommended conditions with an annealing temperature of 61°C and 35 cycles. These reaction plates were then combined into a single plate that preserved the well locations. The pooled PCR products were cleaned with Ampure XP beads (Beckman Coulter), and a second round of PCR with eight cycles was performed to add the remaining Illumina adapter sequence and a unique TruSeq barcode to each well (tables S4 and S5). From each final PCR, 2 μl was removed, pooled, and purified with Ampure XP beads. The final amplicon library was sequenced with paired-end 300-bp reads on an Illumina MiSeq.

RAD analysis

RAD sequencing data were demultiplexed by requiring a perfect barcode and partial restriction site match (*22*). Sequences were aligned to a slightly modified version of a recent rainbow trout genome assembly (see scaffold79929e assembly and annotation) (*60*) using the backtrack algorithm of Burrows-Wheeler Aligner (BWA) (*86*) with default parameters. SAMtools (*87*) was used to sort, filter for proper pairs, remove PCR duplicates, and index binary alignment map (BAM) files (tables S2 and S7). In cases where the same sample was sequenced in multiple libraries, BAM files from the same sample were merged before indexing using SAMtools (tables S1, S2, S6, and S7).

Additional BAM file sets were generated to account for technical variation among samples. To minimize variation associated with the two distinct library preparation protocols used in Chinook (table S7) (*22*), we generated a set of single-end BAM files for Chinook that contained only trimmed reads from the restriction site end of the RAD fragments. To prepare these files, we trimmed these reads to 75 bp from the 3′ end after removing 5 bp from the 5′ end. Next, paired-end alignments were performed and processed as above. Last, reads from the variable end of RAD fragments were removed (table S7). To remove variation associated with variable sequencing depth, we generated a set of subsampled BAM files by using SAMtools to randomly sample approximately 120,000 alignments from paired-end BAM files for steelhead and approximately 60,000 alignments from single-end BAM files for Chinook. Subsampling to a lower number of alignments allows more individuals to be included in the analysis. We determined the optimal alignment numbers for subsampling by testing a variety of thresholds and determining the minimum before which the sample groupings started to become dispersed in PCA.

All RAD analyses were performed using Analysis of Next Generation Sequencing Data (ANGSD) (*61*) with a minimum mapping quality score (minMapQ) of 10, a minimum base quality score (minQ) of 20, and the SAMtools genotype likelihood model (GL 1) (*88*). Unless otherwise noted, samples with less alignments than required for subsampling were excluded (tables S1 and S6), and only sites represented in at least 50% of the included samples (minInd) were used.

PCA and association mapping were performed by identifying polymorphic sites (SNP_pval 1e-6), inferring major and minor alleles (doMajorMinor 1) (*72*), estimating allele frequencies (doMaf 2) (*64*), and retaining SNPs with a minor allele frequency of at least 0.05 (minMaf). For PCA, subsampled BAM files were used and genotype posterior probabilities were calculated with a uniform prior (doPost 2). The ngsCovar (*89*) function implemented in ngsTools (*63*) was used to calculate a covariance matrix from called genotypes. For association mapping, paired-end BAM files were used with two distinct tests. The frequency test with known major and minor alleles (doAsso 1) implements a likelihood ratio test using read counts (*64*). This test has good statistical power even with lower coverage data but does not allow the inclusion of covariates to correct for population stratification. The score test (doAsso 2) uses a generalized linear framework on posterior genotype probabilities (*72*). This test allows the inclusion of covariates to correct for population stratification but has less statistical power than the frequency test. For the Umpqua and Eel steelhead associations, the frequency test with λ correction for population stratification (*65*) was used because there were relatively few samples and a weak population structure. λ is the ratio of observed and expected median χ^2 values and used to correct the observed χ^2 values before converting them to *P* values (fig. S1, A and C, and table S3) (*65*). For the Chinook association, the score test with covariate correction for population stratification was used because there were many samples and a complex population structure (fig. S1E). The positions of each sample along the first 15 PCs were used as covariates.

Genome-wide F_{ST} between population pairs was estimated by first estimating an SFS for each population (doSaf) (*90*) using paired-end BAM files for steelhead and single-end BAM files for Chinook. Two-dimensional SFS and global F_{ST} (weighted) between each population pair were then estimated using realSFS (*61*).

To calculate Watterson's θ (*68*), Tajima's θ (*67*), and Tajima's *D* (*69*), we used SFS that were estimated as described above as priors (pest) with paired-end BAM files to calculate each statistic for each site (doThetas), which were averaged to obtain a single value for each statistic (*91*). The analysis was restricted to 565,000 to 785,000 bp of scaffold79929e for the *GREB1L* region analysis.

The coalescent simulation program ms (*92*) was used to determine 95% confidence intervals for the θ estimates from 10,000 simulations under a neutral demographic model. The input number of chromosomes was equal to the number of individuals used to calculate the θ statistics. For genome-wide confidence intervals, 100 independent loci and an input θ of 1, which is the approximate θ of a single RAD tag, were used. For the *GREB1L* region confidence intervals, a single locus and the empirical θ estimates were used. The significance of the empirical Tajima's *D* value was evaluated by generating a Tajima's *D* distribution from 10,000 ms simulations under a neutral demographic model. A single locus and the average between empirical values of Watterson's and Tajima's θ values in the *GREB1L* region were used. A Tajima's *D* distribution was also generated using the extremes of the θ confidence intervals, and the empirical value remained significant.

Allele frequencies were estimated (doMaf 1) (*64*) for the significant Chinook SNPs in each population that had at least four individuals with enough alignments for subsampling. Paired-end BAM files were used with the reference genome assembly as the prespecified major allele (doMajorMinor 4). Because some populations had low sample sizes, all samples were included regardless of alignment number.

Amplicon analysis

Amplicon sequence data were demultiplexed by requiring perfect barcode and primer matches. Sequences were aligned to the reference genome assembly described above using the BWA-SW algorithm (*93*) with default parameters, and SAMtools was used to sort, filter for proper pairs, and index BAM files (table S5).

Phylogenetic analysis was performed on samples in which two or more amplicons had at least 20 alignments (tables S1 and S5). Genotypes for all sites were called using ANGSD with the SAMtools genotype likelihood model, a uniform prior, and a posterior cutoff of 0.8. The genotype output file was parsed and converted into biallelic consensus sequences, with an IUPAC (International Union of Pure and Applied Chemistry) nucleotide code denoting heterozygous positions. These consensus sequences were input into fastPHASE (*94*) to produce 1000 output files that each contained two phased haplotype sequences per individual. Default parameters were used except that a distinct subpopulation label was specified for each of the five locations and base calls with a posterior of less than 0.8 were converted to Ns (unknown bases). Parsimony trees were then constructed from each fastPHASE output, and a consensus tree was called using PHYLIP (*66*).

In the initial phylogenetic analysis, one sample from the Eel River that was originally classified as premature migrating clustered in the mature migration clade (table S1). A PCA specific to the Eel River placed this sample at an intermediate position between mature migrating and premature migrating sample groups. Furthermore, this was the only Eel River sample that was homozygous for a haplotype on chromosome Omy05 associated with residency (*20*). Examination of the original sampling information revealed that this fish was much smaller than others and collected upstream from the main premature steelhead holding area (*56*), suggesting that it was a resident trout as opposed to an anadromous steelhead. Therefore, this sample was removed, and the analysis was rerun.

Scaffold79929e assembly and annotation

Our initial RAD analysis was aligned against a published reference genome assembly (*60*) and identified highly associated SNPs on three independent scaffolds. Given the state of the assembly, the sizes of the scaffolds with highly associated SNPs, and the positions of the highly associated SNPs on the scaffolds, we hypothesized that these scaffolds might be physically linked despite not being connected in the current assembly. We aligned four large-insert mate-pair libraries to the published assembly to look for linkages and estimate the distance between linked scaffolds (table S9). A perfect sequence match was required, and alignments to regions with high coverage were discarded. The resulting alignments from all libraries strongly supported a linear assembly with a total size of 1,949,089 bp that included the three associated scaffolds as well as four others (tables S9 and S10). This assembled scaffold was named scaffold79929e (e for extended) and added to the published assembly, and the seven independent scaffolds that composed it were removed to create the modified reference assembly used in this study.

Scaffold79929e was annotated with MAKER (*95*) using rainbow trout and Atlantic salmon (*Salmo salar*) EST (expressed sequence tag) sequences from the NCBI (National Center for Biotechnology Information) database, the UniProt/Swiss-Prot database for protein homology, a rainbow trout repeat library (*60*) for masking, AUGUSTUS (human) and SNAP (mamiso) gene predictors, a maximum intron size of 20,000 bp for evidence alignments, and otherwise default parameters.

Klickitat steelhead analysis

Single-end RAD data from 237 Klickitat River steelhead samples (*73*) were aligned to the modified rainbow trout genome as described above. SAMtools (*87*) was used to remove unaligned reads, sort, index, and randomly subsample BAM files to 500,000 reads to reduce the effect of PCR duplicates (*96*). All subsequent analyses were performed on subsampled BAM files using ANGSD (*61*).

Association mapping was performed using the score test (doAsso 2), with the migration date at Lyle Falls (May 1 set to day 1) (*73*) as a quantitative proxy for the premature migration phenotype (yQuant) because more direct measures (for example, gonadal maturation and body fat content at freshwater entry) were not available (this information is difficult to obtain and may require lethal sampling). The positions of each sample along the first nine PCs were used as covariates to correct for population stratification (fig. S1F). The PCA used to generate covariates was performed as described above.

Genotype data from the four associated SNPs were used to categorize individuals as homozygous for the mature migration allele, heterozygous, or homozygous premature. Genotypes were called (doGeno 4) with a uniform prior (doPost 2) and a posterior probability cutoff of 0.8 (postCutoff 0.8). Seven hundred fifty-one of 948 genotypes passed this cutoff. Two SNPs were flanking sites on the same RAD tag, had near-perfect consistency between genotype calls, and were treated as a single genotype for categorization. For an individual to be categorized as homozygous or heterozygous, all called genotypes were required to be in agreement and at least two of the three genotypes must have been called. A total of 158 samples passed these requirements, whereas 51 failed because less than two genotypes were called and 28 failed because of disagreement between called genotypes.

Migration date means were calculated with May 1 set to day 1 because it is an approximate date for the beginning of premature migration at Lyle Falls (*73*). Confidence intervals of the means were calculated by bootstrapping with 1000 replicates. The significance of differences in mean migration date between genotype categories was evaluated with Welch's *t* test. May 1 is somewhat arbitrary, and a subset of premature migrating individuals likely ascends Lyle Falls before this date (fig. S2). Furthermore, some individuals may enter freshwater then hold below Lyle Falls for an extended period before ascending to spawn. In either of these scenarios, individuals would be assigned a migration date indicative of mature migration, even though they were premature migrating. With the available information, we cannot be sure which individuals migrated under these scenarios. However, setting May 1 to day 1 is a conservative approach that, if anything, should underestimate the significance of the differences between mean migration dates for each genotype (Fig. 4B and fig. S2).

SUPPLEMENTARY MATERIALS

Supplementary material for this article is available at http://advances.sciencemag.org/cgi/content/full/3/8/e1603198/DC1

fig. S1. Observed versus expected statistics for association mapping of migration phenotype.
fig. S2. Migration date distribution of Klickitat River steelhead at Lyle Falls with weekly binning.
table S1. Steelhead samples.
table S2. Steelhead RAD sequence.
table S3. Steelhead migration associated SNPs.
table S4. Steelhead amplicon primers.
table S5. Steelhead amplicon sequence.
table S6. Chinook samples.
table S7. Chinook RAD sequence.
table S8. Chinook migration associated SNPs.
table S9. Scaffold links.
table S10. Scaffold79929e assembly.

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Acknowledgments: We thank C. Liu, J. Saxon, P. Tronquet, the National Marine Fisheries Service, the Oregon Department of Fish and Wildlife, and the California Department of Fish and Wildlife for assistance with sample acquisition as well as F. Allendorf, E. Anderson, J. Ashander, G. Coop, and R. Waples for valuable comments on an earlier version of the manuscript. M.R.M. thanks C. Doe, Y. Palti, and G. Thorgaard for invaluable support and encouragement. This work used the Vincent J. Coates Genomics Sequencing Laboratory at the University of California, Berkeley, supported by NIH S10 Instrumentation grants S10RR029668 and S10RR027303. **Funding:** This study was funded by the Department of Animal Science and College of Agricultural and Environmental Sciences at the University of California, Davis. **Author contributions:** Conceptualization: D.J.P., S.M.O., T.Q.T., and M.R.M.; resources: S.M.O., T.J.H., A.P.S., and M.R.M.; investigation: D.J.P., S.M.O., T.Q.T., O.A.A., H.S.L., I.K.S., and M.R.M.; formal analysis: D.J.P., T.Q.T., and M.R.M.; visualization: D.J.P., T.Q.T., and M.R.M.; writing of original draft: D.J.P. and M.R.M.; writing, review, and editing: D.J.P., S.M.O., T.Q.T., O.A.A., H.S.L., I.K.S., T.J.H., A.P.S., and M.R.M.; funding acquisition: S.M.O. and M.R.M.; supervision: M.R.M. **Competing interests:** The authors declare that they have no competing interests. **Data and materials availability:** All sequence data generated in this study are available at the NCBI Sequence Read Archive with identifier SRP101883. Scripts used to execute analysis software are available at https://github.com/djprince/premature-migration-2017. All data needed to evaluate the conclusions in the paper are present in the paper and/or the Supplementary Materials. Additional data related to this paper may be requested from the authors.

Submitted 28 December 2016
Accepted 19 July 2017
Published 16 August 2017
10.1126/sciadv.1603198

Citation: D. J. Prince, S. M. O'Rourke, T. Q. Thompson, O. A. Ali, H. S. Lyman, I. K. Saglam, T. J. Hotaling, A. P. Spidle, M. R. Miller, The evolutionary basis of premature migration in Pacific salmon highlights the utility of genomics for informing conservation. *Sci. Adv.* **3**, e1603198 (2017).

Attachment C

Science Advances

The evolutionary basis of premature migration in Pacific salmon highlights the utility of genomics for informing conservation

Daniel J. Prince, Sean M. O'Rourke, Tasha Q. Thompson, Omar A. Ali, Hannah S. Lyman, Ismail K. Saglam, Thomas J. Hotaling, Adrian P. Spidle and Michael R. Miller

Sci Adv **3** (8), e1603198.
DOI: 10.1126/sciadv.1603198

Wells Aquatic Settlement Work Group
FINAL
Statement of Agreement
To implement a temporary 1.0-foot Fishway-entrance Head Differential for Pacific Lamprey from 17:00 to 00:59 daily during the 2017 Pacific Lamprey Migration at Wells Dam
Date of Approval: 16 August 2017

Statement

The Wells Aquatic Settlement Work Group (Aquatic SWG) requests concurrence from the Wells Habitat Conservation Plan Coordinating Committee (Wells HCP-CC) to operate the Wells Dam fishway collection galleries at a 1.0-foot head differential from 17:00 to 00:59 daily from September 1 to September 30, 2017.

Background

Douglas PUD and the Aquatic SWG continue to evaluate ways to improve ladder entrance efficiency for adult Pacific Lamprey (lamprey) attempting to pass Wells Dam. In 2009 and 2010, reduced head differentials were tested at the entrances to the Wells Dam fishways to assess whether there was an effect of differences in entrance velocities on the passage of lamprey. Concurrently, salmonid passage was monitored to assess whether a reduction in head differential negatively influenced salmonid use of the fishway.

Due to limited numbers of test lamprey in recent years and the relatively large run of lamprey currently being experienced this year, the Aquatic SWG is requesting to temporarily reduce fishway entrance head differentials at Wells Dam.

The Aquatic SWG believes there may be a benefit to lamprey by reducing head differential, and there does not appear to be a significant impact to migrating salmonids[1]. This is based on results of a radio-telemetry study conducted in 2013.

The Wells HCP-CC approved studies in 2009 and 2010 at Wells Dam which used Dual Frequency Identification Sonar (DIDSON) technology to observe the behavior of lamprey attempting to pass the fishway entrances under different operating conditions. The Wells HCP-CC subsequently approved a differential flow study in 2013 and 2014, but low lamprey counts were observed at Wells Dam these years, which reduced the statistical power of treatments.

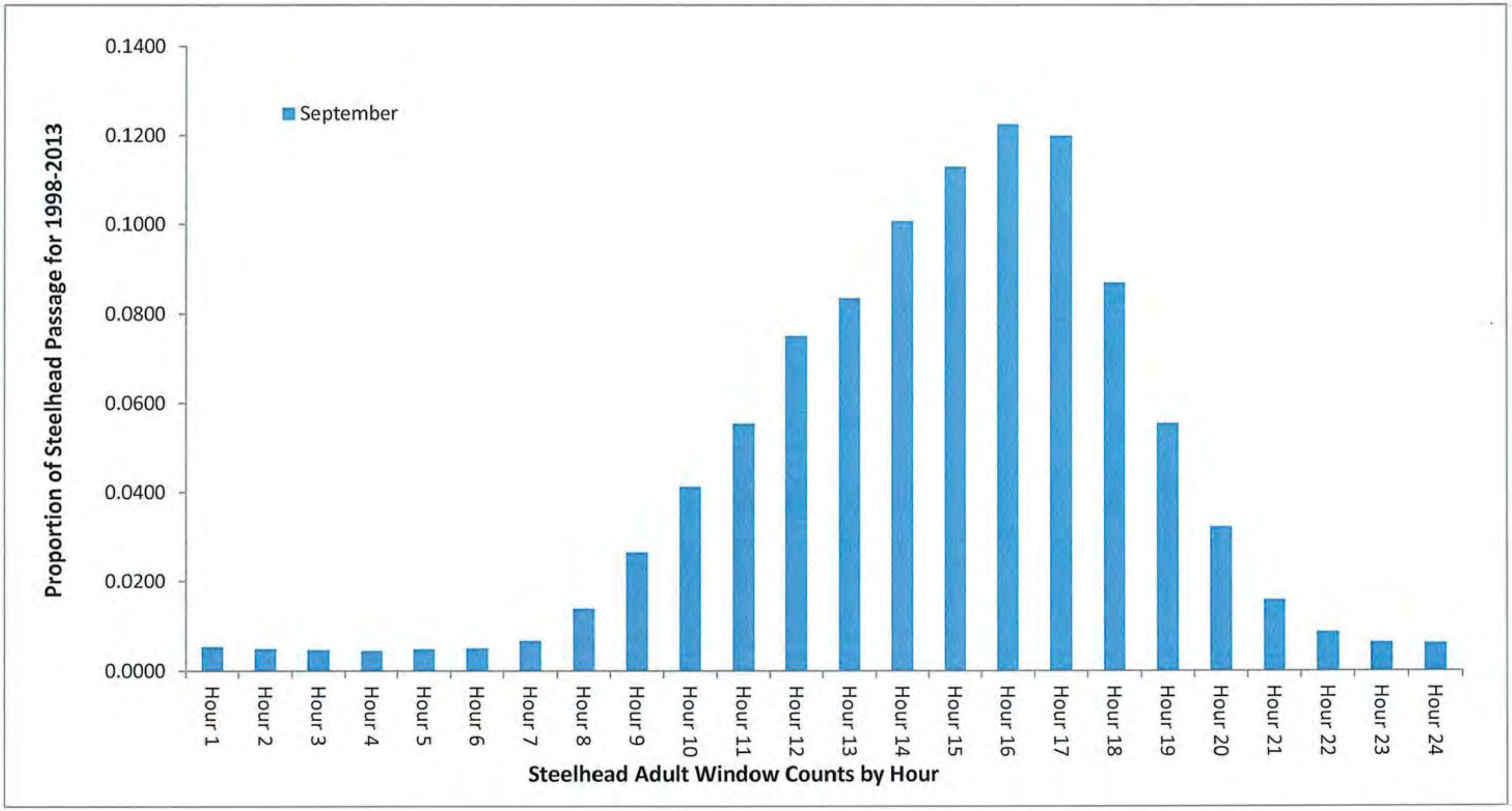
Qualitative results of 2013 and 2014 studies indicate that lamprey entrance efficiency may be enhanced by reducing the collection-gallery-to-tailwater head differential from 1.5-feet to 1.0-foot between 17:00 and 0:59 hours during the peak of the lamprey migration season. Post-hoc analyses indicated the eight-hour period selected for testing had the lowest diel salmonid passage activity and highest diel lamprey activity. Analysis of data on the passage of salmonids during the DIDSON studies indicated no significant difference in passage rates of steelhead or sockeye, Chinook, or coho salmon between the two head differentials tested (1.0-foot or 1.5-feet).

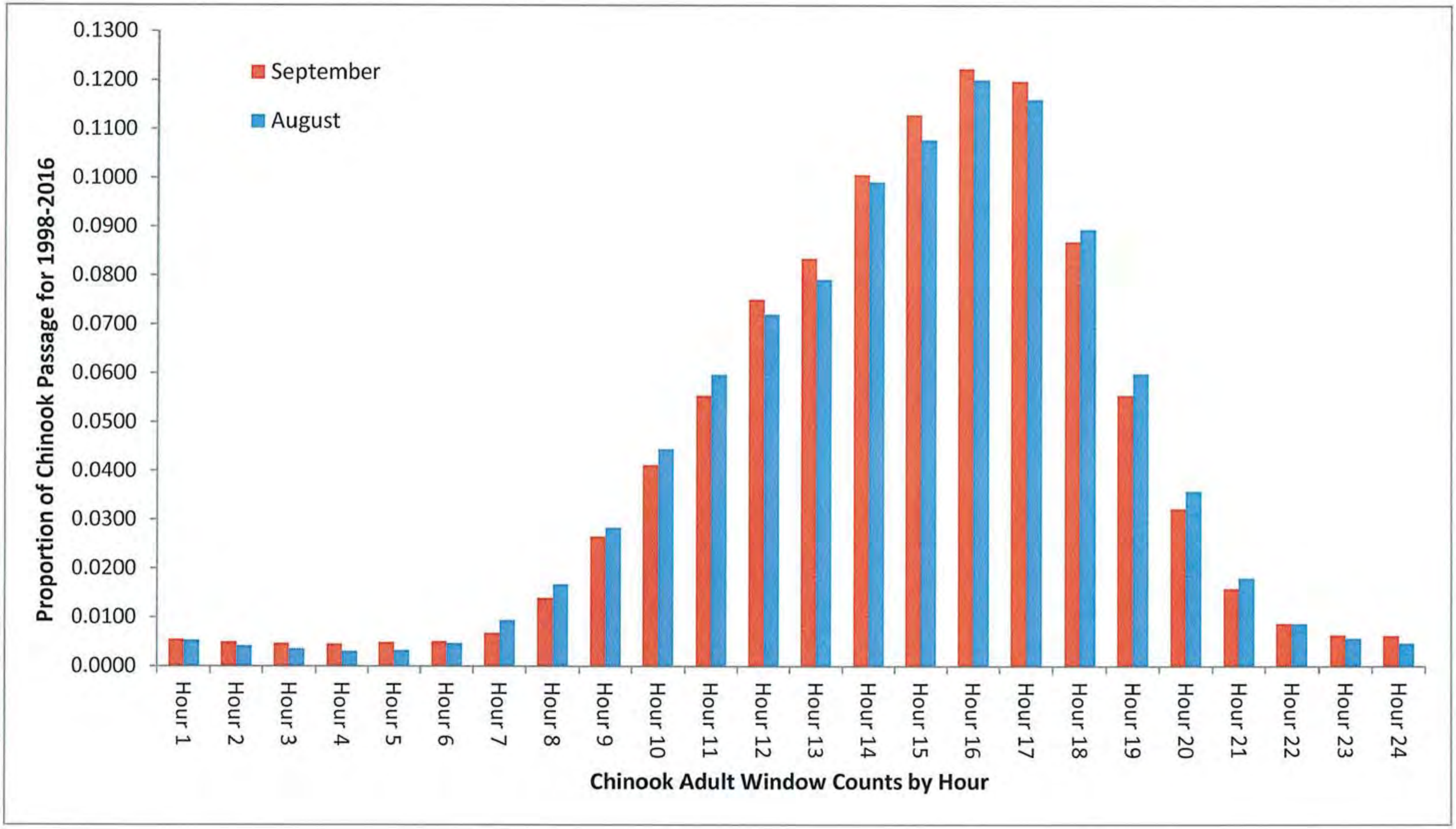
[1] Refer to Section 5 of the April 2012 Assessment of Salmonid Passage Responses to Different Flow Velocities at Wells Dam Fishway for additional information regarding impacts to salmonids.

As a temporary and experimental measure, the Aquatic SWG proposes to operate the Wells Dam fishway entrances with a 1-foot differential at night as a means of enhancing lamprey passage for 2017. These operations would begin September 1 and end on September 30, 2017.

DIDSON technology will not be available at the time of this change in head differential; therefore, currently tagged lamprey in the Columbia River, along with upstream fishway ladder counts on the left and right banks of Wells Dam, will be used to test the effectiveness of this 1.0-foot head differential measure.

Attachment E




September
August
Proportion of Chinook Passage for 1998-2016
0.1300
0.1200
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0.0800
0.0700
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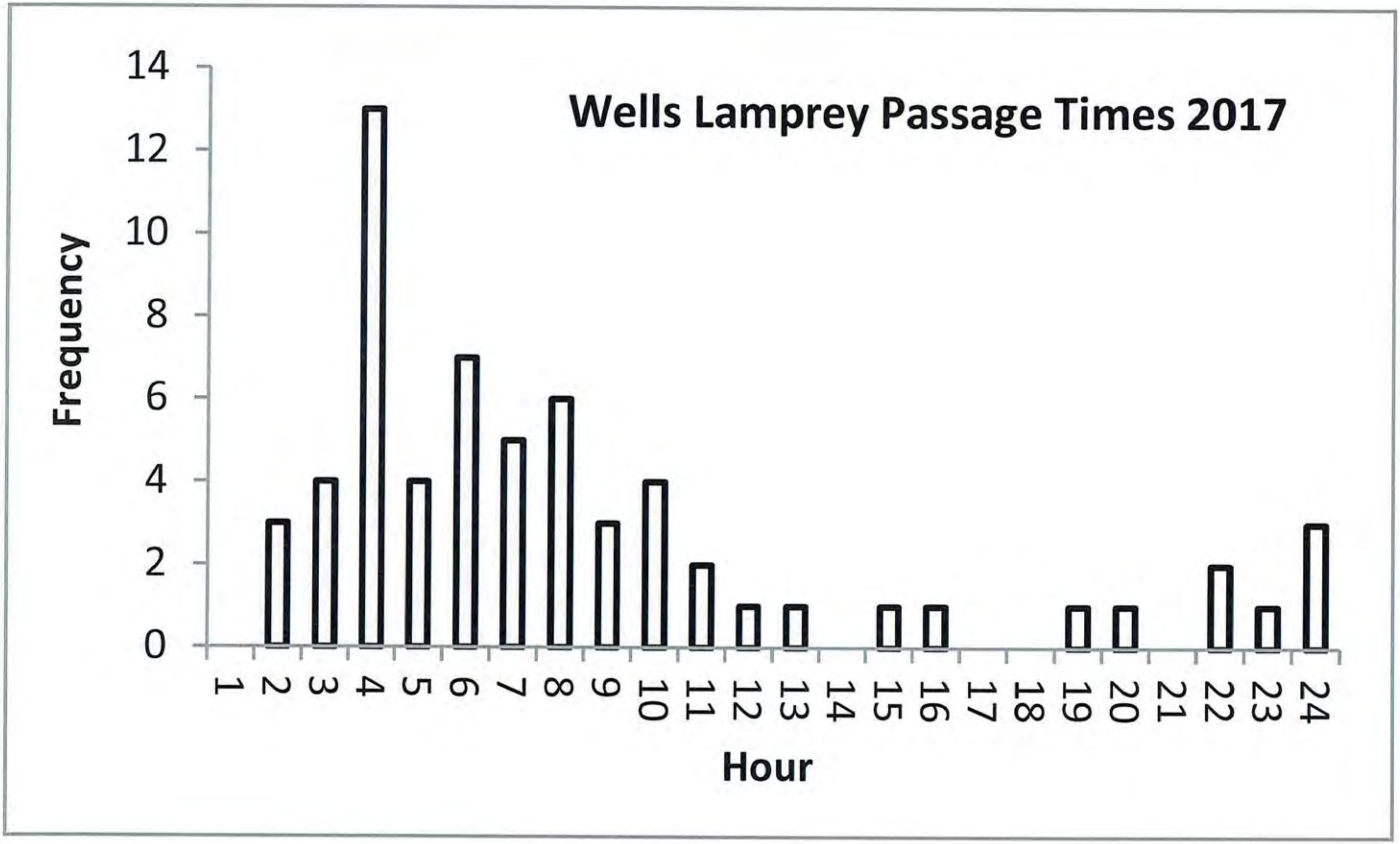
Hour 21
Hour 22
Hour 23
Hour 24
Chinook Adult Window Counts by Hour


Wells Lamprey Passage Times 2017
Frequency
0
2
4
6
8
10
12
14
Hour
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24

Wells Aquatic Settlement Work Group
FINAL
Statement of Agreement
To implement a temporary 1.0-foot Fishway-entrance Head Differential for Pacific Lamprey from 22:00 to 04:00 in 3-day blocks alternating with 3-day blocks of normal fishway operating criteria during the 2017 Pacific Lamprey Migration at Wells Dam
Date of Approval: 28 August 2017

Statement

The Wells Aquatic Settlement Work Group (Aquatic SWG) agrees to operate the Wells Dam fishway collection galleries at a 1.0-foot head differential from 22:00 to 04:00 ("lamprey operations"), in five pairs of 3-day block operations from September 1 to September 30, 2017.

Background

Douglas PUD and the Aquatic SWG continue to evaluate ways to improve ladder entrance efficiency for adult Pacific Lamprey (lamprey) attempting to pass Wells Dam. In 2009 and 2010, reduced head differentials were tested at the entrances to the Wells Dam fishways to assess whether there was an effect of differences in entrance velocities on the passage of lamprey. Concurrently, salmonid passage was monitored to assess whether a reduction in head differential negatively influenced salmonid use of the fishway.

Due to limited numbers of test lamprey in recent years and the relatively large run of lamprey currently being experienced this year, the Aquatic SWG is requesting to temporarily reduce fishway entrance head differentials at Wells Dam.

The Aquatic SWG believes there may be a benefit to lamprey by reducing head differential, and there does not appear to be a significant impact to migrating salmonids[1]. This is based on results of a radio-telemetry study conducted in 2013.

The Wells HCP-CC approved studies in 2009 and 2010 at Wells Dam which used Dual Frequency Identification Sonar (DIDSON) technology to observe the behavior of lamprey attempting to pass the fishway entrances under different operating conditions. The Wells HCP-CC subsequently approved a differential flow study in 2013 and 2014, but low lamprey counts were observed at Wells Dam these years, which reduced the statistical power of treatments.

Qualitative results of 2013 and 2014 studies indicate that lamprey entrance efficiency may be enhanced by reducing the collection-gallery-to-tailwater head differential from 1.5-feet to 1.0-foot between 17:00 and 0:59 hours during the peak of the lamprey migration season. Post-hoc analyses indicated the eight-hour period selected for testing had the lowest diel salmonid passage activity and highest diel lamprey activity. Analysis of data on the passage of salmonids during the DIDSON studies indicated no significant difference in passage rates of steelhead or sockeye, Chinook, or coho salmon between the two head differentials tested (1.0-foot or 1.5-feet).

[1] Refer to Section 5 of the April 2012 Assessment of Salmonid Passage Responses to Different Flow Velocities at Wells Dam Fishway for additional information regarding impacts to salmonids.

As a temporary and experimental measure, the Aquatic SWG proposes to operate the Wells Dam fishway entrances with a 1-foot differential at night as a means of enhancing lamprey passage for 2017. These operations would begin September 1 and end on September 30, 2017. To evaluate the efficacy of the modified operations, those operations will occur in 3-day blocks alternating with 3-day blocks of normal fishway operations, as a means of potentially identifying differences in dam-passage behavior resulting from modified fishway-entrance conditions.

During 2017 temporary lamprey operations the Aquatic SWG members will monitor Pacific Lamprey at Wells Dam from September 1 to September 30, 2017, via the Columbia River Data Access in Real Time (DART) database, and if so interested, will monitor steelhead, and Coho and Chinook salmon passage under the lamprey operations. Based on monitoring of the Pacific Lamprey fish ladder count data, if an Aquatic SWG member feels the lamprey operations are not producing the expected passage conditions, the member will notify all Aquatic SWG members by email and discuss the topic via email or request a coordination call. Additionally, lamprey operations will be implemented, as described, unless observational data clearly suggest and the Aquatic SWG members agree the operations should not continue.

DIDSON technology will not be available at the time of this change in head differential; therefore, currently tagged lamprey in the Columbia River, along with upstream fishway ladder counts on the left and right banks of Wells Dam, will be used to test the effectiveness of this 1.0-foot head differential measure. Following the completions of the temporary 2017 lamprey operations Douglas PUD, potentially in coordination with Columbia Basin Research or LGL Limited, will develop and provide to the Aquatic SWG and Wells HCP-CC, a post-season technical memorandum describing results of the 2017 lamprey operations, based on fish count data.

Wells HCP Coordinating Committee
FINAL
Statement of Agreement
To implement temporary fishway "lamprey operations" in alternating 3-day blocks with normal operations during the 2017 Pacific Lamprey Migration at Wells Dam
Date of Approval: 31 August 2017

Statement

The Wells HCP Coordinating Committee agrees to implement a temporary 1.0-foot fishway-entrance head differential for Pacific Lamprey from 22:00 to 04:00 in 3-day blocks alternating with 3-day blocks of normal fishway operating criteria during the 2017 Pacific Lamprey Migration at Wells Dam, from September 1 to September 30, 2017.

Background

At their August 22, 2017 meeting, the Wells HCP Coordinating Committee (CC) reviewed a request from the Wells Aquatic Settlement Work Group (Aquatic SWG) to implement fishway operations at Wells Dam intended to facilitate fishway entrance by Pacific Lamprey (lamprey operations). The CC reviewed data on lamprey and salmonid passage timing, and conditionally approved the requested lamprey operations provided that the Aquatic SWG, 1) review the 2013 radio-telemetry study report to determine whether the proposed actions would indeed improve lamprey passage considering the equivocal results of that study (specifically considering effects of reduced head differential on lamprey attraction to the fishway entrances); 2) accept the CC's alternative diel schedule of lamprey operations (CC approved 22:00-04:00); 3) accept a block design intended to identify lamprey response to lamprey operations (2 days at 1 foot, alternating with 2 days at 1.5 feet); 4) provide the CC with a report on lamprey response to 2017 lamprey operations; and 5) accept adaptive management of operations such that if a negative response to lamprey operations was observed, those operations could be discontinued before the end of September.

The Aquatic SWG accepted the conditions approved by the CC, but changed the block duration from 2-day blocks to 3-day blocks (see final SOA approved by the Aquatic SWG attached below).

Wells Aquatic Settlement Work Group
FINAL
Statement of Agreement
To implement a temporary 1.0-foot Fishway-entrance Head Differential for Pacific Lamprey from 22:00 to 04:00 in 3-day blocks alternating with 3-day blocks of normal fishway operating criteria during the 2017 Pacific Lamprey Migration at Wells Dam
Date of Approval: 28 August 2017

Statement

> The Wells Aquatic Settlement Work Group (Aquatic SWG) agrees to operate the Wells Dam fishway collection galleries at a 1.0-foot head differential from 22:00 to 04:00 ("lamprey operations"), in five pairs of 3-day block operations from September 1 to September 30, 2017.

Background

Douglas PUD and the Aquatic SWG continue to evaluate ways to improve ladder entrance efficiency for adult Pacific Lamprey (lamprey) attempting to pass Wells Dam. In 2009 and 2010, reduced head differentials were tested at the entrances to the Wells Dam fishways to assess whether there was an effect of differences in entrance velocities on the passage of lamprey. Concurrently, salmonid passage was monitored to assess whether a reduction in head differential negatively influenced salmonid use of the fishway.

Due to limited numbers of test lamprey in recent years and the relatively large run of lamprey currently being experienced this year, the Aquatic SWG is requesting to temporarily reduce fishway entrance head differentials at Wells Dam.

The Aquatic SWG believes there may be a benefit to lamprey by reducing head differential, and there does not appear to be a significant impact to migrating salmonids[1]. This is based on results of a radio-telemetry study conducted in 2013.

The Wells HCP-CC approved studies in 2009 and 2010 at Wells Dam which used Dual Frequency Identification Sonar (DIDSON) technology to observe the behavior of lamprey attempting to pass the fishway entrances under different operating conditions. The Wells HCP-CC subsequently approved a differential flow study in 2013 and 2014, but low lamprey counts were observed at Wells Dam these years, which reduced the statistical power of treatments.

Qualitative results of 2013 and 2014 studies indicate that lamprey entrance efficiency may be enhanced by reducing the collection-gallery-to-tailwater head differential from 1.5-feet to 1.0-foot between 17:00 and 0:59 hours during the peak of the lamprey migration season. Post-hoc analyses indicated the eight-hour period selected for testing had the lowest diel salmonid passage activity and highest diel lamprey activity. Analysis of data on the passage of salmonids during the DIDSON studies indicated no significant difference in passage rates of steelhead or sockeye, Chinook, or coho salmon between the two head differentials tested (1.0-foot or 1.5-feet).

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[1] Refer to Section 5 of the April 2012 Assessment of Salmonid Passage Responses to Different Flow Velocities at Wells Dam Fishway for additional information regarding impacts to salmonids.

As a temporary and experimental measure, the Aquatic SWG proposes to operate the Wells Dam fishway entrances with a 1-foot differential at night as a means of enhancing lamprey passage for 2017. These operations would begin September 1 and end on September 30, 2017. To evaluate the efficacy of the modified operations, those operations will occur in 3-day blocks alternating with 3-day blocks of normal fishway operations, as a means of potentially identifying differences in dam-passage behavior resulting from modified fishway-entrance conditions.

During 2017 temporary lamprey operations the Aquatic SWG members will monitor Pacific Lamprey at Wells Dam from September 1 to September 30, 2017, via the Columbia River Data Access in Real Time (DART) database, and if so interested, will monitor steelhead, and Coho and Chinook salmon passage under the lamprey operations. Based on monitoring of the Pacific Lamprey fish ladder count data, if an Aquatic SWG member feels the lamprey operations are not producing the expected passage conditions, the member will notify all Aquatic SWG members by email and discuss the topic via email or request a coordination call. Additionally, lamprey operations will be implemented, as described, unless observational data clearly suggest and the Aquatic SWG members agree the operations should not continue.

DIDSON technology will not be available at the time of this change in head differential; therefore, currently tagged lamprey in the Columbia River, along with upstream fishway ladder counts on the left and right banks of Wells Dam, will be used to test the effectiveness of this 1.0-foot head differential measure. Following the completions of the temporary 2017 lamprey operations Douglas PUD, potentially in coordination with Columbia Basin Research or LGL Limited, will develop and provide to the Aquatic SWG and Wells HCP-CC, a post-season technical memorandum describing results of the 2017 lamprey operations, based on fish count data.



PUBLIC UTILITY DISTRICT NO. 1 *of* CHELAN COUNTY
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January 10, 2017

VIA ELECTRONIC FILING

Ms. Kimberly D. Bose, Secretary
Federal Energy Regulatory Commission
888 First Street NE
Washington, DC 20426

Re: Rock Island Hydroelectric Project, FERC No. 943
Continuation of Rehabilitation Work (Units B1-B4)

Dear Secretary Bose:

As the Federal Energy Regulatory Commission (Commission or FERC) is aware, the Public Utility District No. 1 of Chelan County, Washington (Chelan PUD) has been engaged in a long-standing effort to rehabilitate the units in the First Powerhouse (PH1) at its Rock Island Hydroelectric Project, FERC No. 943 (Project). This effort began with the rehabilitation of Unit B10, which Chelan PUD completed in 2008,[1] followed by the completion of rehabilitation work for Unit B9 in 2012.[2] Chelan PUD originally advised the Commission of its planned rehabilitation of these units, together with Units B5, B6, and B7, in 2003.[3]

The purpose of this letter is to advise the Commission of its intent to continue its rehabilitation effort at the Project's PH1 by rehabilitating the turbine-generators for Units B1-B4. A detailed description of Chelan PUD's plans for Units B1-B4 appears below.

Consistent with how this rehabilitation program has progressed to date, and pursuant to Chelan PUD's consultation with Commission staff on April 29, 2016, prior Commission approval of the rehabilitation work for Units B1-B4 will not be required for this work. The rehabilitation of Units B1-B4 will not involve any change to the maximum hydraulic capacity of 220,000 cubic feet per second currently authorized under the Project's license, nor will it result in any increase

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1 *Pub. Util. Dist. No. 1 of Chelan County*, 135 FERC ¶ 62,207 (2011) (acknowledging the completion of the Unit B10 rehabilitation and adjusting annual charges for the unit).

2 *See Pub. Util. Dist. No. 1 of Chelan County*, 146 FERC ¶ 62,055 (2014) (acknowledging the completion of the Unit B9 rehabilitation and adjusting annual charges for the unit).

3 *See* Letter from Charles J. Hosken, Public Utility District No. 1 of Chelan County, to Magalie R. Salas, Federal Energy Regulatory Commission, Project No. 943-000 (filed Oct. 29, 2003). As noted in Attachment A herein, Chelan PUD anticipates completing the rehabilitation for Units B5, B6 and B7 in the 2016-22 timeframe.

in the Project's authorized installed capacity, which for each of these units is 20,700 kilowatts.[4] Moreover, because Chelan PUD will only be replacing equipment that is reaching the end of its useful life with comparable equipment, the rehabilitation of Units B1-B4 will not involve a "substantial change" or "substantial alteration" to the approved Project works under Standard Articles 2 and 3 of the Project license.[5]

Although no prior Commission approvals are required for this next phase of the rehabilitation program, Chelan PUD will continue to provide the Commission updates of its progress. After each turbine-generator unit is rehabilitated, Chelan PUD will notify the Commission of the date on which the rehabilitated unit went on line and its capacity in order to confirm whether there will be a need to revise the authorized installed capacity or annual charges for the Project. After rehabilitation work is completed, Chelan PUD will file "as-built" exhibits with the Commission.

In addition, as detailed below and in Attachment B, Chelan PUD has consulted with Washington State Department of Ecology and the Habitat Conservation Plan (HCP) Coordinating Committee, comprised of federal and state resource agencies and Tribes, regarding potential environmental effects of the rehabilitation work.

<u>Proposed Rock Island Rehabilitation</u>

Chelan PUD intends to rehabilitate the 20.7 MW Kaplan turbine-generators in the Rock Island PH1. These units have been in service since the early1930s. The proposed rehabilitation work will begin in 2018 and continue into 2020. The following outlines the proposed work, schedule and environmental considerations. Attachment A provides Chelan PUD's estimated rehabilitation schedule for PH1.

The rehabilitation will not result in a change to generator nameplate or authorized project hydraulic capacity (220,000 cubic feet per second (cfs) or authorized capacity, 20,700 kilowatt (kW). No civil works will be necessary, including no changes to the diameter of the intake or draft tube discharge structures, height of wicket gates, or stator core. The units will continue to operate with fixed blades, the same conditions that met the Habitat Conservation Plan's no-net impact.

The rehabilitation will change the turbine horsepower (HP) from 32,000 HP to about 30,000 HP. The head for PH1 units will be updated to 39.7 feet to be consistent with other updated PH1 rehabilitated units and PH2. A smaller oil-free hub with no gaps will be installed, along with new fixed propeller runners optimized for the current operating head and flow. Currently, the units contain manually adjustable Nagler-type propeller turbines. The units will have more efficient four-blade turbines instead of six-blades. Governor controls will be replaced.

---

4 *See* 18 C.F.R. § 4.201(b)

5 *See Pub. Util. Dist. No. 1 of Chelan County*, 46 FERC ¶ 61,033, at p. 61,208 (1989) (Ordering Paragraph (E), adopting Form L-5 into the license); *see also* 16 U.S.C. § 803(b) (prohibiting "substantial alteration or addition not in conformity with the approved plans . . . without the prior approval of the Commission"); *e.g., International Falls Power Co.*, 66 FERC ¶ 61,086 at p. 61,114-17 (1994).

Upon installation and testing, revised best gate capacities for the units will be submitted to the Commission.

Estimated Return to Service Dates – Powerhouse 1

1. Unit B1 – Quarter 1 2020
2. Unit B2 – Quarter 3 2019
3. Unit B3 – Quarter 2 2019
4. Unit B4 – Quarter 1 2019

Environmental Considerations

The rehabilitation work will not adversely affect aquatic resources or Chelan PUD's obligations under the HCP. Modern turbine design with tighter operating tolerances and fixed blade angle positioned for optimum flow conditions supporting efficient power generation will benefit fish passage survival. Additionally, laminar flow conditions associated with peak generating capability equate to providing fish the best possible flow conditions for turbine route passage. In 2013, the HCP Coordinating Committee approved Chelan PUD's 2013 Comprehensive Progress Report that concluded Chelan PUD had reached no net impact at Rock Island with respect to all planned species.[6] Chelan PUD's achievement of no net impact in 2013 was successfully achieved while operating the vintage 1933 units. The proposed rehabilitation work will not alter the HCP Coordinating Committee's 2013 finding of no net impact and in fact, Chelan PUD anticipates that the new modern design of present day turbines will offer additional survival benefit of fish passing through the rehabbed B1-4 units. A project survival standard check-in study is scheduled for 2020 (post B1-4 rehab) to verify continued achievement of the juvenile survival standard. The schedule has all PH1 units in operation by April 2020 providing the best chance for success during the 2020 HCP check-in.

Consultation

Chelan PUD has kept the HCP Coordinating Committee apprised of maintenance work occurring at the Rock Island Project. On October 25, Chelan PUD Director of Engineering and Project Management, Brett Bickford provided the HCP Coordinating Committee an overview of maintenance work planned on Units B1-B4. On November 15, Chelan PUD provided a draft of this letter to the HCP Coordinating Committee for the agencies' and committee's comments. Additionally, Chelan PUD has kept the Washington State Department of Ecology apprised of the work occurring at Rock Island. On Dec. 16, Chelan PUD provided Ecology with a copy of the draft letter for comment. Documentation, including comments received and Chelan PUD responses are included in Attachment B.

[6] Statement of Agreement, Approval of Rock Island and Rocky Reach HCPs 2013 Comprehensive Progress Report (Approved February 26, 2013).

Conclusion

Chelan PUD appreciates the support of Commission staff and federal and state resource agencies as it continues with this important rehabilitation program for the Rock Island Hydroelectric Project. Should you have any questions regarding this matter, please contact me.

Regards,

Jeffrey G. Osborn

Jeffrey G. Osborn
License Compliance Supervisor
Public Utility District No. 1 of Chelan County
jeff.osborn@chelanpud.org
(509) 661-4176

cc: FERC DHAC Director
FERC D2SI Director
FERC D2SI Regional Engineer
Chelan PUD Brett Bickford
Chelan PUD Michelle Smith

Attachment A: Table of Proposed Authorized Capacities
Attachment B: Consultation Documentation

ATTACHMENT A

ESTIMATED MAINTENANCE SCHEDULES AND CAPACITIES

Modified November 2016 by Chelan PUD to reflect estimated maintenance schedules and anticipated capacities for PH1 Units B1-4.

	License Issued 01/18/1989	**Amendment Issued 03/14/2002**	**Amendment Issued 09/22/2004**	**Amendment Issued 06/09/2011**	**Amendment Issued 01/24/2014**	**Anticipated B1-B4 Rehab 2018-2020**	**Estimated Maintenance Schedule**
Units	Authorized Capacity kW	Authorized Capacity kW	Authorized Capacity kW	Authorized Capacity kW	Authorized Capacity kW	Authorized Capacity kW	
B1	15,000	15,000	20,700	20,700	20,700	**20,700**	**2020**
B2	20,700	20,700	20,700	20,700	20,700	**20,700**	**2019**
B3	20,700	20,700	15,000	20,700	20,700	**20,700**	**2019**
B4	20,700	20,700	20,700	20,700	20,700	**20,700**	**2018**
B5	22,500	22,500	18,000	22,500	22,500		Est. 2020/2021
B6	22,500	22,500	18,000	22,500	22,500		2017
B7	22,500	22,500	18,000	22,500	22,500		2017/18
B8	22,500	22,500	18,000	18,000	18,000		Est. 2021/2022
B9	22,500	22,500	18,000	15,312	14,355		Completed in 2012
B10	22,500	22,500	18,000	14,100	14,100		Completed in 2008
U1	51,300	51,300	27,975	27,975	27,975		
U2	51,300	51,300	27,975	27,975	27,975		
U3	51,300	51,300	27,975	27,975	27,975		
U4	51,300	51,300	27,975	27,975	27,975		
U5	51,300	51,300	27,975	27,975	27,975		
U6	51,300	51,300	27,975	27,975	27,975		
U7	51,300	51,300	27,975	27,975	27,975		
U8	51,300	51,300	27,975	27,975	27,975		
AW		700	700	700	700		Application to Remove from License filed 9/27/2016
	622,500	623,200	409,600	422,212	421,255		

ATTACHMENT B

CONSULTATION DOCUMENTATION

Sokolowski, Rosana

Subject: FW: Draft FERC Letter For Rock Island B1-B4 Maintenance
Attachments: 2016_11_15 Chelan - Draft FERC B1-B4 Notification Letter.docx

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From: Keller, Lance
Sent: Tuesday, January 03, 2017 3:34 PM
To: Smith, Michelle
Subject: FW: Draft FERC Letter For Rock Island B1-B4 Maintenance

Hi Michelle,

Below is the email that was sent to the HCP Coordinating Committee regarding the Draft FERC notification letter. The letter was provided to the Committee Members on November 15, 2016 for a 30 day review by December 15, 2016. No comments or edits were received.

Thanks,

Lance Keller
Senior Fisheries Biologist
Chelan County PUD #1
Office: 509-661-4299
Cell: 509-669-8722
E-mail: lance.keller@chelanpud.org

From: Kristi Geris [mailto:kgeris@anchorqea.com]
Sent: Tuesday, November 15, 2016 8:49 AM
To: Bob Rose (rosb@yakamafish-nsn.gov); Jim Craig (jim_l_craig@fws.gov); John Ferguson; Keller, Lance; kirk.truscott@colvilletribes.com; Korth, Jeff (DFW) (Jeff.Korth@dfw.wa.gov); Kristi Geris; Scott Carlon; 'Tom Kahler (tkahler@dcpud.org)'
Cc: (Carmen.andonaegui@dfw.wa.gov); Aaron Beavers; Underwood, Alene; Bill Tweit; Dale Bambrick; Gallaher, Becky; Justin Yeager; Truscott, Keith; 'Mary Mayo'; Ritchie Graves; Shane Bickford (sbickford@dcpud.org); Hemstrom, Steven; Steve Parker; Verhey, Patrick M (DFW); 'william_gale@fws.gov'
Subject: FW: Draft FERC Letter For Rock Island B1-B4 Maintenance

Chelan County PUD IT Warning:
Please use caution! This is an external email with links or attachments.

Hi HCP-CC: please see the email below from Lance and the attached Draft FERC Letter For Rock Island B1-B4 Maintenance, to be discussed during today's CC 11/15 meeting.

The attached draft letter is also available for download from the HCP Coordinating Committees Extranet Site, under: Draft Documents > All by Mtg Date > 11/15/2016 (instructions below). Thanks! –kristi ☺

Instructions:

To gain access to the HCP Coordinating Committees Extranet Homepage, please use the following procedure:

* Visit: https://extranet.dcpud.net/sites/nr/hcpcc/
* Login using "Forms Authentication" (for non-Douglas PUD employees)

You should now be at the HCP CC homepage.

If you encounter problems, or need a login username and password to access the site:

Please feel free to contact me or Julene McGregor [jmcgregor@dcpud.org; (509) 881-2236] and we will gladly assist you with questions or issues.

Kristi Geris

ANCHOR QEA, LLC
kgeris@anchorqea.com
T 509.491.3151 x104
C 360.220.3988

From: Keller, Lance [mailto:Lance.Keller@chelanpud.org]
Sent: Tuesday, November 15, 2016 8:44 AM
To: Kristi Geris <kgeris@anchorqea.com>
Subject: Draft FERC Letter For Rock Island B1-B4 Maintenance

Good morning Kristi,

Attached for distribution to the HCP CC is Chelan's draft letter to FERC regarding the Rock Island B1-B4 maintenance. I will have hard copies to pass out at the meeting today.

Sorry about the late distribution,

Lance Keller
Senior Fisheries Biologist
Chelan County PUD #1
Office: 509-661-4299
Cell: 509-669-8722
E-mail: lance.keller@chelanpud.org



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(Draft 11/15/2016 – for HCP Coordinating Committee 30-day Review)

Ms. Kimberly D. Bose, Secretary
Federal Energy Regulatory Commission
888 First Street NE
Washington, DC 20426

Re: Rock Island Hydroelectric Project, FERC No. 943
Continuation of Rehabilitation Work (Units B1-B4)

Dear Secretary Bose:

As the Federal Energy Regulatory Commission (Commission or FERC) is aware, the Public Utility District No. 1 of Chelan County, Washington (Chelan PUD) has been engaged in a long-standing effort to rehabilitate the units in the First Powerhouse (PH1) at its Rock Island Hydroelectric Project, FERC No. 943 (Project). This effort began with the rehabilitation of Unit B10, which Chelan PUD completed in 2008,[1] followed by the completion of rehabilitation work for Unit B9 in 2012.[2] Chelan PUD originally advised the Commission of its planned rehabilitation of these units, together with Units B5, B6, and B7, in 2003.[3]

The purpose of this letter is to advise the Commission of its intent to continue its rehabilitation effort at the Project's PH1 by rehabilitating the turbine-generators for Units B1-B4. A detailed description of Chelan PUD's plans for Units B1-B4 appears below.

Consistent with how this rehabilitation program has progressed to date, and pursuant to Chelan PUD's consultation with Commission staff on April 29, 2016, prior Commission approval of the rehabilitation work for Units B1-B4 will not be required for this work. The rehabilitation of Units B1-B4 will not involve any change to the maximum hydraulic capacity of 220,000 cubic

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1 *Pub. Util. Dist. No. 1 of Chelan County*, 135 FERC ¶ 62,207 (2011) (acknowledging the completion of the Unit B10 rehabilitation and adjusting annual charges for the unit).

2 *See Pub. Util. Dist. No. 1 of Chelan County*, 146 FERC ¶ 62,055 (2014) (acknowledging the completion of the Unit B9 rehabilitation and adjusting annual charges for the unit).

3 *See* Letter from Charles J. Hosken, Public Utility District No. 1 of Chelan County, to Magalie R. Salas, Federal Energy Regulatory Commission, Project No. 943-000 (filed Oct. 29, 2003). As noted in Attachment A herein, Chelan PUD anticipates completing the rehabilitation for Units B5, B6 and B7 in the 2016-22 timeframe.

feet per second currently authorized under the Project's license, nor will it result in any increase in the Project's authorized installed capacity, which for each of these units is 20,700 kilowatts.[4] Moreover, because Chelan PUD will only be replacing equipment that is reaching the end of its useful life with comparable equipment, the rehabilitation of Units B1-B4 will not involve a "substantial change" or "substantial alteration" to the approved Project works under Standard Articles 2 and 3 of the Project license.[5]

Although no prior Commission approvals are required for this next phase of the rehabilitation program, Chelan PUD will continue to provide the Commission updates of its progress. After each turbine-generator unit is rehabilitated, Chelan PUD will notify the Commission of the date on which the rehabilitated unit went on line and its capacity in order to confirm whether there will be a need to revise the authorized installed capacity or annual charges for the Project. After rehabilitation work is completed, Chelan PUD will file "as-built" exhibits with the Commission.

In addition, as detailed below and in Attachment B, Chelan PUD has consulted with the Habitat Conservation Plan (HCP) Coordinating Committee, comprised of federal and state resource agencies and Tribes, regarding potential environmental effects of the rehabilitation work.

<u>Proposed Rock Island Rehabilitation</u>

Chelan PUD intends to rehabilitate the 20.7 MW Kaplan turbine-generators in the Rock Island PH1. These units have been in service since the early 1930s. The proposed rehabilitation work will begin in 2018 and continue through 2020. The following outlines the proposed work, schedule and environmental considerations. Attachment A provides Chelan PUD's estimated rehabilitation schedule for PH1.

The rehabilitation will not result in a change to generator nameplate or authorized project hydraulic capacity (220,000 cubic feet per second (cfs) or authorized capacity, 20,700 kilowatt (kW). No civil works will be necessary, including no changes to the diameter of the intake or draft tube discharge structures, height of wicket gates, or stator core. The units will continue to operate with fixed blades, the same conditions that met the Habitat Conservation Plan's no-net impact.

The rehabilitation will change the turbine horsepower (HP) from 32,000 HP to about 30,000 HP. The head for PH1 units will be updated to 39.7 feet to be consistent with other updated PH1 rehabilitated units and PH2. A smaller oil-free hub with no gaps will be installed, along with new fixed propeller runners optimized for the current operating head and flow. Currently, the units contain manually adjustable Nagler-type propeller turbines. The units will have more efficient four-blade turbines instead of six-blades. Governor controls will be replaced.

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4 *See* 18 C.F.R. § 4.201(b)

5 *See Pub. Util. Dist. No. 1 of Chelan County*, 46 FERC ¶ 61,033, at p. 61,208 (1989) (Ordering Paragraph (E), adopting Form L-5 into the license); *see also* 16 U.S.C. § 803(b) (prohibiting "substantial alteration or addition not in conformity with the approved plans . . . without the prior approval of the Commission"); *e.g.*, *International Falls Power Co.*, 66 FERC ¶ 61,086 at p. 61,114-17 (1994).

Upon installation and testing, revised best gate capacities for the units will be submitted to the Commission.

Estimated Schedule – Powerhouse 1

1. Unit B1 – 2020
2. Unit B2 – 2019
3. Unit B3 – 2019
4. Unit B4 – 2018

Environmental Considerations

The rehabilitation work will not adversely affect aquatic resources or Chelan PUD's obligations under the HCP. Modern turbine design with tighter operating tolerances and fixed blade angle positioned for optimum flow conditions supporting efficient power generation will benefit fish passage survival. Additionally, laminar flow conditions associated with peak generating capability equate to providing fish the best possible flow conditions for turbine route passage. In 2013, the HCP Coordinating Committee approved Chelan PUD's 2013 Comprehensive Progress Report that concluded Chelan PUD had reached no net impact at Rock Island with respect to all planned species.[6] Chelan PUD's achievement of no net impact in 2013 was successfully achieved while operating the vintage 1933 units. The proposed rehabilitation work will not alter the HCP Coordinating Committee's 2013 finding of no net impact and in fact, Chelan PUD anticipates that the new modern design of present day turbines will offer additional survival benefit of fish passing through the rehabbed B1-4 units. A project survival standard check-in study is scheduled for 2020 (post B1-4 rehab) to verify continued achievement of the juvenile survival standard. The schedule has all PH1 units in operation by April 2020 providing the best chance for success during the 2020 HCP check-in.

Consultation

Chelan PUD has kept the HCP Coordinating Committee apprised of maintenance work occurring at the Rock Island Project. On October 25, Chelan PUD Director of Engineering and Project Management, Brett Bickford provided the HCP Coordinating Committee an overview of maintenance work planned on Units B1-B4. On November 15, Chelan PUD provided a draft of this letter to the HCP Coordinating Committee for the agencies' and committee's comments. Documentation, including comments received and Chelan PUD responses are included in Attachment B.

Conclusion

Chelan PUD appreciates the support of Commission staff and federal and state resource agencies as it continues with this important rehabilitation program for the Rock Island Hydroelectric Project. Should you have any questions regarding this matter, please contact me.

---

[6] Statement of Agreement, Approval of Rock Island and Rocky Reach HCPs 2013 Comprehensive Progress Report (Approved February 26, 2013).

Regards,

Jeffrey G. Osborn
License Compliance Supervisor
Public Utility District No. 1 of Chelan County
jeff.osborn@chelanpud.org
(509) 661-4176

cc: FERC DHAC Director
FERC D2SI Director
FERC D2SI Regional Engineer

Attachment A: Table of Proposed Authorized Capacities
Attachment B: Consultation Documentation

ATTACHMENT A

ESTIMATED MAINTENANCE SCHEDULES AND CAPACITIES

Modified November 2016 by Chelan PUD to reflect estimated maintenance schedules and anticipated capacities for PH1 Units B1-4.

	License Issued 01/18/1989	**Amendment Issued 03/14/2002**	**Amendment Issued 09/22/2004**	**Amendment Issued 06/09/2011**	**Amendment Issued 01/24/2014**	**B1-B4 Rehab 2018-2020**	**Maintenance Schedule**
Units	Authorized Capacity kW	Authorized Capacity kW	Authorized Capacity kW	Authorized Capacity kW	Authorized Capacity kW	Authorized Capacity kW	
B1	15,000	15,000	20,700	20,700	20,700	20,700	2020
B2	20,700	20,700	20,700	20,700	20,700	20,700	2019
B3	20,700	20,700	15,000	20,700	20,700	20,700	2019
B4	20,700	20,700	20,700	20,700	20,700	20,700	2018
B5	22,500	22,500	18,000	22,500	22,500		2020/2021
B6	22,500	22,500	18,000	22,500	22,500		2017
B7	22,500	22,500	18,000	22,500	22,500		2017/18
B8	22,500	22,500	18,000	18,000	18,000		2021/2022
B9	22,500	22,500	18,000	15,312	14,355		Completed in 2012
B10	22,500	22,500	18,000	14,100	14,100		Completed in 2008
U1	51,300	51,300	27,975	27,975	27,975		2022
U2	51,300	51,300	27,975	27,975	27,975		2023
U3	51,300	51,300	27,975	27,975	27,975		2024
U4	51,300	51,300	27,975	27,975	27,975		2025
U5	51,300	51,300	27,975	27,975	27,975		2026
U6	51,300	51,300	27,975	27,975	27,975		2027
U7	51,300	51,300	27,975	27,975	27,975		2028
U8	51,300	51,300	27,975	27,975	27,975		2029
AW		700	700	700	700		Application to Remove from License filed 9/27/2016
	622,500	623,200	409,600	422,212	421,255		

ATTACHMENT B

CONSULTATION DOCUMENTATION

Sokolowski, Rosana

From: Clement, Marcie
Sent: Friday, January 06, 2017 3:41 PM
To: Smith, Michelle; Osborn, Jeff; Sokolowski, Rosana
Subject: FW: For your Review Please: Draft FERC B1-B4 Notification Letter

All,

I called Breean to check in with her regarding our response (see below) to her question regarding our B1-B4 notification letter. Breean said she did not have any further questions and that Ecology is good with us sending the letter to FERC, knowing that we will continue to keep them informed and coordinate within our projects to minimize TDG exceedances.

Thank you,

Marcie Clement | **Water Resources Specialist**
Public Utility District No.1 of Chelan County | 327 N. Wenatchee Ave. | Wenatchee, WA 98801
509.661.4186 (w) | 509.280.1955 (c) | marcie.clement@chelanpud.org

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From: Clement, Marcie
Sent: Tuesday, December 27, 2016 12:54 PM
To: 'Zimmerman, Breean (ECY)'; Peterschmidt, Mark F. (ECY)
Cc: Osborn, Jeff; Smith, Michelle; Sokolowski, Rosana
Subject: RE: For your Review Please: Draft FERC B1-B4 Notification Letter

Breean,

Thank you, for your comments and reviewing the letter so quickly. The units will be rehabbed one at a time, over a period of 3 to 4-years. We coordinate operations between Rocky Reach and Rock Island projects to minimize TDG levels. We will continue our efforts to minimize TDG and will keep you informed as we progress through the rehab work. We will also keep you informed of any TDG exceedances, if they develop. Please don't hesitate to email or call me with any additional questions.

Thank you,

Marcie Clement | **Water Resources Specialist**
Public Utility District No.1 of Chelan County | 327 N. Wenatchee Ave. | Wenatchee, WA 98801
509.661.4186 (w) | 509.280.1955 (c) | marcie.clement@chelanpud.org

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From: Zimmerman, Breean (ECY) [mailto:bzim461@ECY.WA.GOV]
Sent: Thursday, December 22, 2016 10:50 AM
To: Clement, Marcie; Peterschmidt, Mark F. (ECY)
Cc: Osborn, Jeff; Smith, Michelle
Subject: RE: For your Review Please: Draft FERC B1-B4 Notification Letter

Good morning,

My apologies for the delayed response. Thank you for the notification. I think I will defer to the fish agencies regarding propeller designs and such. However, my only comment, or question rather, is do you foresee any change in operations that could affect water quality, specifically higher spill with a lower generation capacity, since the rehab activity will likely be occurring outside of spill season when the facility must meet the 110%?

Otherwise, that's it from me.

Breean Zimmerman | **Hydropower Projects Manager**
Water Quality Program | Central Regional Office
(509) 575-2808 (w) | (509) 406-5130 (c) | bzim461@ecy.wa.gov

From: Clement, Marcie [mailto:Marcie.Clement@chelanpud.org]
Sent: Friday, December 16, 2016 12:30 PM
To: Peterschmidt, Mark F. (ECY) <MAPE461@ECY.WA.GOV>; Zimmerman, Breean (ECY) <bzim461@ECY.WA.GOV>
Cc: Osborn, Jeff <Jeff.Osborn@chelanpud.org>; Smith, Michelle <michelle.smith@chelanpud.org>
Subject: For your Review Please: Draft FERC B1-B4 Notification Letter

Mark and Breean,

Early January, we are planning to send FERC the attached notification letter related to rehabilitation of Rock Island Powerhouse 1 units B1 through B4. Even though we've provided you with updates related to the Rock Island rehab work, we wanted to make sure you and members of the HCP Coordinating Committee were given opportunity to review the letter before sending it to the FERC. We appreciate your time to review and provide any comments.

Thank you both, and please don't hesitate to call if you have any questions.

Marcie Clement | **Water Resources Specialist**
Public Utility District No.1 of Chelan County | 327 N. Wenatchee Ave. | Wenatchee, WA 98801
509.661.4186 (w) | 509.280.1955 (c) | marcie.clement@chelanpud.org

PUBLIC UTILITY DISTRICT NO. 1 *of* CHELAN COUNTY
P.O. Box 1231, Wenatchee, WA 98807-1231 • 327 N. Wenatchee Ave., Wenatchee, WA 98801
(509) 663-8121 • Toll free 1-888-663-8121 • www.chelanpud.org

(Draft – for Ecology and HCP Coordinating Committee Review)

Ms. Kimberly D. Bose, Secretary
Federal Energy Regulatory Commission
888 First Street NE
Washington, DC 20426

Re: Rock Island Hydroelectric Project, FERC No. 943
Continuation of Rehabilitation Work (Units B1-B4)

Dear Secretary Bose:

As the Federal Energy Regulatory Commission (Commission or FERC) is aware, the Public Utility District No. 1 of Chelan County, Washington (Chelan PUD) has been engaged in a long-standing effort to rehabilitate the units in the First Powerhouse (PH1) at its Rock Island Hydroelectric Project, FERC No. 943 (Project). This effort began with the rehabilitation of Unit B10, which Chelan PUD completed in 2008,[1] followed by the completion of rehabilitation work for Unit B9 in 2012.[2] Chelan PUD originally advised the Commission of its planned rehabilitation of these units, together with Units B5, B6, and B7, in 2003.[3]

The purpose of this letter is to advise the Commission of its intent to continue its rehabilitation effort at the Project's PH1 by rehabilitating the turbine-generators for Units B1-B4. A detailed description of Chelan PUD's plans for Units B1-B4 appears below.

Consistent with how this rehabilitation program has progressed to date, and pursuant to Chelan PUD's consultation with Commission staff on April 29, 2016, prior Commission approval of the rehabilitation work for Units B1-B4 will not be required for this work. The rehabilitation of Units B1-B4 will not involve any change to the maximum hydraulic capacity of 220,000 cubic

[1] *Pub. Util. Dist. No. 1 of Chelan County*, 135 FERC ¶ 62,207 (2011) (acknowledging the completion of the Unit B10 rehabilitation and adjusting annual charges for the unit).

[2] *See Pub. Util. Dist. No. 1 of Chelan County*, 146 FERC ¶ 62,055 (2014) (acknowledging the completion of the Unit B9 rehabilitation and adjusting annual charges for the unit).

[3] *See* Letter from Charles J. Hosken, Public Utility District No. 1 of Chelan County, to Magalie R. Salas, Federal Energy Regulatory Commission, Project No. 943-000 (filed Oct. 29, 2003). As noted in Attachment A herein, Chelan PUD anticipates completing the rehabilitation for Units B5, B6 and B7 in the 2016-22 timeframe.

feet per second currently authorized under the Project's license, nor will it result in any increase in the Project's authorized installed capacity, which for each of these units is 20,700 kilowatts.[4] Moreover, because Chelan PUD will only be replacing equipment that is reaching the end of its useful life with comparable equipment, the rehabilitation of Units B1-B4 will not involve a "substantial change" or "substantial alteration" to the approved Project works under Standard Articles 2 and 3 of the Project license.[5]

Although no prior Commission approvals are required for this next phase of the rehabilitation program, Chelan PUD will continue to provide the Commission updates of its progress. After each turbine-generator unit is rehabilitated, Chelan PUD will notify the Commission of the date on which the rehabilitated unit went on line and its capacity in order to confirm whether there will be a need to revise the authorized installed capacity or annual charges for the Project. After rehabilitation work is completed, Chelan PUD will file "as-built" exhibits with the Commission.

In addition, as detailed below and in Attachment B, Chelan PUD has consulted with the Habitat Conservation Plan (HCP) Coordinating Committee, comprised of federal and state resource agencies and Tribes, regarding potential environmental effects of the rehabilitation work.

Proposed Rock Island Rehabilitation

Chelan PUD intends to rehabilitate the 20.7 MW Kaplan turbine-generators in the Rock Island PH1. These units have been in service since the early1930s. The proposed rehabilitation work will begin in 2018 and continue through 2020. The following outlines the proposed work, schedule and environmental considerations. Attachment A provides Chelan PUD's estimated rehabilitation schedule for PH1.

The rehabilitation will not result in a change to generator nameplate or authorized project hydraulic capacity (220,000 cubic feet per second (cfs) or authorized capacity, 20,700 kilowatt (kW). No civil works will be necessary, including no changes to the diameter of the intake or draft tube discharge structures, height of wicket gates, or stator core. The units will continue to operate with fixed blades, the same conditions that met the Habitat Conservation Plan's no-net impact.

The rehabilitation will change the turbine horsepower (HP) from 32,000 HP to about 30,000 HP. The head for PH1 units will be updated to 39.7 feet to be consistent with other updated PH1 rehabilitated units and PH2. A smaller oil-free hub with no gaps will be installed, along with new fixed propeller runners optimized for the current operating head and flow. Currently, the units contain manually adjustable Nagler-type propeller turbines. The units will have more efficient four-blade turbines instead of six-blades. Governor controls will be replaced.

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4 *See* 18 C.F.R. § 4.201(b)

5 *See Pub. Util. Dist. No. 1 of Chelan County*, 46 FERC ¶ 61,033, at p. 61,208 (1989) (Ordering Paragraph (E), adopting Form L-5 into the license); *see also* 16 U.S.C. § 803(b) (prohibiting "substantial alteration or addition not in conformity with the approved plans . . . without the prior approval of the Commission"); *e.g., International Falls Power Co.*, 66 FERC ¶ 61,086 at p. 61,114-17 (1994).

Upon installation and testing, revised best gate capacities for the units will be submitted to the Commission.

Estimated Schedule – Powerhouse 1

1. Unit B1 – 2020
2. Unit B2 – 2019
3. Unit B3 – 2019
4. Unit B4 – 2018

Environmental Considerations

The rehabilitation work will not adversely affect aquatic resources or Chelan PUD's obligations under the HCP. Modern turbine design with tighter operating tolerances and fixed blade angle positioned for optimum flow conditions supporting efficient power generation will benefit fish passage survival. Additionally, laminar flow conditions associated with peak generating capability equate to providing fish the best possible flow conditions for turbine route passage. In 2013, the HCP Coordinating Committee approved Chelan PUD's 2013 Comprehensive Progress Report that concluded Chelan PUD had reached no net impact at Rock Island with respect to all planned species.[6] Chelan PUD's achievement of no net impact in 2013 was successfully achieved while operating the vintage 1933 units. The proposed rehabilitation work will not alter the HCP Coordinating Committee's 2013 finding of no net impact and in fact, Chelan PUD anticipates that the new modern design of present day turbines will offer additional survival benefit of fish passing through the rehabbed B1-4 units. A project survival standard check-in study is scheduled for 2020 (post B1-4 rehab) to verify continued achievement of the juvenile survival standard. The schedule has all PH1 units in operation by April 2020 providing the best chance for success during the 2020 HCP check-in.

Consultation

Chelan PUD has kept the HCP Coordinating Committee apprised of maintenance work occurring at the Rock Island Project. On October 25, Chelan PUD Director of Engineering and Project Management, Brett Bickford provided the HCP Coordinating Committee an overview of maintenance work planned on Units B1-B4. On November 15, Chelan PUD provided a draft of this letter to the HCP Coordinating Committee for the agencies' and committee's comments. Documentation, including comments received and Chelan PUD responses are included in Attachment B.

Conclusion

Chelan PUD appreciates the support of Commission staff and federal and state resource agencies as it continues with this important rehabilitation program for the Rock Island Hydroelectric Project. Should you have any questions regarding this matter, please contact me.

[6] Statement of Agreement, Approval of Rock Island and Rocky Reach HCPs 2013 Comprehensive Progress Report (Approved February 26, 2013).

Regards,

Jeffrey G. Osborn
License Compliance Supervisor
Public Utility District No. 1 of Chelan County
jeff.osborn@chelanpud.org
(509) 661-4176

cc: FERC DHAC Director
FERC D2SI Director
FERC D2SI Regional Engineer

Attachment A: Table of Proposed Authorized Capacities
Attachment B: Consultation Documentation

ATTACHMENT A

ESTIMATED MAINTENANCE SCHEDULES AND CAPACITIES

Modified November 2016 by Chelan PUD to reflect estimated maintenance schedules and anticipated capacities for PH1 Units B1-4.

	License Issued 01/18/1989	**Amendment Issued 03/14/2002**	**Amendment Issued 09/22/2004**	**Amendment Issued 06/09/2011**	**Amendment Issued 01/24/2014**	**Anticipated B1-B4 Rehab 2018-2020**	**Maintenance Schedule**
Units	Authorized Capacity kW	Authorized Capacity kW	Authorized Capacity kW	Authorized Capacity kW	Authorized Capacity kW	Authorized Capacity kW	
B1	15,000	15,000	20,700	20,700	20,700	20,700 n/c	2020
B2	20,700	20,700	20,700	20,700	20,700	20,700 n/c	2019
B3	20,700	20,700	15,000	20,700	20,700	20,700 n/c	2019
B4	20,700	20,700	20,700	20,700	20,700	20,700 n/c	2018
B5	22,500	22,500	18,000	22,500	22,500		2020/2021
B6	22,500	22,500	18,000	22,500	22,500		2017
B7	22,500	22,500	18,000	22,500	22,500		2017/18
B8	22,500	22,500	18,000	18,000	18,000		2021/2022
B9	22,500	22,500	18,000	15,312	14,355		Completed in 2012
B10	22,500	22,500	18,000	14,100	14,100		Completed in 2008
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U3	51,300	51,300	27,975	27,975	27,975		2024
U4	51,300	51,300	27,975	27,975	27,975		2025
U5	51,300	51,300	27,975	27,975	27,975		2026
U6	51,300	51,300	27,975	27,975	27,975		2027
U7	51,300	51,300	27,975	27,975	27,975		2028
U8	51,300	51,300	27,975	27,975	27,975		2029
AW		700	700	700	700		Application to Remove from License filed 9/27/2016
	622,500	623,200	409,600	422,212	421,255		

ATTACHMENT B

CONSULTATION DOCUMENTATION

STATE OF WASHINGTON
DEPARTMENT OF FISH AND WILDLIFE
1550 Alder St. N.W., Ephrata, Washington 98823 • (509) 754-4624 FAX (509) 754-5257

August 14, 2017

John Ferguson, Facilitator
Habitat Conservation Plan Coordinating Committee
720 Olive Way, Suite 1900
Seattle, WA 98101

Dear Mr. Ferguson:

This letter is to request a change in the Washington Department of Fish and Wildlife's (WDFW) staff representation on the Habitat Conservation Plan Coordinating Committee (HCP-CC).

Effective immediately, Chad Jackson (Region 2 Fish Program Manager) will serve as WDFW's primary voting member on the HCP-CC. Patrick Verhey (Energy and Major Project Section Biologist) will serve as WDFW's alternate voting member on the HCP-CC.

Additionally, I would like to add Mike Tonseth (Upper Columbia ESA/HCP Biologist) to the list of HCP-CC attendees. Mike's role will be as technical advisor to Chad and Patrick. Finally, please make sure Chad, Patrick, and Mike are added to the HCP-CC email distribution list and receive access to the document repository. If any additional process or procedures are required to process my request, please let me know.

Thank you for your assistance.

Sincerely,

Jim Brown
WDFW Region 2 Director

Cc: Chad Jackson
Patrick Verhey
Mike Tonseth
Bill Tweit
Alene Underwood (Chelan PUD)
Tom Kahler (Douglas PUD)

FINAL

720 Olive Way, Suite 1900
Seattle, Washington 98101
206.287.9130

ANCHOR QEA

Memorandum

To: Wells, Rocky Reach, and Rock Island HCP Coordinating Committees

Date: October 25, 2017

From: John Ferguson, HCP Coordinating Committees Chairman

cc: Kristi Geris

Re: Final Minutes of the September 26, 2017, HCP Coordinating Committees Conference Call

The Wells, Rocky Reach, and Rock Island Hydroelectric Projects Habitat Conservation Plan (HCP) Coordinating Committees met by conference call on Tuesday September 26, 2017, from 10:00 to 11:30 a.m. Attendees are listed in Attachment A to these conference call minutes.

Action Item Summary

- Chelan PUD will provide a Rocky Reach Dam large unit repair update during the HCP Coordinating Committees meeting on October 24, 2017 (Item I-C).
- Kristi Geris will coordinate with Tracy Hillman and will notify the HCP Coordinating Committees of the date the HCP Hatchery Committees plan to tour the new Wells Fish Hatchery (tentatively scheduled for November 2017; Item II-A).
- Lance Keller will evaluate how well the percentage of the fish run covered by annual spill based on daily fish bypass index counts, which is the current approach used to estimate the percentage, compares to the percentage estimated using detections of passive integrated transponder (PIT)-tagged fish passing through the juvenile fish bypass system at Rocky Reach Dam (Item III-A).
- Douglas PUD will present Pacific Lamprey and salmonid count data for the time period when Lamprey Operations were implemented at Wells Dam (September 1 through September 30, 2017) during the HCP Coordinating Committees meeting on October 24, 2017 (Item IV-A).
- Kristi Geris will contact Mackenzie Gavery (Postdoctoral Research Associate, University of Washington/National Oceanic and Atmospheric Administration [NOAA] Northwest Fisheries Science Center) to confirm a 10:00 a.m. start time to present her epigenetics research during the HCP Coordinating Committees meeting on October 24, 2017 (Item V-B). *(Geris contacted Gavery, who confirmed she can present at the proposed 10:00 a.m. start time.)*
- Kristi Geris will coordinate with Tracy Hillman and will notify the HCP Coordinating Committees of the WebEx and call-in number to attend a presentation by Barry Berejikian (NOAA Northwest Fisheries Science Center) regarding his ongoing research on steelhead in Hood Canal and how it might apply to steelhead hatchery issues in the Twisp River, during the HCP Hatchery Committees meeting on October 18, 2017 (Item V-B). *(Sarah Montgomery*

distributed the agenda with this information to the HCP Coordinating Committees on October 17, 2017.)

- The HCP Coordinating Committees meeting on October 24, 2017, will be held in-person at the Grant PUD office in Wenatchee, Washington (Item V-B).

Decision Summary

- There were no HCP Decision Items approved during today's conference call.

Agreements

- There were no HCP Agreements discussed during today's conference call.

Review Items

- Sarah Montgomery (HCP Hatchery Committees Support Staff) sent an email to the HCP Coordinating Committees on September 15, 2017, notifying them the Draft 2017 Rock Island and Rocky Reach Fish Spill Program Report is available for review. Edits and comments on the report are due to Lance Keller by Monday, October 16, 2017 (Item III-B).

Finalized Documents

- There are no documents that have been recently finalized.

I. Welcome

A. Review Agenda (John Ferguson)

John Ferguson welcomed the HCP Coordinating Committees and reviewed the agenda. Ferguson asked for any additions or changes to the agenda. Lance Keller removed the Rock Island Powerhouse Maintenance Update, because no updates are available at this time. Keller said Chelan PUD will present updates on the maintenance to the HCP Coordinating Committees when key updates and information become available.

B. Meeting Minutes Approval (John Ferguson)

The HCP Coordinating Committees reviewed the revised draft August 22, 2017 meeting minutes. Kristi Geris said a third revised version of the minutes were distributed to the HCP Coordinating Committees prior to the conference call on September 26, 2017. She said new revisions were from Tom Kahler, which are tracked in redline strikeout, and mainly applied to the Aquatic Settlement Work Group (SWG) Lamprey Operations Statement of Agreement (SOA) discussion. Geris said there was also one other revision regarding a comment by Mike Tonseth under the HCP Hatchery

Committees update, which Tonseth clarified. HCP Coordinating Committees members present approved the August 22, 2017 meeting minutes, as revised.

C. Last Meeting Action Items (John Ferguson)

Action items from the HCP Coordinating Committees meeting on August 22, 2017, and follow-up discussions, were as follows. *(Note: italicized text corresponds to agenda items from the meeting on August 22, 2017):*

- *Bob Rose will coordinate internally to develop and provide a Yakama Nation (YN) HCP Representation Designation document for distribution to the HCP Coordinating Committees (Item I-C).*
  Rose provided a designation letter to Kristi Geris following the HCP Coordinating Committees meeting on August 22, 2017, which Geris distributed to the HCP Coordinating Committees on August 23, 2017.
- *Kristi Geris will coordinate with Tracy Hillman and Sarah Montgomery to obtain meeting and WebEx information for Jeff Jorgensen's (NOAA Northwest Fisheries Science Center) presentation to the HCP Hatchery Committees on September 20, 2017, on a life-cycle model for Wenatchee River spring Chinook salmon, which Geris will distribute to the HCP Coordinating Committees (Item I-C).*
  Montgomery distributed this information, as described in the agenda for the HCP Hatchery Committees meeting on September 20, 2017, to the HCP Coordinating Committees on September 19, 2017.
- *Chelan PUD will provide a Rocky Reach Dam large unit repair update during an HCP Coordinating Committees meeting in late-summer 2017 (Item I-C).*
  This action item will be carried forward and discussed during the HCP Coordination Committees meeting on October 24, 2017.
- *John Ferguson will provide the paper, "The evolutionary basis of premature migration in Pacific salmon highlights the utility of genomics for informing conservation," by Daniel Prince et al., to Kristi Geris and Tracy Hillman for distribution to the HCP Coordinating and Hatchery Committees (Item II-A).*
  Ferguson provided the paper to Geris and Hillman following the HCP Coordinating Committees meeting on August 22, 2017, which Hillman distributed to the HCP Hatchery Committees that same day and Geris distributed to the HCP Coordinating Committees on August 23, 2017.
- *Tom Kahler will discuss internally the feasibility to implement a temporary 1.0-foot fishway-entrance head differential from 22:00 to 04:00 daily during September 2017 to improve Pacific Lamprey passage at Wells Dam ("lamprey operations"), in 1- or 2-day blocks (Item IV-A).*

Kahler confirmed Wells Dam can accommodate the 2-day block design for head differentials at the fishway entrances, as distributed to the HCP Coordinating Committees by Kristi Geris on August 25, 2017.

- *Anchor QEA will coordinate with Douglas PUD and the Aquatic Settlement Work Group (Aquatic SWG) regarding the Wells HCP Coordinating Committee discussion and HCP Decision about the Aquatic SWG Lamprey Operations SOA (Item IV-A).*
  The Aquatic SWG convened a conference call on August 28, 2017, to discuss the HCP Decision about the Aquatic SWG Lamprey Operations SOA.
- *Chelan PUD will provide a Rock Island Dam Powerhouse 1 Turbine Units B1 to B4 Rehabilitation Fact Sheet to Kristi Geris for distribution to the HCP Coordinating Committees (Item V-A).*
  Lance Keller provided the rehabilitation work submittal to Geris on August 23, 2017, which Geris distributed to the HCP Coordinating Committees that same day.
- *Anchor QEA will contact Mackenzie Gavery regarding possibly presenting her epigenetics research during the HCP Coordinating Committees meeting on October 24, 2017 (Item VI-B).*
  Gavery confirmed she can present her research in-person during the HCP Coordinating Committees meeting on October 24, 2017.

II. HCP Tributary and Hatchery Committees Update

A. HCP Tributary and Hatchery Committees Update (Tracy Hillman)

Tracy Hillman reported that the HCP Tributary Committees did not meet in September 2017 and will next meet on October 12, 2017, if necessary.

Hillman updated the HCP Coordinating Committees on the following actions and discussions that occurred during the HCP Hatchery Committees meeting on September 20, 2017:

- *DECISION: Chelan PUD Coho Salmon Mitigation SOA*: Chelan PUD requested approval of their Coho Salmon Mitigation SOA; however, the Colville Confederated Tribes (CCT) asked for additional time to discuss the SOA internally, as well as with the YN. The CCT may propose revisions to the SOA for review during the HCP Hatchery Committees meeting on October 18, 2017.
- *Tumwater Feasibility Study for Pacific Lamprey Update*: Chelan PUD has been working on a feasibility study for Pacific lamprey passage at Tumwater Dam. The contractor is currently addressing questions received from Chelan PUD, and an updated study will be available for review to the fish forums and HCP Coordinating Committees in October 2017. Hillman added that Chelan PUD and the Washington Department of Fish and Wildlife (WDFW) observed adult Pacific lamprey passing the count window at Tumwater Dam. Hillman said about 14 adults had been observed as of September 20, 2017. Jim Craig asked about fish management at the dam,

specifically, if managers were routing passage through the denil. Hillman said these fish passed during non-trapping times; however, WDFW does have video of adult Pacific lamprey passing via the denil and trapping structure. John Ferguson asked about a total count to date, but Hillman said he is uncertain about counts after September 20, 2017. Hillman also noted that the YN had been conducting Pacific lamprey translocation efforts in the Wenatchee River basin the week of, and the week preceding, the HCP Hatchery Committees meeting.

- *Transition Plan for Douglas PUD Hatcheries:* Douglas PUD notified the HCP Hatchery Committees that they terminated their contract with WDFW to operate the Wells and Methow fish hatcheries. The termination includes a 90-day transition period per the contract, which may be extended. During the meeting, parties to the HCPs made it clear they would like to see a longer transition period. Douglas PUD indicated they are not opposed to a longer period (e.g., 120 days); however, no determination to extend the transition period has been made. Douglas PUD is in the process of hiring new hatchery staff and drafting a transition plan. The Wells HCP Hatchery Committee indicated they want Douglas PUD to coordinate with the Committee during the transition. Douglas PUD will continue contracting with WDFW for hatchery monitoring and evaluation (M&E) work.
- *Wells Fish Hatchery Modernization:* The Wells Fish Hatchery Modernization project is nearly complete. Douglas PUD extended the contract end date past August 31, 2017, so the contractor can finish a few minor items. The HCP Hatchery Committees will visit the facility this fall. Ferguson said Kristi Geris will coordinate with Hillman and will notify the HCP Coordinating Committees of the date the HCP Hatchery Committees plan to tour the new Wells Fish Hatchery. Hillman noted that this will likely take place in November 2017.
- *U.S. Fish and Wildlife Service Bull Trout Consultation Update*: The U.S. Fish and Wildlife Service (USFWS) completed edits and responses to comments on the Biological Opinion (BiOp) for the Wenatchee subbasin programs. The BiOp is now undergoing USFWS internal review.
- *National Marine Fisheries Service Consultation Update*: The National Marine Fisheries Service (NMFS) intends to finish the proposed action for the Upper Columbia River unlisted summer Chinook salmon programs. NMFS is now incorporating edits and comments received from reviewers.
- *PRESENTATION: Wenatchee Spring Chinook Salmon Life Cycle Modeling*: Jeff Jorgensen presented the Wenatchee spring Chinook salmon life-cycle model, which is a tool that NOAA and their collaborators are developing to understand the effects of habitat, predation (avian and pinnipeds), dams, hatchery, harvest, and climate on salmon survival. The model is a complex matrix model, which tracks salmon survival and abundance throughout their life cycle. The hatchery component of the model includes proportionate natural influence (PNI) targets, proportion of hatchery-origin spawners, hatchery-origin recruits, and natural-origin recruits. Based on results from the relative reproductive success studies, the model applies a

progeny discount depending on PNI scores. Jorgensen shared results of different model runs, and among the scenarios modeled, hatcheries, pinniped predation, and ocean conditions had relatively large effects on salmon survival and quasi-extinction risk. Jorgensen concluded by talking about further additions to the model, including juvenile Chinook salmon survival in Lake Wenatchee, egg-to-fry and fry-to-parr survival, and developing a better model to predict continuous stream temperatures in space and time. Hillman said the HCP Hatchery Committees provided Jorgenson with feedback, and they may ask Jorgenson to run a few scenarios to help the Committees with their studies. Ferguson asked if this Wenatchee spring Chinook salmon life-cycle model can be considered as up and running, calibrated, and usable now, and Hillman said it is. Hillman said NOAA is still working to improve the model, but the model is already producing results. Hillman also noted that the development of the Wenatchee model has more data available than other models in other river basins, as a result of PUD-funded hatchery M&E programs and Bonneville Power Administration-funding.

- *Draft 2017 Hatchery M&E Plan for PUD Hatchery Programs Update*: The HCP Hatchery Committees are currently reviewing revisions to the Hatchery M&E Plan, including changes to the adaptive management and Non-Target Taxa of Concern sections. Hillman is currently drafting an appendix to the Hatchery M&E Plan titled, "Estimation of Carrying Capacity." The HCP Hatchery Committees will review the appendix during the HCP Hatchery Committees meeting on October 18, 2017. The Committees hope to finalize the plan and share it with the Independent Scientific Advisory Board.
- *Next meeting*: The next meeting of the HCP Hatchery Committees will be on October 18, 2017.

III. Chelan PUD

A. Draft 2017 Rock Island and Rocky Reach Fish Spill Program Report (Lance Keller and Thad Mosey)

Lance Keller said Thad Mosey (Chelan PUD Fish Biologist and Spill Coordinator) will present the Draft 2017 Rock Island and Rocky Reach Fish Spill Program Report (Attachment B), which was distributed to the HCP Coordinating Committees by Sarah Montgomery on September 15, 2017.

Spring Spill – Rock Island

Mosey said the juvenile fish bypass system at Rock Island Dam was operational on March 29, 2017. He said over-under gates were installed, which are designed to allow full river flow to pass through the gates. He said, as in previous years, he expected to observe an increase in sockeye salmon numbers once the bypass was operational; however, this was not the case this year with sockeye salmon, Chinook salmon, or steelhead. He said numbers eventually did increase by April 14, 2017, and upstream hatchery releases were scheduled to start April 15, 2017. He said based on this information, he felt confident to start spring spill on April 17, 2017. Mosey said he kept in touch with the bypass crew over the weekend preceding April 17, 2017, and numbers increased significantly. He said to ensure all fish spill gates were being employed, he had the operators incorporate six notch spill gates. He said even with hydraulic spill, spring spill at Rock Island Dam officially started on April 16, 2017, and he noted that the percent of run targets were met. He said if spring spill had started on April 17, 2017, as initially estimated, the percent of run with spill targets would have been missed. He then reviewed the spring spill data for Rock Island Dam presented in Attachment B.

Summer Spill – Rock Island and Rocky Reach

Mosey said in early May 2017, Chelan PUD began monitoring daily counts of subyearling Chinook smolts at both the Rock Island and Rocky Reach Juvenile Fish Bypass Facilities. He said Chelan PUD was also coordinating with the CCT and Douglas PUD regarding upcoming fish releases. Mosey recalled that the 2017 Rock Island and Rocky Reach Fish Spill Plan states, "summer spill will start at midnight no later than the day on which the estimated 1-percentile passage point is reached." He said on May 25, 2017, it appeared that counts of subyearlings at both facilities had reached 1%; therefore, summer spill at Rock Island Dam and Rocky Reach Dam officially started on May 26, 2017.

Mosey reviewed the summer spill data for Rock Island and Rocky Reach dams presented in Attachment B. He said summer spill operations at Rock Island and Rocky Reach dams ended on August 18 and 25, 2017, respectively, after meeting the criteria of covering 95% of the subyearling outmigration and subyearling index counts from the corresponding juvenile bypass sampling facility were 0.3 percent of the cumulative run for 3 of 5 consecutive days.

Mosey said, despite the hydraulic spill at Rock Island Dam from March to late-June 2017, the spring and summer spill programs at Rock Island and Rocky Reach dams went smoothly this year with regard to monitoring numbers and coordination with dam operators.

Kirk Truscott asked if there is a comment period open for this report. Kristi Geris said based on the distribution date, a 30-day comment period means edits and comments on the report are due to Keller by Monday, October 16, 2017.

Truscott asked if the percentage of the fish run covered by annual spill is based on daily fish bypass index counts. Keller said this is correct. Truscott noted that there is also a database of PIT-tagged fish passing through the juvenile fish bypass system at Rocky Reach Dam. Keller said this is also correct. Truscott asked, how well do these two data sources correspond to one another? Keller said he does not have this information available at this time; however, he will evaluate the data and provide a response to Geris for distribution to the HCP Coordination Committees.

IV. Douglas PUD

A. Wells Dam Fishway Operations for Pacific Lamprey Update (Tom Kahler)

Tom Kahler said he just emailed Pacific lamprey data from Wells Dam showing block comparisons (Attachment C) to Kristi Geris, which Geris forwarded to the HCP Coordinating Committees during the meeting on September 26, 2017. Kahler said 4 of 5 blocks[1] have been implemented to date[2]. He said the Pacific lamprey run at Wells Dam has already peaked and is now tapering off.

Kahler said most fish seem to be passing between 00:00 and 10:00. He said there are some differences in passage from the 1-foot to 1.5-foot head differentials, with more fish tending to be counted under the normal 1.5-foot head operation; however, the differences were subtle. He noted that around 05:00 to 06:00 passage is increasing, and then drops at the 1-foot head differential, but peaks at the 1.5-foot head differential. He recalled that if there seemed to be an alarming interference with passage, these block operations would be discontinued; however, he said nothing alarming has been observed to date.

John Ferguson agreed with Kahler's comments, and added that the emails exchanged within the Aquatic SWG are reporting similar findings. Ferguson said there does not seem to be an apparent pattern between block and normal operations; although, he did note a slight difference in the 06:00 to 08:00 hour period.

Kahler said civil twilight during September is around 20:00 to 21:00. He said if darkness is a cue to start entering and ascending the fish ladder, and if what was concluded from the radio-telemetry studies is accurate (i.e., under the 1-foot head differential fish more readily passed through the lower portion of the fish ladder), then one would expect to see a pattern of more fish passing the count windows in hours 01:00 to 04:00 during the 1.0-foot operations because those fish would have entered the fishways during the normal operating differential (hours 20:00-22:00), but would have more readily ascended the lower ladder once the 1.0-foot-differential operations commenced at 22:00 hours.

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[1] Note: A block equals three consecutive days where the Wells Dam fishway entrances are operated at a head differential of 1.0 foot (versus the usual 1.5 foot), from 22:00 to 04:00 daily. On days between the blocks, the fishway entrances are operated at a normal head differential of 1.5 foot.

[2] Note: Block 1 = September 1 to 3; Block 2 = September 7 to 9; Block 3 = September 13 to 15; Block 4 = September 19 to 21; and Block 5 = September 25 to 27, 2017.

Kirk Truscott said about 260 Pacific lamprey passed Wells Dam, and he asked how this compares to the overall conversion between Rocky Reach and Wells dams. Kahler said there were about 23,000 Pacific lamprey counted at Rocky Reach Dam, so the conversion is miniscule (about 0.01 percent).

Kahler said Douglas PUD will present Pacific Lamprey and salmonid count data for the time period when Lamprey Operations were implemented at Wells Dam (September 1 through September 30, 2017), during the HCP Coordinating Committees meeting on October 24, 2017.

B. Transition Plan for Douglas PUD Hatcheries (Tom Kahler)

Tom Kahler said Douglas PUD already contacted and has had conversations with the individual Wells HCP Coordinating and Hatchery Committees representatives prior to this conference call. He said this agenda item was requested by Bob Rose, who is not in attendance today. Kahler said he is open to further discuss anything the Committee members would like to hear about.

John Ferguson asked for an update on the Douglas PUD transition plan. Kahler said the transition plan is currently under internal review and it should be available for distribution by the end of the week. He said Douglas PUD provided the transition plan's table of contents to the HCP Hatchery Committees for review. He said Douglas PUD asked the HCP Hatchery Committees to let them know if the table of contents is missing anything. He said no comments have been received to date. He said if no comments are received, Douglas PUD plans to proceed with the plan, as written.

Kahler said the hiring process is underway for hatchery staffing, with the idea to have hatchery supervisors in place first, and have them fully engaged in filling the rest of the positions with the best qualified staff.

Kahler said Douglas PUD plans to continue their current hatchery M&E contract with WDFW. He said the idea is to have Douglas PUD and WDFW M&E personnel continuing to work together in the same roles they have had, with potentially additional roles arising. He said maintaining the hatchery M&E contract with WDFW is very practical. He said this is a role WDFW has already played, and they have a very intimate knowledge of the M&E components. He said Douglas PUD has had a great working relationship with these folks.

Ferguson asked about extending the 90-day transition period to 120 days. Kahler said 90 days is stipulated in the contract, which is why Douglas PUD is operating under this timeframe. He said Douglas PUD is also open to extending the timeframe. He said there is a lot to accomplish in 90 days, which is doable; however, additional time may be more comfortable. He said he is unaware of an offer from WDFW for a longer transition period.

Chad Jackson said WDFW looks forward to seeing Douglas PUD's transition plan at the end of this week. Jackson said WDFW has been waiting on this plan before appointing a point of contact for the transition and proposing an extended time period. Kahler said he did not believe the transition plan is a prerequisite for establishing a point person; however, Douglas PUD will conform, as needed.

Ferguson invited Commissioner Dave Graybill (WDFW) to ask questions and provide his perspectives. Commissioner Graybill said WDFW is eager to work with Douglas PUD. He said the concern is that WDFW does not yet have enough details to fully understand the process. He said the Wells facility and the HCP Plan species being reared there are precious resources. He said WDFW will be watched very carefully, and this transition needs to be executed carefully. He said he is glad to hear that Douglas PUD, from his perspective, agrees this is not a 90-day process. He said once WDFW has received Douglas PUD's transition plan, a point of contact for WDFW will be established.

Ferguson asked if WDFW has been discussing who might be the person to assign the point of contact after receiving the transition plan. Jackson said a specific staff member has not yet been identified. He said there are a number of potential staff persons; however, selecting the most appropriate person depends on the details (e.g., how much work this will entail). He said WDFW is already thinking about this, but needs more details on the transition plan.

V. HCP Administration

A. Extranet Access for Sarah Montgomery (John Ferguson)

John Ferguson said Sarah Montgomery was given administrative access to the HCP Coordinating Committees Extranet site from Julene McGregor (Douglas PUD Information Systems Staff), in order to provide back-up assistance for Kristi Geris. Geris recalled that historically, administrative support staff have been added to email distribution lists and given extranet access without HCP Coordinating Committees approval. Ferguson asked if the HCP Coordinating Committees had any concerns about this, and no concerns were expressed.

B. Next Meetings

The next scheduled HCP Coordinating Committees meeting is on October 24, 2017, to be held in-person at the Grant PUD Wenatchee Office in Wenatchee, Washington.

John Ferguson recalled that Mackenzie Gavery accepted the invitation to present her epigenetics research during the HCP Coordinating Committees meeting on October 24, 2017. The HCP Coordinating Committees proposed a 10:00 a.m. start time for Gavery's presentation, with the monthly HCP Coordinating Committees meeting to follow. Kristi Geris will contact Gavery to confirm a 10:00 a.m. start time will work for her. *(Geris contacted Gavery, who confirmed she can present at the proposed 10:00 a.m. start time.)*

Tom Kahler said the HCP Hatchery Committees invited Barry Berejikian (NOAA Northwest Fisheries Science Center) to discuss his ongoing research on steelhead in Hood Canal and how it might apply to steelhead hatchery issues in the Twisp River, during the HCP Hatchery Committees meeting on October 18, 2017. Kahler suggested that HCP Coordinating Committees members also attend the meeting, if interested. Geris will coordinate with Tracy Hillman and will notify the HCP Coordinating Committees of the WebEx and call-in number to attend a presentation by Berejikian.

The November 28, 2017, December 26, 2017, and January 23, 2018, meetings will be held by conference call or in-person at the Grant PUD Wenatchee Office in Wenatchee, Washington, as is yet to be determined.

VI. List of Attachments

Attachment A	List of Attendees
Attachment B	Draft 2017 Rock Island and Rocky Reach Fish Spill Program Report
Attachment C	Pacific lamprey data from Wells Dam showing block comparisons

Attachment A
List of Attendees

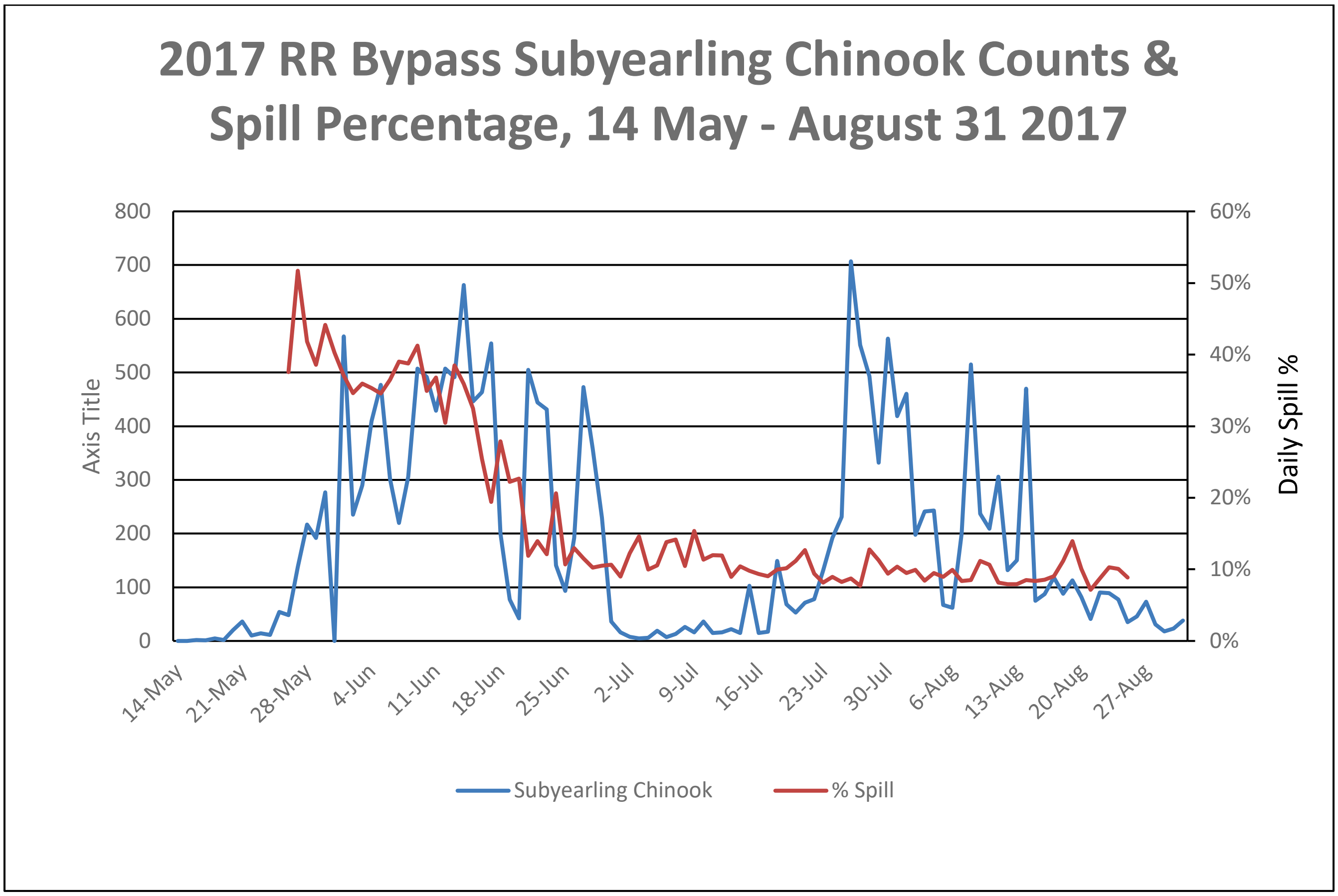
Name	Organization
John Ferguson	Anchor QEA, LLC
Kristi Geris	Anchor QEA, LLC
Tracy Hillman	BioAnalysts
Lance Keller*	Chelan PUD
Thad Mosey	Chelan PUD
Tom Kahler*	Douglas PUD
Scott Carlon*	National Marine Fisheries Service
Jim Craig*	U.S. Fish and Wildlife Service
Chad Jackson*	Washington Department of Fish and Wildlife
Patrick Verhey*	Washington Department of Fish and Wildlife
Commissioner Dave Graybill	Washington Department of Fish and Wildlife
Mike Tonseth	Washington Department of Fish and Wildlife
Kirk Truscott*	Colville Confederated Tribes

Notes:
* Denotes HCP Coordinating Committees member or alternate

Chelan PUD
Rocky Reach and Rock Island HCPs
Draft 2017 Fish Spill Report

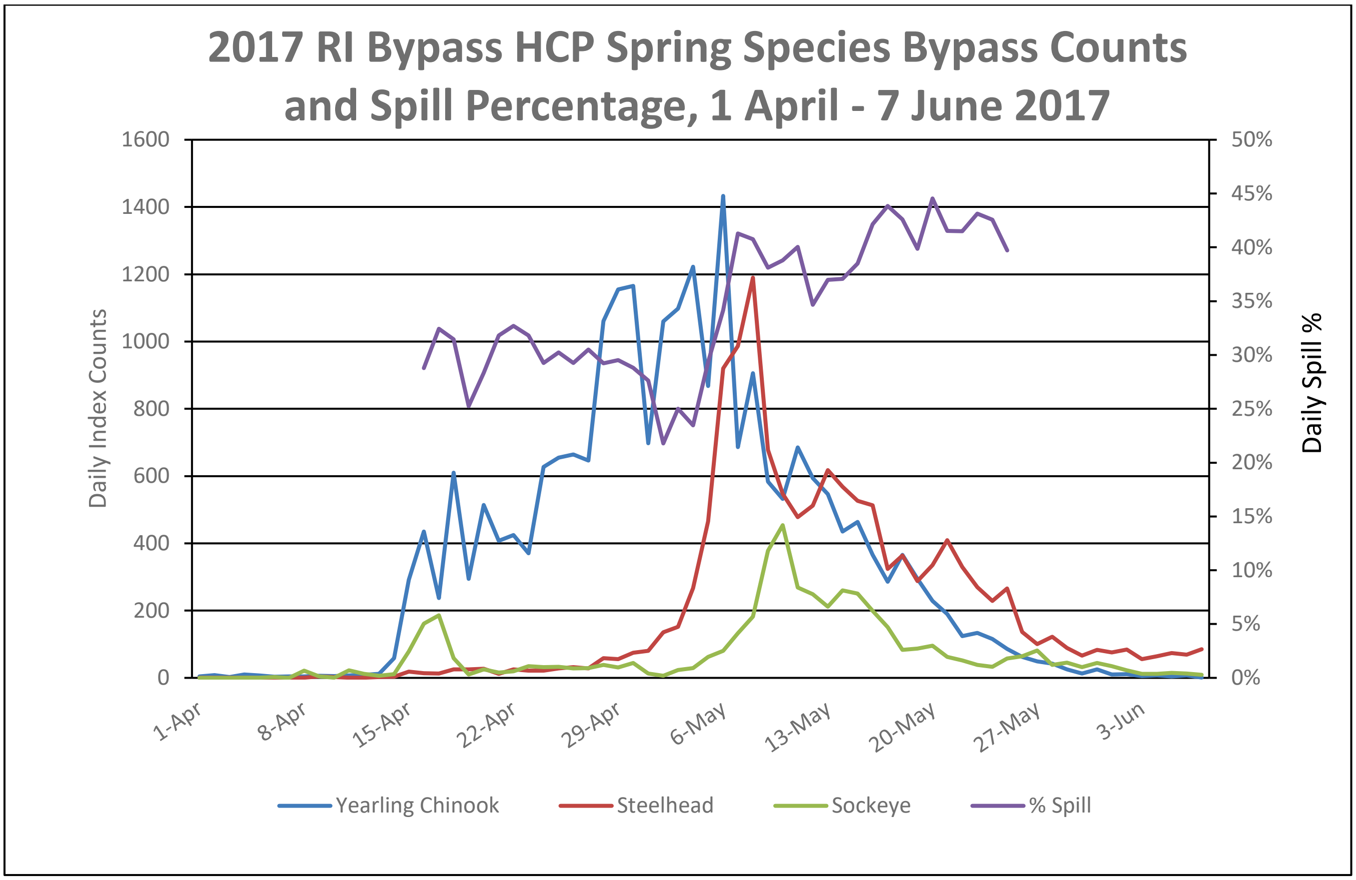
2017 ROCKY REACH
Summer Spill

Target species:	Subyearling Chinook
Spill target percentage:	9% of day average river flow
Spill start date:	26 May, 0001 hours
Spill stop date:	25 August, 2400 hours
95% Est. passage date:	14 August
Percent of run with spill:	98.5% on 25 August (estimated as of 31 August)
Cumulative index count:	27,404 subyearling Chinook (as of 31 August)
Summer spill percentage:	21.74% (9.06% fish spill, plus 12.68% forced spill)
Avg river flow at RR:	149,598 cfs (26 May - 25 August)
Avg spill rate at RR:	32,518 cfs (26 May - 25 August)
Total spill days:	92



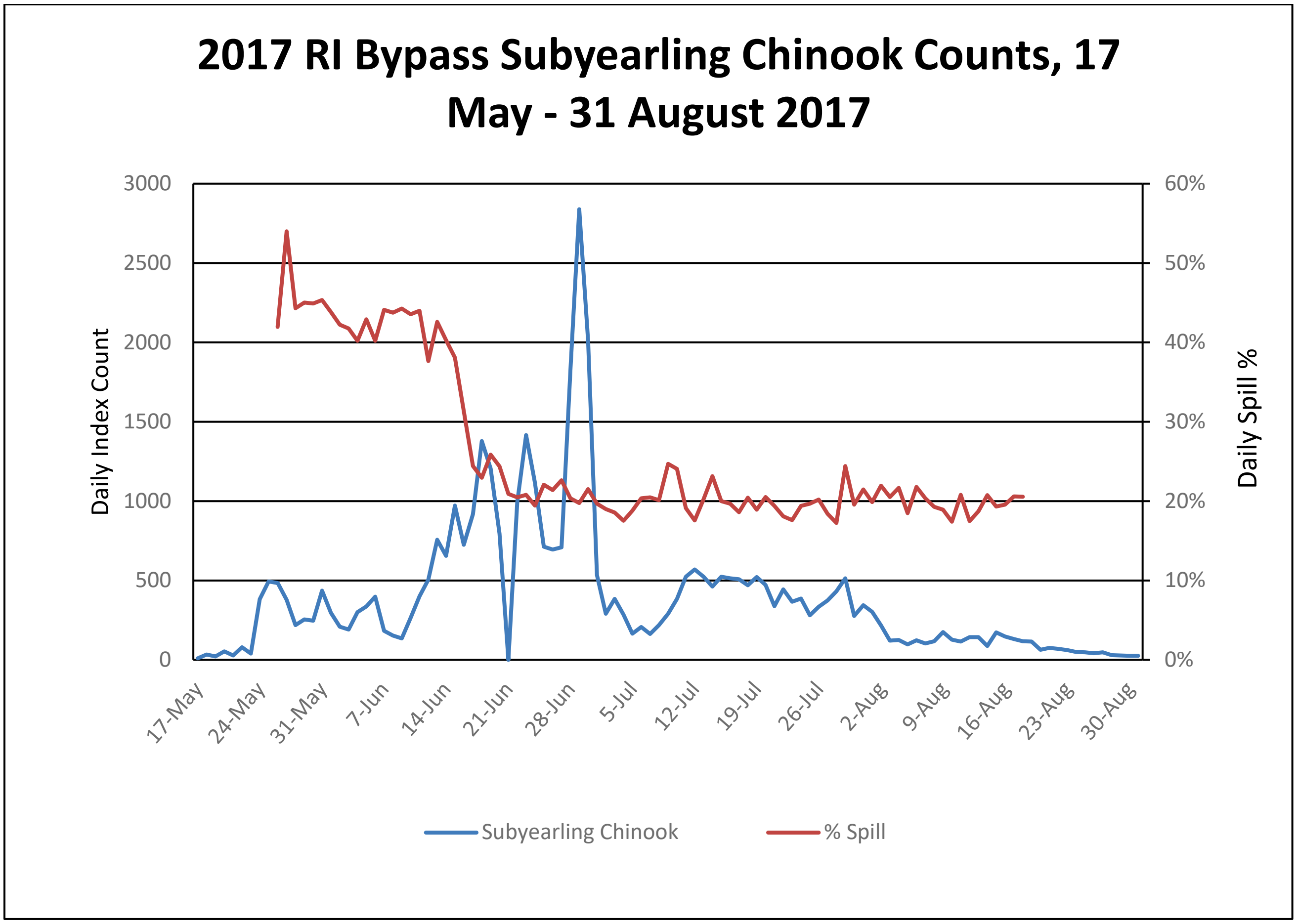
<u>2017 ROCK ISLAND</u>
Spring Spill

Target species:	Yearling Chinook, steelhead, sockeye
Spill target percentage:	10% of day average river flow
Spill start date:	16 April, 0001 hours
Spill stop date:	25 May, 2400 hours (immediate increase to 20% summer spill)
Percent of run with spill:	Yearling Chinook – 98.4%; steelhead – 99.8%; sockeye – 97.0% (spring and summer fish spill combined)
Cumulative index count:	50,604 yearling Chinook**;** 32,135 steelhead**;** 11,117 sockeye (as of 31 August)
Spring spill percentage:	35.22% (9.69% fish spill, plus 25.53% forced spill)
Avg river flow at RI:	227,790 cfs (16 April – 25 May)
Avg spill flow at RI:	80,222 cfs (16 April – 25 May)
Total spill days:	40



Summer Spill

Target species:	Subyearling Chinook
Spill target percentage:	20% of day average river flow
Spill start date:	26 May, 0001 hours
Spill stop date:	18 August, 2400 hours
95% Est. passage date:	5 August
Percent of run with spill:	97.5% on 18 August (estimated as of 31 August)
Cumulative index count:	63,579 subyearling Chinook (as of 31 August)
Summer spill percentage**:**	29.47% (19.89% fish spill, plus 9.58% forced spill)
Avg river flow at RI:	162,085 cfs (26 May - 18 August)
Avg spill flow at RI:	47,774 cfs (26 May - 18 August)
Total spill days:	85



Juvenile Index Counts 2007-2017 from the Rocky Reach Juvenile Fish Bypass Sampling Facility and Rock Island Bypass Trap Smolt Monitoring Program (SMP) 1 April – 31 August (Tables 1 and 2).

Table 1. Rocky Reach Juvenile Bypass index sample counts, 2007-2017

Species	2007	2008	2009	2010	2011	2012	2013	2014*	2015	2016	2017
Sockeye	169,937	136,206	40,758	724,394	67,879	384,224	199,497	553,645	53,575	1,374,418	**60,432**
Steelhead	4,532	8,721	6,309	4,931	5,683	4,902	2,528	5,270	4,157	1,478	**2,928**
Yearling Chinook	18,080	38,394	18,946	33,840	24,400	95,207	29,018	15,871	32,220	41,676	**37,302**
Subyearling Chinook	13,496	11,820	11,944	59,751	17,246	5,774	22,073	22,327	37,104	8,905	**27,404**

Table 2. Rock Island Smolt Monitoring Program index sample counts, 2007-2017

Species	2007	2008	2009	2010	2011	2012	2013	2014*	2015	2016	2017
Sockeye	16,410	38,965	4,926	37,404	18,697	46,788	25,111	38,596	4,128	56,638	**11,117**
Steelhead	18,482	22,780	17,636	17,194	28,408	16,957	15,099	28,299	12,549	17,663	**32,135**
Yearling Chinook	23,714	22,562	9,225	11,802	26,407	25,759	28,324	26,429	16,762	44,784	**50,604**
Subyearling Chinook	15,686	15,940	8,189	23,205	27,397	27,298	17,170	34,527	15,349	13,270	**63,579**

***** In 2014, as directed by the HCP, Chelan PUD conducted bypass operations outside of the normal operating period of 1 April to 31 August to assess achievement of bypass operations for 95% of the subyearling Chinook outmigration. The Rocky Reach juvenile fish bypass operated from 1 April through 15 September, and the Rock Island bypass facility at powerhouse 2 operated from 1 April through 15 September.

From: Kristi Geris
To: Jackson, Chad S (DFW); Jim Craig (jim_l_craig@fws.gov); John Ferguson; Keely Murdoch (murk@yakamafish-nsn.gov); Keller, Lance; kirk.truscott@colvilletribes.com; Kristi Geris; Scott Carlon; "Tom Kahler (tkahler@dcpud.org)"
Cc: Aaron Beavers; Alene.Underwood@chelanpud.org; Bill Tweit; Bob Rose; Casey Baldwin; Catherine Willard; Dale Bambrick; Gallaher, Becky; jeff.smith@chelanpud.org; Justin Yeager; "Mary Mayo"; Mike Tonseth (tonsemat@dfw.wa.gov); Ritchie Graves; Shane Bickford (sbickford@dcpud.org); Steve Hemstrom (steven.hemstrom@chelanpud.org); Steve Parker; Verhey, Patrick M (DFW); "william_gale@fws.gov"
Subject: FW: Pacific Lamprey data from Wells
Date: Tuesday, September 26, 2017 10:48:42 AM
Attachments: image005.png
image006.png

Hi HCP-CC: please see the email below from Tom regarding Pacific Lamprey data from Wells. Thanks!
-kristi

Kristi Geris

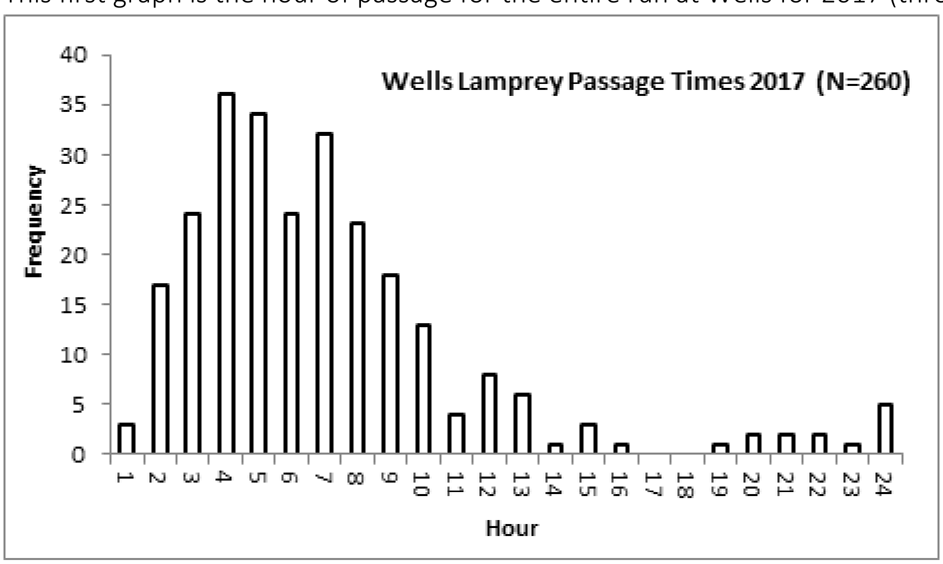
ANCHOR QEA, LLC
kgeris@anchorqea.com
C 360.220.3988

From: Tom Kahler [mailto:tomk@dcpud.org]
Sent: Tuesday, September 26, 2017 10:40 AM
To: Kristi Geris <kgeris@anchorqea.com>
Cc: John Ferguson <jferguson@anchorqea.com>
Subject: Pacific Lamprey data from Wells

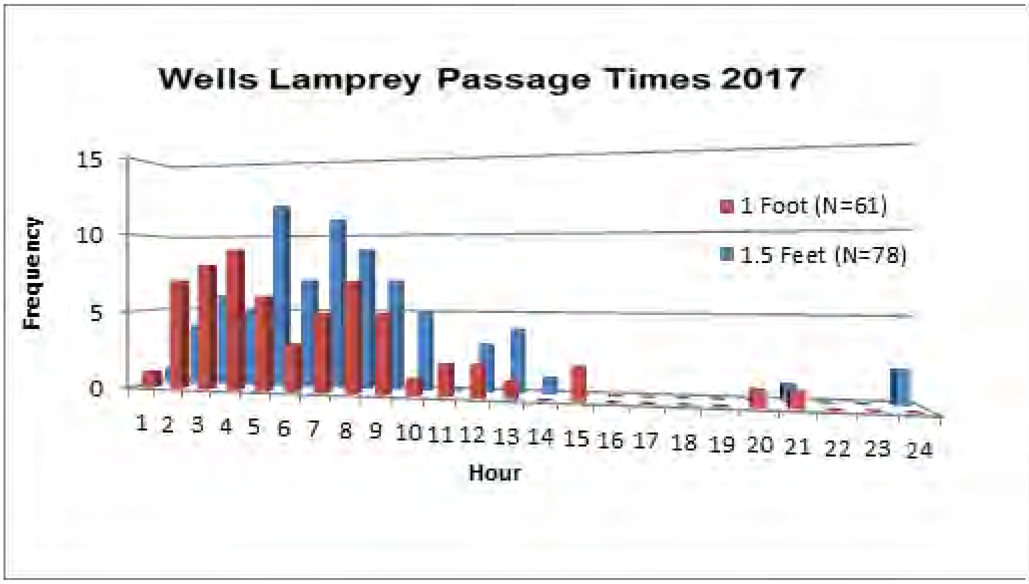
Hi Kristi,

Here's the latest from the block comparison of Pacific Lamprey passage at Wells.

This first graph is the hour of passage for the entire run at Wells for 2017 (through 9/24)



This second graph is the hour of passage for Pacific Lamprey at Wells during the comparison of fishway head-differentials (through 9/24, which comprises nearly four complete blocks)



Thanks,

Tom

FINAL

720 Olive Way, Suite 1900
Seattle, Washington 98101
206.287.9130

ANCHOR QEA

Memorandum

To: Wells, Rocky Reach, and Rock Island HCP Coordinating Committees

Date: December 13, 2017

From: John Ferguson, HCP Coordinating Committees Chairman

cc: Kristi Geris

Re: Final Minutes of the October 24, 2017, HCP Coordinating Committees Meeting

The Wells, Rocky Reach, and Rock Island Hydroelectric Projects Habitat Conservation Plan (HCP) Coordinating Committees met at the Grant PUD Office in Wenatchee, Washington, on Tuesday October 24, 2017, from 10:00 a.m. to 1:30 p.m. Attendees are listed in Attachment A to these meeting minutes.

Action Item Summary

- Kristi Geris will coordinate with Tracy Hillman and will notify the HCP Coordinating Committees of the date the HCP Hatchery Committees plan to tour the new Wells Fish Hatchery (tentatively scheduled for early 2018; Item II-C).
- Kristi Geris will locate the presentation, "Potential to improve the conservation benefits of steelhead hatcheries," presented by Barry Berejikian (National Oceanic and Atmospheric Administration [NOAA] Northwest Fisheries Science Center) during the HCP Hatchery Committees meeting on October 18, 2017, and will distribute the presentation to the HCP Coordinating Committees (Item III-A). *(Note: Geris distributed Berejikian's presentation to the HCP Coordinating Committees on October 26, 2017.)*
- Douglas PUD will: 1) incorporate comments received on the Transition Plan for Wells and Methow Fish Hatcheries, and provide the updated plan to Kristi Geris for distribution to the HCP Coordinating Committees; 2) either incorporate sections of the Memorandum of Understanding (MOU) into the transition plan or distribute the MOU to the HCP Coordinating Committees; and 3) check on the status of the Operations Plan (Item IV-B). *(Note: Sections of the MOU were incorporated into the final transition plan, and Tom Kahler provided the final plan to Geris on November 7, 2017, which Geris distributed to the HCP Coordinating Committees that same day.)*
- Douglas PUD, in coordination with Richard Townsend (Columbia Basin Research), will incorporate wild yearling Chinook salmon passage data for 2017 into the corrected Draft 2017 Wells Dam Passage Dates Analysis (Item IV-C).
- Douglas PUD, in coordination with Richard Townsend, will include wild yearling Chinook salmon passage data for all years of analyses in an addendum to the Draft 2017 Wells Dam Passage Dates Analysis (Item IV-C).

- Douglas PUD will provide a proposal on which study species to use for the Douglas PUD 2020 Survival Verification Study for the Wells HCP Coordinating Committee to consider, and will convene a conference call for discussion, if necessary (Item IV-D).
- Chelan PUD will provide the Final 2017 Rock Island and Rocky Reach Fish Spill Program Report to Kristi Geris for distribution to the HCP Coordinating Committees (Item V-A).
- Chelan PUD will provide a written list of the repairs planned for the Rocky Reach Dam fish ladders during the 2017/2018 winter maintenance outage, and 2014 passage data, for Rocky Reach HCP Coordinating Committee consideration and vote via email (Item V-D). *(Note: Keller provided the list of repairs and 2014 passage data to Kristi Geris following the meeting on October 24, 2017, which Geris distributed to the HCP Coordinating Committees on October 25, 2017.)*
- Chad Jackson will provide an official Washington Department of Fish and Wildlife (WDFW) HCP Hatchery Committees Representation Designation Letter to Kristi Geris for the administrative record (Item VI-A). *(Note: Jackson provided this letter to Geris on November 6, 2017, which Geris distributed to the HCP Coordinating Committees and to Sarah Montgomery [Anchor QEA] for distribution to the HCP Hatchery Committees that same day.)*
- Kristi Geris will coordinate with Denny Rohr (Priest Rapids Coordinating Committee [PRCC] Facilitator) and the PRCC regarding rescheduling the HCP Coordinating Committees meeting in December 2017 (Item VI-B). *(Note: Geris coordinated with Rohr, who indicated the PRCC plans to meet on December 13, 2017; therefore, the HCP Coordinating Committees meeting on December 26, 2017, has been rescheduled to December 12, 2017.)*
- The HCP Coordinating Committees meeting on December 26, 2017, has been rescheduled to December 12, 2017, to accommodate the Christmas holiday and best coordinate with the PRCC, and will be held by conference call or in-person at the Grant PUD Wenatchee Office in Wenatchee, Washington, as is yet to be determined (Item VI-B).

Decision Summary

- Rock Island and Rocky Reach HCP Coordinating Committees members present approved the 2017 Rock Island and Rocky Reach Fish Spill Program Report, with the Colville Confederated Tribes (CCT) abstaining (Item V-A).

Agreements

- HCP Coordinating Committees members present agreed to cancel the HCP Coordinating Committees meeting on November 28, 2017, due to lack of agenda items and a scheduling conflict with the U.S. Army Corps of Engineers (USACE's) 2017 Anadromous Fish Evaluation Program (AFEP) Annual Review (Item VI-B).

- The Rocky Reach HCP Coordinating Committee agreed via email to Chelan PUD's request to begin the 2017/2018 winter maintenance work period at Rocky Reach Dam, 3 weeks earlier than usual to allow more time to complete required work. Rather than beginning work during the first week in January (per usual), maintenance work will begin on December 11, 2017. Approvals were as follows: Chelan PUD, National Marine Fisheries Service (NMFS), WDFW, and the CCT approved November 1, 2017, and U.S. Fish and Wildlife Service (USFWS) and the Yakama Nation (YN) approved November 2, 2017 (Item V-D).

Review Items

- A corrected Draft 2017 Wells Dam Passage Dates Analysis was distributed to the HCP Coordinating Committees by Kristi Geris on October 23, 2017. The draft analysis is available for a 30-day review period, with edits and comments due to Tom Kahler by November 22, 2017 (Item IV-C).
- A written list of the repairs planned for the Rocky Reach Dam fish ladders during the 2017/2018 winter maintenance outage, and 2014 passage data, were distributed to the HCP Coordinating Committees by Kristi Geris on October 25, 2017. Rocky Reach HCP Coordinating Committee votes are due to Lance Keller (with a copy to Geris) via email by Friday, November 3, 2017 (Item V-D). *(Note: the Rocky Reach HCP Coordinating Committee approved this request; see Agreements)*
- Kristi Geris notified the Rock Island HCP Coordinating Committee on November 15, 2017, that an Application for Non-Capacity Amendment is available for a 30-day review period, with edits and comments due to Jeff Osborn (Chelan PUD) by December 15, 2017.

Finalized Documents

- The Final Public Transition Plan for Wells and Methow Fish Hatcheries was distributed to the HCP Coordinating Committees by Kristi Geris on November 7, 2017 (Item IV-B).

I. University of Washington/NOAA Northwest Fisheries Science Center

A. PRESENTATION: Epigenetics (Mackenzie Gavery)

Mackenzie Gavery (Postdoctoral Research Associate, University of Washington/NOAA Northwest Fisheries Science Center) shared the presentation, "Epigenetics: what is it and why is it relevant to hatchery practices?" (Attachment B), which was distributed to the HCP Coordinating Committees by Kristi Geris on September 27, 2017.

The presentation included an overview of epigenetics, discussion of a specific epigenetic marker called deoxyribonucleic acid (DNA) methylation, and a presentation of DNA methylation data from Methow River steelhead. Epigenetics refers to heritable changes in trait or phenotype caused by a mechanism other than a mutation to the DNA sequence. The epigenome of an organism provides the instruction for which genes should be expressed, and is influenced by the environment, especially during early development, and even after the environmental signal is removed. Gavery's research investigated whether there are discernable epigenetic differences between hatchery- and natural-origin steelhead at Winthrop National Fish Hatchery. In 2014, blood and sperm samples extracted from returning hatchery- and natural-origin adult steelhead were used in a DNA methylation analysis to evaluate somatic and germline cells (which are passed on to the next generation). The results indicated steelhead have a heavily methylated genome compared to other species. Comparisons of differentially methylated regions between blood and sperm cells show sperm carry important epigenetic information regarding which genes are going to be turned on in the early embryo. Results also showed there are differences in DNA methylation between hatchery- and natural-origin steelhead in both somatic and germline-derived cell types. Epigenetics can help organisms retain and pass on information about their environment and the study of the epigenome is an emerging tool to help understand how the environment affects the phenotypes of hatchery fish. Gavery has a second study underway where offspring from natural-origin Methow steelhead families are divided into two groups and reared in a hatchery tank and an artificial stream.

II. Welcome

A. Review Agenda (John Ferguson)

John Ferguson welcomed the HCP Coordinating Committees and reviewed the agenda. Ferguson asked for any additions or changes to the agenda. The following revisions were requested:

- Tom Kahler added: 1) Draft 2017 Wells Dam Passage Dates Analysis; 2) choice of study species for the Douglas PUD 2020 Survival Verification Study.
- Lance Keller added: 1) 2017 Rock Island and Rocky Reach Fish Spill Program Report; 2) Rocky Reach Dam fish ladder, request for an early winter maintenance outage.

B. Meeting Minutes Approval (John Ferguson)

The HCP Coordinating Committees reviewed the revised draft September 26, 2017 conference call minutes. Kristi Geris said the revised minutes were distributed to the HCP Coordinating Committees by Sarah Montgomery on October 17, 2017. Geris said all comments and revisions received from members of the Committees were incorporated into the revised minutes. She noted that a few edits were reflected in tracked changes; however, there were no outstanding issues to be discussed. HCP Coordinating Committees members present approved the September 26, 2017 conference call minutes, as revised. The YN abstained, because a YN representative was not present during the September 26, 2017 conference call.

C. Last Meeting Action Items (John Ferguson)

Action items from the HCP Coordinating Committees conference call on September 26, 2017, and follow-up discussions, were as follows. *(Note: italicized text corresponds to agenda items from the meeting on September 26, 2017):*

- *Chelan PUD will provide a Rocky Reach Dam large unit repair update during the HCP Coordinating Committees meeting on October 24, 2017 (Item I-C).*
  This will be discussed during today's meeting.
- *Kristi Geris will coordinate with Tracy Hillman and will notify the HCP Coordinating Committees of the date the HCP Hatchery Committees plan to tour the new Wells Fish Hatchery (tentatively scheduled for November 2017; Item II-A).*
  Geris said the tour has been postponed to early 2018, due to uncertainty of a construction completion date. This action item will be carried forward.
- *Lance Keller will evaluate how well the percentage of the fish run covered by annual spill based on daily fish bypass index counts, which is the current approach used to estimate the percentage, compares to the percentage estimated using detections of passive integrated transponder (PIT)-tagged fish passing through the juvenile fish bypass system at Rocky Reach Dam (Item III-A).*
  Keller provided subyearling Chinook salmon PIT detections at the Rocky Reach Juvenile Fish Bypass System (RRJFBS) in 2017 compared to index counts to Sarah Montgomery on October 17, 2017, which Montgomery distributed to the HCP Coordinating Committees that same day. Kirk Truscott said he has not yet thoroughly reviewed these data, but will contact Keller if any questions arise.
- *Douglas PUD will present Pacific Lamprey and salmonid count data for the time period when Lamprey Operations were implemented at Wells Dam (September 1 through September 30, 2017) during the HCP Coordinating Committees meeting on October 24, 2017 (Item IV-A).*
  This will be discussed during today's meeting.
- *Kristi Geris will contact Mackenzie Gavery to confirm a 10:00 a.m. start time to present her epigenetics research during the HCP Coordinating Committees meeting on October 24, 2017 (Item V-B).*
  Geris contacted Gavery, who confirmed she can present at the proposed 10:00 a.m. start time.
- *Kristi Geris will coordinate with Tracy Hillman and will notify the HCP Coordinating Committees of the WebEx and call-in number to attend a presentation by Barry Berejikian (NOAA Northwest Fisheries Science Center) regarding his ongoing research on steelhead in Hood Canal and how it*

might apply to steelhead hatchery issues in the Twisp River, during the HCP Hatchery Committees meeting on October 18, 2017 (Item V-B).
Sarah Montgomery distributed the agenda with this information to the HCP Coordinating Committees on October 17, 2017.

III. HCP Tributary and Hatchery Committees Update

A. HCP Tributary and Hatchery Committees Update (Tracy Hillman)

Tracy Hillman reported that the HCP Tributary Committees did not meet in October 2017 and will next meet on November 9, 2017. Hillman also announced that Steve Hays (Chelan PUD) plans to retire at the end of 2017. Hillman said the HCP Tributary Committees are planning a farewell party for Hays during the November meeting, and Hays will also provide a presentation on the Chelan River habitat restoration work.

Hillman updated the HCP Coordinating Committees on the following actions and discussions that occurred during the HCP Hatchery Committees meeting on October 18, 2017:

- *Draft 2018 Hatchery Monitoring and Evaluation Implementation Plan*: Douglas PUD submitted the Draft Douglas PUD 2018 Hatchery Monitoring and Evaluation (M&E) Implementation Plan to the HCP Hatchery Committees for review. There is little change in the plan from the previous year. Comments are due to Douglas PUD by December 1, 2017, and the plan will likely be approved during the HCP Hatchery Committees meeting in December 2017.
- *Wells Hatchery Transition Plan*: Douglas PUD distributed the Draft Transition Plan for the Wells and Methow Fish Hatcheries in mid-October 2017, and the HCP Hatchery Committees are reviewing and providing comments back to Douglas PUD as soon as possible. USFWS provided a few comments during the meeting on October 18, 2017. Douglas PUD reported that managers have now been hired for the Methow and Wells fish hatcheries. The plan is to have the transition completed within the 90-day period; however, some items may need a longer transition period, which will be evaluated on a case-by-case basis.
- *PRESENTATION: Potential to improve the conservation benefits of steelhead hatcheries*: Barry Berejikian provided a presentation on his work with steelhead in Hood Canal. Briefly, Berejikian discussed: 1) approaches for egg collection, rearing, and release for small hatchery programs; 2) effects on abundance and genetic diversity; 3) alternative rearing strategies to improve smolt performance and reduce domestication; and 4) developing practical and flexible rearing strategies for conservation programs. Based on his work, Berejikian found: a) collecting eggs from redds using hydraulic sampling can increase effective population size in small conservation programs; b) this method works best for steelhead in rain-driven systems or for summer-spawning fish; and c) natural spawning of steelhead can be increased

in the short-term and in the generation post-supplementation. Berejikian also discussed the heritability of fitness loss in steelhead and the effects of rearing steelhead to age-2 (S2) smolt. He said body size at time of release affects downstream migration (i.e., migration timing and survival) and survival in seawater. He noted that age-1 (S1) smolts experience size-selective mortality and possibly respond to selection, while S2 smolts experience no size-selective mortality or possible response to selection (i.e., low heritability); however, S2 smolts experience higher rates of residualism and precocious maturation. Therefore, not all hatcheries can or should implement S2 smolt programs. Berejikian indicated that a useful approach to improve steelhead smolting is to sort parr by size after 8 weeks post-ponding. Larger fish (greater than 60 millimeters [mm]) would receive high rations and be released as S1 smolts; smaller fish (less than 60 mm) would experience modulated growth and be released as S2 smolts. Hillman said Berejikian's presentation was extremely informative and recommended that the HCP Coordinating Committees obtain a copy. Kristi Geris said she would locate and forward a copy of the presentation to the HCP Coordinating Committees. *(Note: Geris distributed Berejikian's presentation to the HCP Coordinating Committees on October 26, 2017.)*

- *Twisp Steelhead Program*: Following Barry Berejikian's presentation, the HCP Hatchery Committees discussed implementing Berejikian's methodologies for the Twisp Steelhead Program. However, the HCP Hatchery Committees noted that hydraulic mining of eggs from redds in the Twisp River is likely not appropriate given that it is a snow-fed stream and high flows would preclude hydraulic sampling. The HCP Hatchery Committees discussed several alternatives including releasing S1 or S2 smolts, or both, and the idea of combining the Twisp and Winthrop programs, but still allowing local adaptation. The HCP Hatchery Committees also discussed the use of spawning channels, which could be a substitute to hydraulic sampling. A small group agreed to prepare a white paper on management alternatives for Twisp River steelhead, which the HCP Hatchery Committees will review during the meeting on November 15, 2017.
- *NMFS Consultation Update*: NMFS provided an update on consultation for the unlisted programs in the upper Columbia River. NMFS is requesting initiation of consultation from Chelan PUD, Grant PUD, and WDFW, which will serve as an official request to NMFS to begin consultation. Once NMFS receives the requests, NMFS will respond with a letter of sufficiency.
- *USFWS Bull Trout Consultation Update*: USFWS is working to get the Biological Opinion for the numerous Wenatchee subbasin programs signed this week. USFWS is also coordinating with NMFS on the Methow River steelhead consultation, consultation for the hatchery programs for unlisted Chinook salmon stocks in the upper Columbia River, and re-initiation of Mitchell Act consultation for the Ringold fall Chinook salmon program with USACE. USFWS

also completed consultation on maintenance of the Nason Creek Acclimation Facility intake structure.

- *Draft 2017 Hatchery M&E Plan for PUD Hatchery Programs*: The HCP Hatchery Committees are currently reviewing updated sections of the Hatchery M&E Plan for PUD Hatchery Programs. Specifically, the Committees are reviewing Section 7.2 (Non-target Taxa of Concern), Section 8 (Adaptive Management), and Appendix 1 (Estimation of Carrying Capacity). The HCP Hatchery Committees will review and hopefully approve the updated sections during the meeting on November 15, 2017. The HCP Hatchery Committees hope to finalize the plan and share it with the Independent Scientific Advisory Board before the Board completes their review.
- *Timeline of Changes in Hatchery Programs*: The HCP Hatchery Committees are preparing timelines for hatchery programs within the Wenatchee River and Methow River basins to help determine how interruptions in time series data will affect statistical analyses. The HCP Hatchery Committees are currently reviewing spring Chinook salmon timelines, and next will develop timelines for steelhead and summer Chinook salmon. This task will likely be completed by late-2017 or early 2018.
- *Next meeting*: The next meeting of the HCP Hatchery Committees will be on November 15, 2017.

IV. Douglas PUD

A. Pacific Lamprey and Salmonid Count Data during Lamprey Operations at Wells Dam (Tom Kahler)

Tom Kahler said Andrew Gingerich (Douglas PUD Aquatic Settlement Work Group [SWG] Technical Representative) is currently drafting a report which summarizes Pacific lamprey and salmonid data responses to the "lamprey operations"[1] implemented at Wells Dam in 2017 (September 1 to 30). Kahler said the report is not yet ready for distribution; however, he distributed hard copies of *Wells Dam count window data for Pacific lamprey, steelhead, and Chinook and Coho salmon* (Attachment C), which Kristi Geris distributed electronically to the HCP Coordinating Committees on October 25, 2017. Kahler recalled that the Pacific lamprey count window data previously distributed on September 26, 2017, reported Wells Dam count window data on the y-axis. He said the current version reports the proportion of total Pacific lamprey on the y-axis, which he noted, still shows similar results compared to the previous graphs. He said Pacific lamprey at the fishway entrance seemed to pass easier at the lower head differential, which he said makes sense considering the layout of the collection gallery. He noted a higher proportion of fish passing during the 0200 to 0500

[1] A temporary 1.0-foot fishway-entrance head differential from 22:00 to 04:00 daily in alternating 3-day blocks with normal operations.

hours, and low points in the data during the 0600, 0700, and 0900 hours. He also noted that coho salmon initially appear to pass more during the 1-foot head differential (as shown on page 5 of Attachment C); however, this trend may actually be due to the coho salmon run shape (as shown on page 6 of Attachment C). He said ultimately, observations are purely speculative. He said overall, Douglas PUD did not observe any alarming differences in Pacific lamprey or salmonid passage between the lamprey operations and normal operations.

John Ferguson asked what, "proportion of" means. Kahler explained that "proportion of" represents the number of fish of a species that passed Wells Dam in 1 hour divided by the total number that passed during all time periods.

Keely Murdoch recalled, based on past Pacific lamprey studies at Wells Dam, that it seemed easier for Pacific lamprey to pass the fishway at the 1-foot head differential; however, the concern was that it was harder for Pacific lamprey to locate the fish ladder at the reduced head differential. She asked if this is a correct recollection. Kahler said this is correct. He also clarified the difference between the fish ladder and the fishway. He said the fishway includes the collection gallery, while the actual fish ladder is located at the upstream end of the collection gallery. He said salmonids seem to react best to a 1.5-foot head differential; however, a 1.0-foot head differential is also acceptable in other systems. He said past radio-telemetry studies at Wells Dam indicated that fewer Pacific lamprey entered the fish ladder at a 1.0-foot head differential (i.e., less attractive entrance); however, passage times were faster at the 1.0-foot head differential for those fish that successfully entered.

Murdoch recalled the small sample sizes of past studies, and asked if the differences are statistically significant. Kahler said this question falls under the purview of the Aquatic SWG. He said the Wells HCP Coordinating Committee was tasked to monitor affects to salmonids. He added, not to dismiss the question, but he does not have the answer to this question. He said it would be ideal to run this type of analysis over the entire run to obtain a greater sample size. Kirk Truscott also noted that without active tags there is no way to know which fish actually entered the fish ladder under the 1.0- or 1.5-foot head differential, nor is there a way to evaluate statistically the efficacy of locating the collection gallery.

B. Transition Plan for Douglas PUD Hatcheries (Tom Kahler)

Tom Kahler said the draft Transition Plan for Wells and Methow Fish Hatcheries was distributed to the HCP Hatchery Committees for review on October 16, 2017. He said Douglas PUD discussed the draft plan with WDFW and is expecting to receive written comments, which Douglas PUD plans to incorporate into a revised draft plan before distributing to the HCP Coordinating Committees for review. Chad Jackson said WDFW sent written comments to Shane Bickford (Douglas PUD Natural Resources Supervisor) and Gary Ivory (Douglas PUD General Manager) on October 18, 2017. Kahler said Bickford has been out of the office, and Jackson said he will forward the comments to Kahler.

Kirk Truscott asked about a review deadline for the HCP Hatchery Committees to submit comments on the draft plan. Kahler said the review period was left open-ended; however, Douglas PUD would like to receive comments as soon as possible.

John Ferguson asked when the HCP Coordinating Committees might expect the revised draft plan to be available for review. Kahler said it depends on the nature of the WDFW comments. Jackson said the comments range from straight-forward edits to clarifications, and include some items which may require internal discussion (for example, regarding fish health and euthanasia). Kahler said Bickford will be back in the office on October 27, 2017, and they will review and discuss the WDFW comments at that time.

Kahler said Douglas PUD has hired all hatchery staff at every level. He said some staff have already started, most start November 6, 2017, and the last will start by November 16, 2017.

Ferguson asked if WDFW has assigned a point of contact for the transition. Jackson said he and Eric Kinne (WDFW; Hatcheries Division Manager) have been appointed as contacts.

Truscott asked if Douglas PUD is developing an updated Operations Plan, including a production plan, with the hatchery modernization. Kahler said yes, Ken Ferjancic at HDR Engineering, Inc., is working on an Operations Plan. Kahler said he is unsure of the current status of the plan. He said some production will remain the same and other parts will be new. He said Greg Mackey (Douglas PUD HCP Hatchery Committees Representative) is the contact person to answer questions about production.

Jackson also noted that there is a draft MOU between WDFW and Douglas PUD which outlines a comingled workforce through the end of November 2017. Jackson said WDFW already provided comments on the draft MOU, including requesting a section on contingencies in case certain tasks are not complete by the November 2017 deadline. Truscott asked if details about process are included in the MOU, and Mike Tonseth (WDFW) said there should be.

Kahler said Douglas PUD will: 1) incorporate comments received on the Transition Plan for Wells and Methow Fish Hatcheries, and provide the updated plan to Kristi Geris for distribution to the HCP Coordinating Committees; 2) either incorporate sections of the MOU into the transition plan or distribute the MOU to the HCP Coordinating Committees; and 3) check on the status of the Operations Plan. *(Note: Sections of the MOU were incorporated into the final transition plan, and Kahler provided the final plan to Geris on November 7, 2017, which Geris distributed to the HCP Coordinating Committees that same day.)*

Kahler said the Operations Plan is somewhat of a living document as Douglas PUD continues to learn how to use the modernized facilities most optimally (e.g., optimized water usage, computer programming). Kahler also noted that manufacturer technical representatives, and Douglas PUD technicians, mechanics, Natural Resources and hatchery staff witnessed the commissioning of the new equipment, which was also video recorded so there will be video tutorials available for new staff.

C. Draft 2017 Wells Dam Passage Dates Analysis (Tom Kahler)

Tom Kahler said a *Draft 2017 Wells Dam Passage Dates Analysis* was distributed to the HCP Coordinating Committees by Sarah Montgomery on October 20, 2017, and a corrected analysis (Attachment D) was distributed to the HCP Coordinating Committees by Kristi Geris on October 23, 2017.

Kahler said the Wells HCP includes a requirement to provide bypass passage for greater than or equal to 95% of the migrations of both spring- and summer-migrating Plan Species at Wells Dam. He said when the spring spill season ends at 24:00, the summer spill season begins immediately after at 00:00. He said bypass dates at Wells Dam were established based on 20 years of fyke net and acoustic studies. He said initially, based on arrival dates, the bypass was operated from April 12 to August 26. He said the Wells HCP also includes a requirement to reevaluate bypass dates every 10 years. He said, because there was no desire to revisit fyke netting, and PIT detection was available at the RRJFBS, passage times at Rocky Reach Dam and travel times between Rocky Reach and Wells dams were used to back-calculate probable passage times at Wells Dam. He clarified that this methodology (PIT-tag passage dates) is used for all species except sockeye salmon. He said sockeye salmon passage dates are determined based on sampling at the RRJFBS, because there are not many PIT-tagged fish in the system. He said the Data Access in Real Time program is then used to calculate what percentage of fish migrate through the project during various time periods (as described in Table 2 of Attachment D). He said in 2012, bypass operation dates were modified to run from April 9 to August 19, to provide better coverage for the spring run.

Kahler said in 2017, Wells Dam bypass operations provided passage for: 99.85% for yearling Chinook salmon; 100% for steelhead; 99.99% for sockeye salmon; 100% for coho salmon; and 99.59% for subyearling Chinook salmon.

Scott Carlon noted the assumed 2-day travel time for subyearling Chinook salmon, and asked if PIT-tag data were used to confirm this. Kahler said there are no actual measured travel times for subyearlings, because they tend to pass Wells Dam on river-left and PIT detection at the dam is on river-right. Kirk Truscott asked how upstream hatchery release dates relate to subyearling passage dates at Rocky Reach Dam. Kahler said they vary from 2 to greater than 70 days. He added that it is unclear when subyearlings leave the Wells reservoir. He said there needs to be more PIT-tag detections at Wells Dam Bypass Bay 2 (PIT-Tag Information System code: WEJ) and subsequent detections at Rocky Reach Dam.

Keely Murdoch asked, regarding spring Chinook salmon, if there has ever been an attempt to parse out wild versus hatchery, or is the sample size for the wild run too small? Kahler said this year, the wild run past Wells Dam was about 230-something; so very small. Murdoch said data were presented at the 2017 Salmon Recovery Conference indicating that wild fish migrate earlier than hatchery fish for spring Chinook salmon. She asked, among the few fish which migrate before the passage period, what proportion of the wild run does this really represent? She said if the entire run is dominated by hatchery fish, the estimated migration proportions may not be accurate for the wild portion.

Truscott said this has been a reoccurring subject raised in the HCP Coordinating Committees. He said it is an interesting subject; however, the HCPs do not distinguish proportional protection between natural versus hatchery fish. He said the HCPs only require providing spill for yearling Chinook salmon, including hatchery, wild, spring, and summer. He said if something undesirable is observed, the task is to determine what can be done to improve the metric.

Kahler said the introduction of the Wells HCP states, "This Agreement is intended to constitute a comprehensive and long-term adaptive management plan for Plan Species and their habitat as affected by the Project." Kahler said obviously, negotiation of the HCPs preceded a lot of information that is now known. He said the HCPs were written with a different mindset of what recovery looks like. He said Douglas PUD considers the Wells HCP as a recovery plan. He said Douglas PUD attempts to accomplish what is possible, in coordination with the Wells HCP Coordinating Committee, and with what data are available. He said for 2017, when only wild yearling data were considered, the proportion of passage covered was only 92.96%. He said to achieve 95%, bypass operations were 3 days late. He noted to keep in mind, these data are based on Rocky Reach Dam detections which start April 1, and there are no data available indicating what passage looked like before April 1.

Truscott said this is when data obtained from the tributary arrays and screw traps could be useful. Kahler noted, when the lower Methow River PIT-tag array is functional it can be useful; however, he said this array is best for adults. He added that WDFW is proposing to replace this array with one in a better location to improve reliability. Mike Tonseth said the array has already been replaced and was moved from river mile 1.2 to 5. Kahler said this new location should greatly improve detections, and Tonseth said this location also has better protection from river ice.

Truscott noted that in years with early spring freshets, detection of a large proportion of migrating fish may still be missed. John Ferguson asked if the HCP Coordinating Committees need to have a discussion about climate change possibly causing earlier freshets. Ferguson also asked if Douglas PUD should ask Richard Townsend to incorporate the new detection site into next year's analysis.

Kahler said if there is interest, wild counts for yearlings and subyearlings can be incorporated into the analysis. He said Douglas PUD is also open to discussing a new bypass operations start date; however, this discussion needs to happen before February 28, 2018, when the Aquatic SWG submits the Wells Dam Bypass Operations Plan to the Washington State Department of Ecology.

Truscott said he believes adding wild counts to the analysis would be useful. He also asked what additional information is available to justify an alternative bypass operation start date at Rocky Reach Dam.

Jim Craig said he can look into available screw trap data in the Entiat River to help inform this question. Kahler suggested also looking into Methow and Wenatchee rivers-specific data on entry to the Columbia River. *(Note: Craig provided yearling Chinook salmon emigration timing data at rotary screw traps in the Methow, Entiat, and Wenatchee rivers, which support the need for earlier bypass operation start dates, to Geris on October 26, 2017, which Geris distributed to the HCP Coordinating Committees that same day.)*

Kahler noted that when the Wells HCP Coordinating Committee approved the most recent bypass operations dates (April 9 to August 19), the approval included contingency language stating that the "current timing of bypass operations will continue annually, unless modified as a result of future investigations that demonstrate an inadequacy of these dates at providing bypass passage for greater than or equal to 95% of the migrations of both spring- and summer-migrating Plan Species at Wells Dam." Kahler said this means the Wells HCP Coordinating Committee has the capacity to change the bypass operations dates at any time within the 10-year review interval specified in the HCP, if data support it.

Truscott said he believes what is needed is a hard discussion on how and when monitoring is operated. He asked if there is real interest in operating the Rocky Reach Dam bypass earlier than April 1; and if so, what is involved in making this decision?

Lance Keller said the Rocky Reach Dam bypass is a complicated system and it is not as simple as just turning it on, as off-season maintenance of the entire bypass system begins September 1 and continues until the following mid-March, which allows enough time to test the system prior to the April 1 startup date. Keller said internal stakeholder engagement is also an issue, because a staffing increase is needed to operate the bypass as well as monitor fish condition. Truscott noted that the Rocky Reach HCP Coordinating Committee has approved operating the bypass longer in the season; therefore, it seems a Rocky Reach HCP Coordinating Committee representative could propose to operate the bypass earlier. Keller added that in 2014, the bypass was operated outside of the usual April 1 to August 31 timeframe in order to verify operations covered 95% of the outmigration for Plan Species, per the Rocky Reach HCP. He recalled that operations were extended to September 15, because the Rocky Reach HCP Coordinating Committee expressed concerned that the subyearling Chinook salmon run timing lasted beyond August 31.

Ferguson noted Table 4 in Attachment D, where the last column ("Bypass ended this many days after the 95% standard was achieved") includes some years where days are in the double-digits. Ferguson suggested these data may indicate the possibility of shutting down the bypass earlier in the season.

Kahler said historic fyke net data for Wells Dam show subyearlings moving in the first two weeks in July, peaking in late-July into early August, and dropping off in the third week of August. He said he would not want to shut down the bypass much earlier than August 19 to be sure to catch the peak of the subyearling migration.

Kahler said Douglas PUD, in coordination with Townsend, will incorporate wild yearling Chinook salmon passage data for 2017 into the corrected Draft 2017 Wells Dam Passage Dates Analysis that was distributed to the HCP Coordinating Committees by Geris on October 23, 2017. Kahler said this version is also currently available for a 30-day review period, with edits and comments due to Kahler by November 22, 2017. Kahler said Douglas PUD, in coordination with Townsend, will also include wild yearling Chinook salmon passage data for all years of analyses, in an addendum to the Draft 2017 Passage Dates Analysis.

Kahler said another metric to flesh out is travel time for subyearlings. He discussed using passage times for Chinook salmon released as subyearlings from Chief Joseph Hatchery and dividing the time by half; however, he noted that sometimes subyearlings do not migrate immediately, so simply dividing passage times by half may not be accurate. He concluded that more reasonable data are needed to get at this question.

Kahler said if the HCP Coordinating Committees want to formally address potential earlier bypass operation dates in 2018 for Wells Dam, a decision is needed by the HCP Coordinating Committees meeting in January 2018 (considering the Aquatic SWG's deadline to Washington State Department of Ecology on February 28, 2018). Keller said for Rocky Reach Dam, he would need to take a request back to Chelan PUD to discuss internally, but implementing a change to the start date in 2018 would be difficult.

D. Choice of Study Species for 2020 Survival Verification Study (Tom Kahler)

Tom Kahler recalled that non-listed (Endangered Species Act), Wells Hatchery stock, yearling summer Chinook salmon were used for the Douglas PUD 2010 Survival Verification Study. He said spring Chinook salmon were not chosen because they are Endangered Species Act-listed, and based on discussions with Bob Rose, Tom Scribner (YN), and Cory Kamphaus (YN), there was no interest in using coho salmon. Kahler said the 2010 release locations included: 1) at the mouth of the

Methow River; 2) in the Wells Dam tailrace; and 3) per a request from the CCT in regard to Section 4.2.1 of the Wells HCP, at the mouth of the Okanogan River. Kahler said study fish were PIT-tagged. He said half of the study fish were released in the Wells Dam tailrace, and the other half were released at each river mouth proportional to the historic natural and hatchery production originating from that river (it was previously determined that release numbers would be fewer to the Okanogan River mouth compared to the Methow River mouth). Kahler said it is now time to begin thinking about which species to use for the 2020 Survival Verification Study.

Keely Murdoch said if the YN can collect extra coho salmon for this study and find a place to raise them, this may be the best option. Kahler noted that there are no coho salmon in the Okanogan River. He said if this species is chosen there will only be a Methow River release, and he asked if the CCT want an Okanogan River component. He also noted that roughly 75,000 PIT-tags are needed to get sufficient detections at Rocky Reach Dam to meet precision targets and a sufficient number of returning adults to meet the delayed mortality requirement of Wells HCP, Section 4.1.4.

Kirk Truscott asked if Douglas PUD would consider using acoustic tags. Kahler said, although the Wells HCP does not necessarily stipulate a PIT-tag study, Section 4.1.4 of the Wells HCP requires testing for "direct, indirect, and delayed mortality as it relates to the Project." Kahler said the only way to evaluate this is with PIT-tags. He said because of low smolt-to-adult return ratios (SARs), delayed mortality cannot be evaluated using acoustic tags.

Truscott said there are acoustic receivers in the Wells pool up to Chief Joseph Dam, and acoustic receivers in the Wells Dam tailrace for white sturgeon M&E. He asked what opportunity is there to use acoustic tags on a smaller number of fish, for example, spring Chinook salmon yearlings.

Lance Keller said in 2004, Chelan PUD conducted a PIT- versus acoustic-tag comparative study, and for the Rock Island Dam project there was no difference based on a side-by-side analysis.

Truscott asked what a 75,000-sample size is based on. Kahler said this is what is needed to achieve precision standards. Truscott asked if there is a SARs standard in the Wells HCP. Kahler said the idea behind SARs is, are there enough adults returning to generate a valid adult survival standard to differentiate a Project effect? He said a bad year for SARs would create issues. Truscott asked what would happen if PIT-tags were used and poor SARs were encountered? He added that if spring Chinook salmon are not being considered because of the 75,000 PIT-tags needed, he said only needing 2,700 acoustic tags may change minds. Kahler noted that Douglas PUD did use spring Chinook salmon one year and had 99.7% survival from the mouth of the Methow River.

John Ferguson asked when Douglas PUD needs a decision, and Kahler said in time to be included in the 2018 Broodstock Collection Protocols. Kahler said Douglas PUD will be collecting broodstock for the 2020 study next summer (2018). Mike Tonseth said the first draft of the protocols will be distributed in early February 2018; therefore, a decision will be needed no later than the HCP Coordinating Committees meeting in January 2018.

Kahler said Douglas PUD will provide a proposal on which study species to use for the Douglas PUD 2020 Survival Verification Study for the Wells HCP Coordinating Committee to consider, and will convene a conference call for discussion, if necessary.

V. Chelan PUD

A. DECISION: 2017 Rock Island and Rocky Reach Fish Spill Program Report (Lance Keller)

Lance Keller said Sarah Montgomery sent an email to the HCP Coordinating Committees on September 15, 2017, notifying them the Draft 2017 Rock Island and Rocky Reach Fish Spill Program Report was available for review. Edits and comments on the report were due to Keller by Monday, October 16, 2017.

Kirk Truscott said he was unable to review the report; therefore, the CCT abstains from voting.

Rock Island and Rocky Reach HCP Coordinating Committees members present approved the 2017 Rock Island and Rocky Reach Fish Spill Program Report, with the CCT abstaining.

Keller said Chelan PUD will provide the Final 2017 Rock Island and Rocky Reach Fish Spill Program Report to Kristi Geris for distribution to the HCP Coordinating Committees.

B. Rocky Reach Dam Large Unit Repair Update (Lance Keller)

Lance Keller recalled providing a Rocky Reach Dam large unit repair update during the HCP Coordinating Committees meeting on June 27, 2017, at which time he also provided an updated timeline for completion of repairs. Keller recalled the shift in deadlines was due to issues with the bridge crane, which moves the length of the powerhouse and is used to hoist the turbines and components for repairs. He said cracks were identified in the wheels of the bridge crane, which is currently being repaired. He said the large unit repairs are still on the same schedule described in June 2017, as follows:

Schedule for Rocky Reach Dam Large Unit Repair, 2017

Turbine Unit	Return to Service
C8	Fourth Quarter 2017
C9	First Quarter 2019
C10	First Quarter 2020
C11	First Quarter 2021

Keller noted that the repair schedule is set to be complete in time for Chelan PUD to conduct the HCP 10-year check-in survival study for Rocky Reach Dam. He said if necessary, Chelan PUD determined that turbine unit C11 is the preferred unit to be offline during a survival study. He explained that given C11 is the northern-most unit, being offline will not cause a shift in flow nor provide a calm, central area for predators to stage in the immediate tailrace.

John Ferguson asked when discussions need to begin within the HCP Coordinating Committees for the Rocky Reach Dam 2021 check-in study. Keller said he envisions these discussions to begin in 2018. He said the Rocky Reach Project has less lead time compared to the Wells Project, because Chelan PUD uses the RRJFBS to determine the run-of-the-river dominant species.

C. Rock Island Dam Powerhouse 2 Rehabilitation (Lance Keller)

Lance Keller said the Chelan PUD Board of Commissioners is now being engaged in planning for the rehabilitation of Powerhouse 2 at Rock Island Dam. Keller said an economic analysis of Powerhouse 2, which was built in the 1970s, recommended a rehabilitation, versus a full overhaul, to extend the lifespan of the system by an additional 40 years. Keller explained the rehabilitation timeline and other key dates, as follows:

Schedule for Rock Island Dam Powerhouse 2 Rehabilitation

Activity	Date
10-year check-in	2020
Begin rehabilitation	Third Quarter 2021
Complete rehabilitation	First Quarter 2029
10-year check-in	2030

Keller noted the window of time between the next 10-year check-in at Rock Island Dam and the beginning of the rehabilitation. He said this timing was proposed in case the need for additional studies arise during the 10-year check-in. He also noted that the completion date includes all 8 units.

Keller said in-depth analyses will be regularly conducted throughout the duration of the rehabilitation. He said parts will be refurbished and sandblasted to ensure they are structurally sound. He said machine tolerances will be returned to their original specifications. He said the runners will stay the same, and there will be no changes to the name plate discharge or horsepower.

Kirk Truscott and Chad Jackson asked if the rehabilitation might affect relicensing in 2028. Keller said, in general, he does not believe the rehabilitation should impact the relicensing process; however, Chelan PUD's relicensing group has been engaged in this discussion.

D. Rocky Reach Dam Fish Ladder, Request for Early Winter Maintenance Outage (Lance Keller)

Lance Keller said on October 20, 2017, the Rocky Reach Dam maintenance crew notified him of potential time constraints to complete the amount of work and unique projects planned for the 2017/2018 winter maintenance work period at Rocky Reach Dam. Keller said Chelan PUD is requesting Rocky Reach HCP Coordinating Committee agreement to begin the 2017/2018 winter maintenance work period at Rocky Reach Dam, 3 weeks earlier than usual to allow more time to complete required work. Rather than beginning work during the first week in January (per usual), maintenance work would begin on December 11, 2017.

Keller reviewed key projects driving this request, as follows:

- **Butterfly valve actuator** – a preventative maintenance inspection is due (conducted every 3 years)
- **Middle spillway entrance gate** – an in-depth inspection is due
- **Middle spillway entrance fish fence** – once installed, this fence will be deployed in the area adjacent to a dewatered middle spillway to prevent fish from retreating into the middle spillway, which will assist with fish rescue activities
- **Attraction water pump C** – the intermediate bearing needs an inspection
- **Traveling water screen** (screens the intake water that turns the attraction water pumps) – the pinch bolts on the south screen need an inspection
- **Picket barrier screens** – reduce spacing (Chelan PUD plans to reduce the 1-inch spacing to 3/4-inch for Pacific lamprey)
- **Attraction water pump intake** – slight modification needed
- **30-inch raw water valve** (located behind the auxiliary water system, which needs to be offline and dewatered to repair the water valve) – needs repair by a contractor (one of which did not seem confident the work can be completed within the normal outage)

Keller said while he discussed these projects with the maintenance crew, he did not identify anything too much out of the ordinary; however, staff is limited and one issue can cause a needed inspection or repair to fall off this list.

Keller said in 2014, the count system at Rocky Reach Dam was operated through the end of the year to monitor for any possible passage effects, primarily due to a concern over steelhead. He said in 2014, the total steelhead run past Rocky Reach Dam was 1,894 fish. He said from December 11, 2014, to December 31, 2014, there were 7 wild steelhead, 10 adipose-clipped steelhead, and 4 adult bull trout observed passing the Rocky Reach Dam count window. He said based on this year's counts to date, he expects these numbers to be even lower in 2017.

John Ferguson asked when Chelan PUD needs a response to this request. Keller said the request is slightly time-sensitive because of the 30-inch raw water valve out for bid. He said increasing the winter outage window will increase the number of contractors willing to bid on the project.

Chad Jackson requested that Chelan PUD provide a written list of the repairs and the 2014 passage data reviewed, and a vote via email. Ferguson suggested a voting deadline of Friday, November 3, 2017. Keller agreed to this deadline and said he will provide the requested information by the end of the day. *(Note: Keller provided the list of repairs and 2014 passage data to Kristi Geris following the meeting on October 24, 2017, which Geris distributed to the HCP Coordinating Committees on October 25, 2017.)*

Kirk Truscott asked what will happen if the extension is not approved. Keller said Chelan PUD will need to prioritize the maintenance and complete as much as time allows. Truscott noted that there are criteria established for fish ladders to be offline for a reason, but there is a regular request for deviating from these criteria. He asked if this request is because, even with double-staffing the work still cannot be completed, or is it just to save money? Keller said Chelan PUD determined how many labor hours are required to complete these repairs, and there is a deficit to complete the needed repairs. He said Chelan PUD does not have the workforce to complete the needed work. He added that the 30-inch raw water valve requiring a contractor also needs additional time. He said if the early outage is not approved, there is a good chance Chelan PUD will be asking for an extension at the backend of the maintenance period because the fish ladder cannot be brought back online until the 30-inch raw water line work is completed.

Keller recalled Chelan PUD's request last year for an extension of the winter maintenance outage at Rocky Reach Dam; however, maintenance crews were unable to complete everything and the fish ladder was back online on February 14, 2017. Ferguson asked if last year's unfinished work is on this year's list. Keller said no, that work can wait another year.

Keller said he will discuss Truscott's comments internally with Chelan PUD.

The Rocky Reach HCP Coordinating Committee agreed via email to Chelan PUD's request to begin the 2017/2018 winter maintenance work period at Rocky Reach Dam, 3 weeks earlier than usual to allow more time to complete required work. Rather than beginning work during the first week in January (per usual), maintenance work will begin on December 11, 2017. Approvals were as follows: Chelan PUD, NMFS, WDFW, and the CCT approved November 1, 2017, and USFWS and the YN approved November 2, 2017.

VI. HCP Administration

A. WDFW HCP Hatchery Committees Representation Designation Update (John Ferguson)

Chad Jackson has been added to the HCP Hatchery Committees email distribution list and has been given access to the HCP Hatchery Committees Extranet site, per a request from Mike Tonseth (WDFW HCP Hatchery Committees Representative). Jackson has replaced Jeff Korth (WDFW, retired) as the WDFW HCP Hatchery Committees Alternate. *(Note: recall, HCP Coordinating Committees approval is not needed to add HCP representatives and alternates to the email lists and extranet sites; however, granting this type of access typically occurs after an official designation letter is received from the Party.)*

Jackson will provide an official WDFW HCP Hatchery Committees Representation Designation Letter to Kristi Geris for the administrative record. *(Note: Jackson provided this letter to Geris on November 6, 2017, which Geris distributed to the HCP Coordinating Committees and to Sarah Montgomery for distribution to the HCP Hatchery Committees that same day.)*

B. Next Meetings

The HCP Coordinating Committees noted that the USACE's 2017 AFEP Annual Review is scheduled for November 28 to 29, 2017, in Richland, Washington, which conflicts with the HCP Coordinating Committees meeting on November 28, 2017. HCP Coordinating Committees members present agreed to cancel the HCP Coordinating Committees meeting on November 28, 2017, due to lack of agenda items and a scheduling conflict with the 2017 AFEP Annual Review.

John Ferguson said the next scheduled HCP Coordinating Committees meeting is on December 26, 2017, 1 day after the Christmas holiday. Kristi Geris said she will coordinate with Denny Rohr and the PRCC regarding rescheduling the HCP Coordinating Committees meeting in December 2017. *(Note: Geris coordinated with Rohr, who indicated the PRCC plans to meet on December 13, 2017; therefore, the HCP Coordinating Committees meeting on December 26, 2017, has been rescheduled to December 12, 2017, to accommodate the Christmas holiday and best coordinate with the PRCC.)*

The next scheduled HCP Coordinating Committees meeting is on December 12, 2017, to be held by conference call or in-person at the Grant PUD Wenatchee Office in Wenatchee, Washington, pending agenda items.

The January 23 and February 27, 2018 meetings will be held by conference call or in-person at the Grant PUD Wenatchee Office in Wenatchee, Washington, as is yet to be determined.

VII. List of Attachments

Attachment A	List of Attendees
Attachment B	"Epigenetics: what is it and why is it relevant to hatchery practices?"
Attachment C	Wells Dam count-window data for Pacific Lamprey, steelhead, and Chinook and Coho salmon
Attachment D	Draft 2017 Wells Dam Passage Dates Analysis (corrected)

Attachment A
List of Attendees

Name	Organization
John Ferguson	Anchor QEA, LLC
Kristi Geris	Anchor QEA, LLC
Tracy Hillman††	BioAnalysts
Lance Keller*	Chelan PUD
Tom Kahler*	Douglas PUD
Scott Carlon*†	National Marine Fisheries Service
Mackenzie Gavery⁰	National Marine Fisheries Service
Jim Craig*	U.S. Fish and Wildlife Service
Chad Jackson*	Washington Department of Fish and Wildlife
Patrick Verhey*†	Washington Department of Fish and Wildlife
Mike Tonseth	Washington Department of Fish and Wildlife
Kirk Truscott*	Colville Confederated Tribes
Keely Murdoch*	Yakama Nation

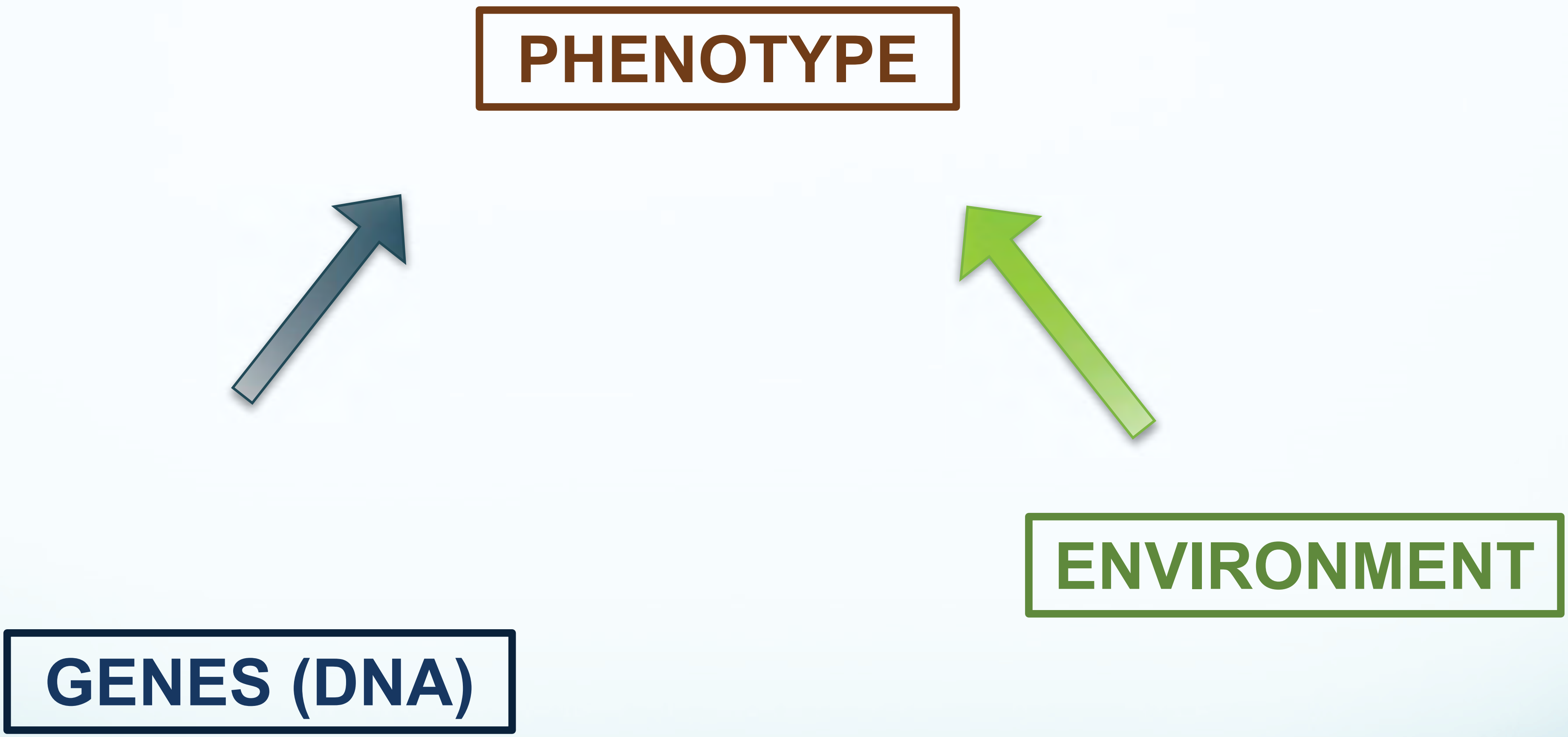
Notes:
- * Denotes HCP Coordinating Committees member or alternate
- † Joined by phone
- †† Joined by phone for the HCP Tributary and Hatchery Committees Update
- ⁰ Joined for the Epigenetics Presentation

Epigenetics: what is it and why is it relevant to hatchery practices?

Mackenzie Gavery[1], Krista M. Nichols[2], Giles Goetz[1], Mollie A. Middleton[1], Penny Swanson[2]

[1] University of Washington, SAFS

[2] NOAA Fisheries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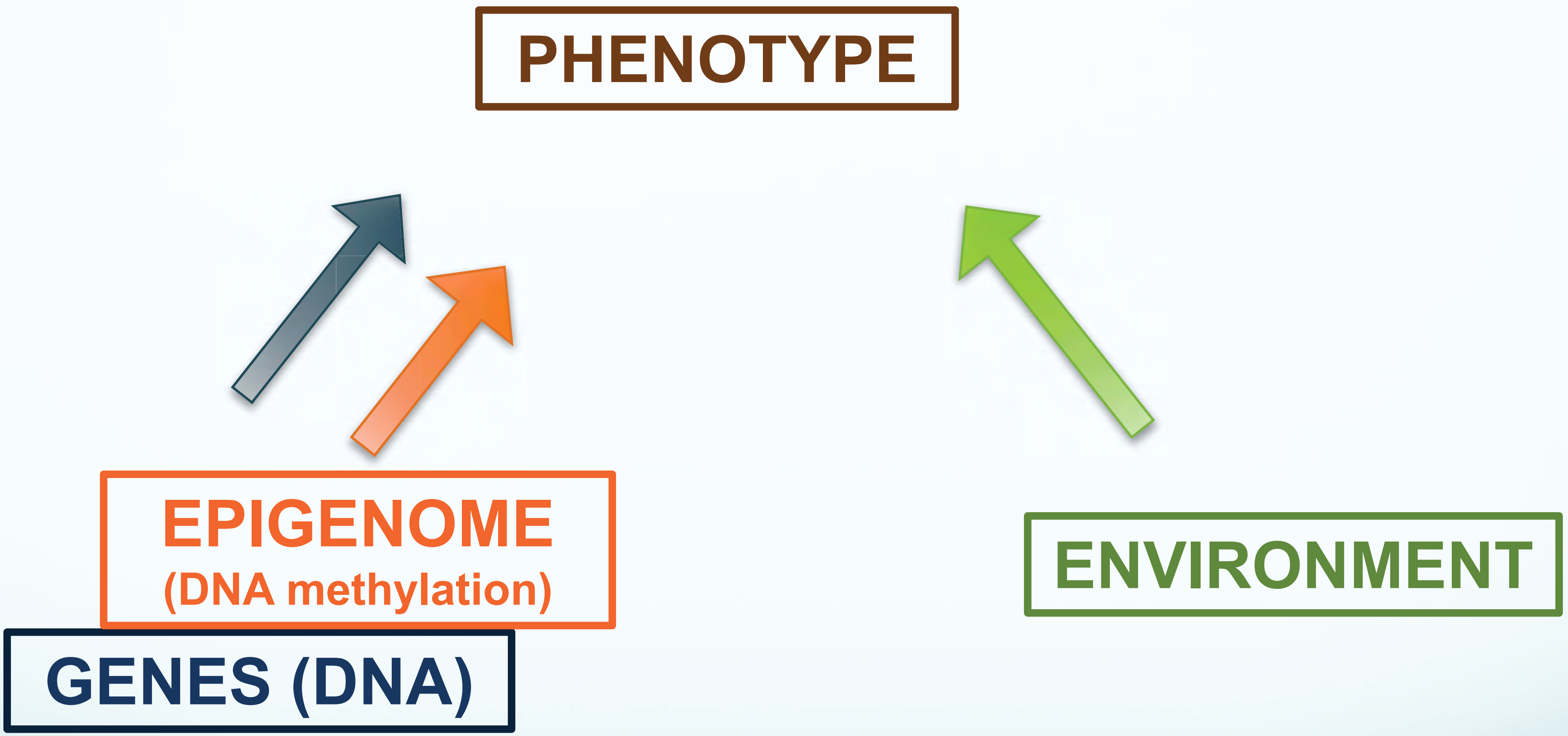
GENES (DNA)
ENVIRONMENT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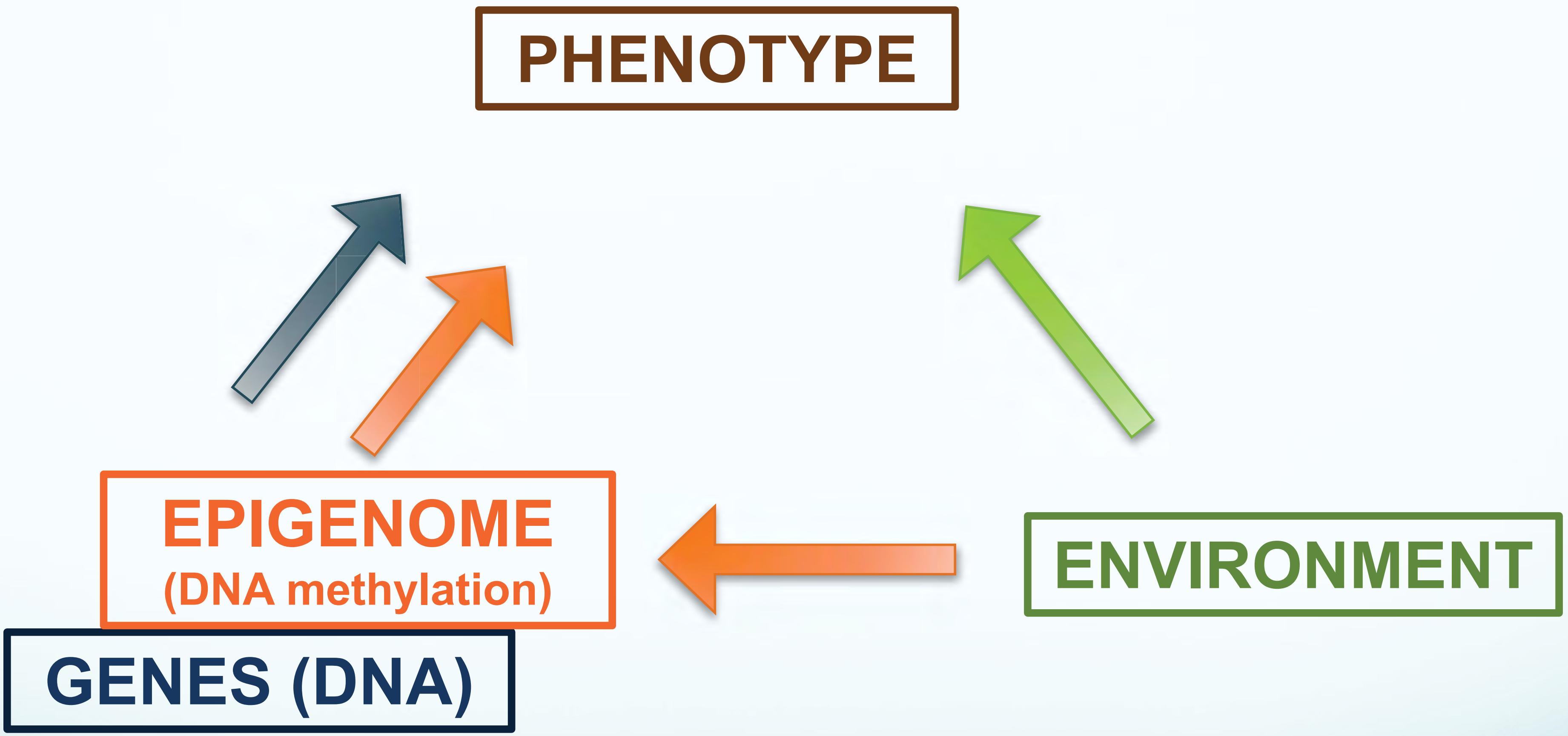
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(DNA methylation)
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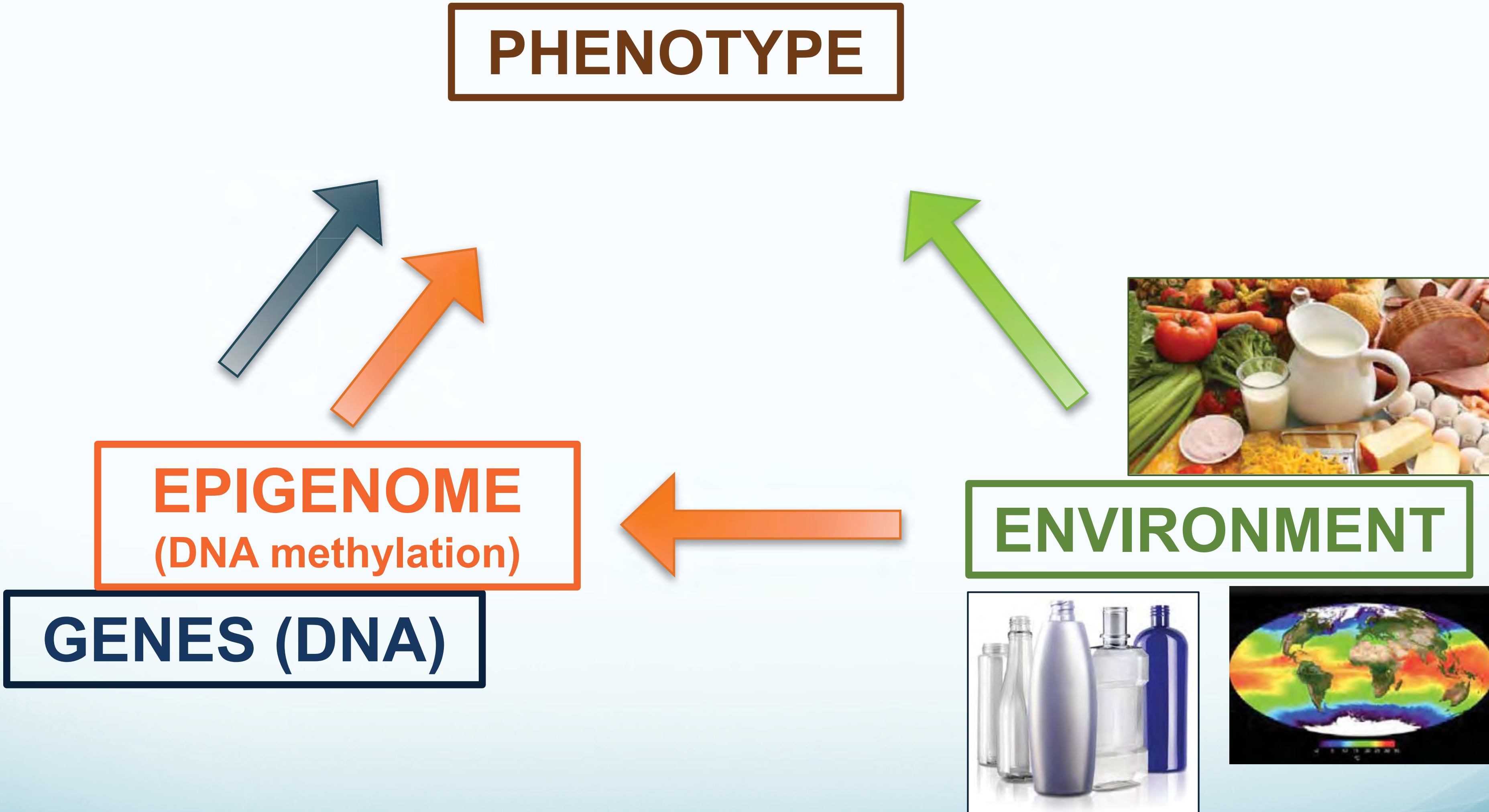
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(DNA methylation)
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Outline

- Epigenetics Basics
  - Definitions
  - DNA methylation
    - Functions
    - Environment
    - Epigenetic inheritance
- Why is epigenetics relevant to hatchery practices?
  - DNA methylation data from Methow River steelhead

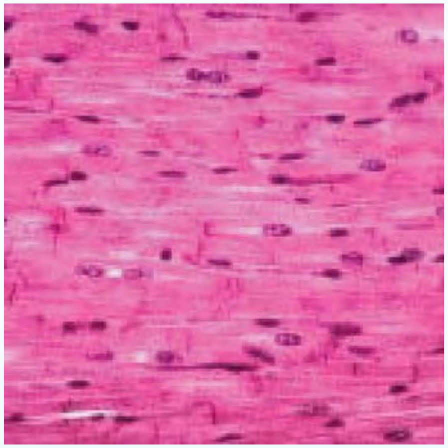
Epigenetics

- Heritable changes in trait or phenotype, caused by a mechanism other than mutation to the DNA sequence

Epigenetics

- Heritable changes in trait or phenotype, caused by a mechanism other than mutation to the DNA sequence

All of these cell types contain the same DNA.. so why do they look so different?


Epigenetics

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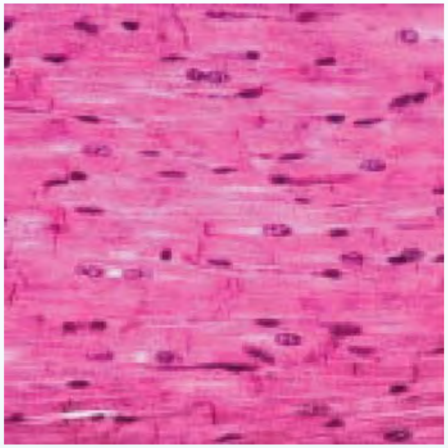
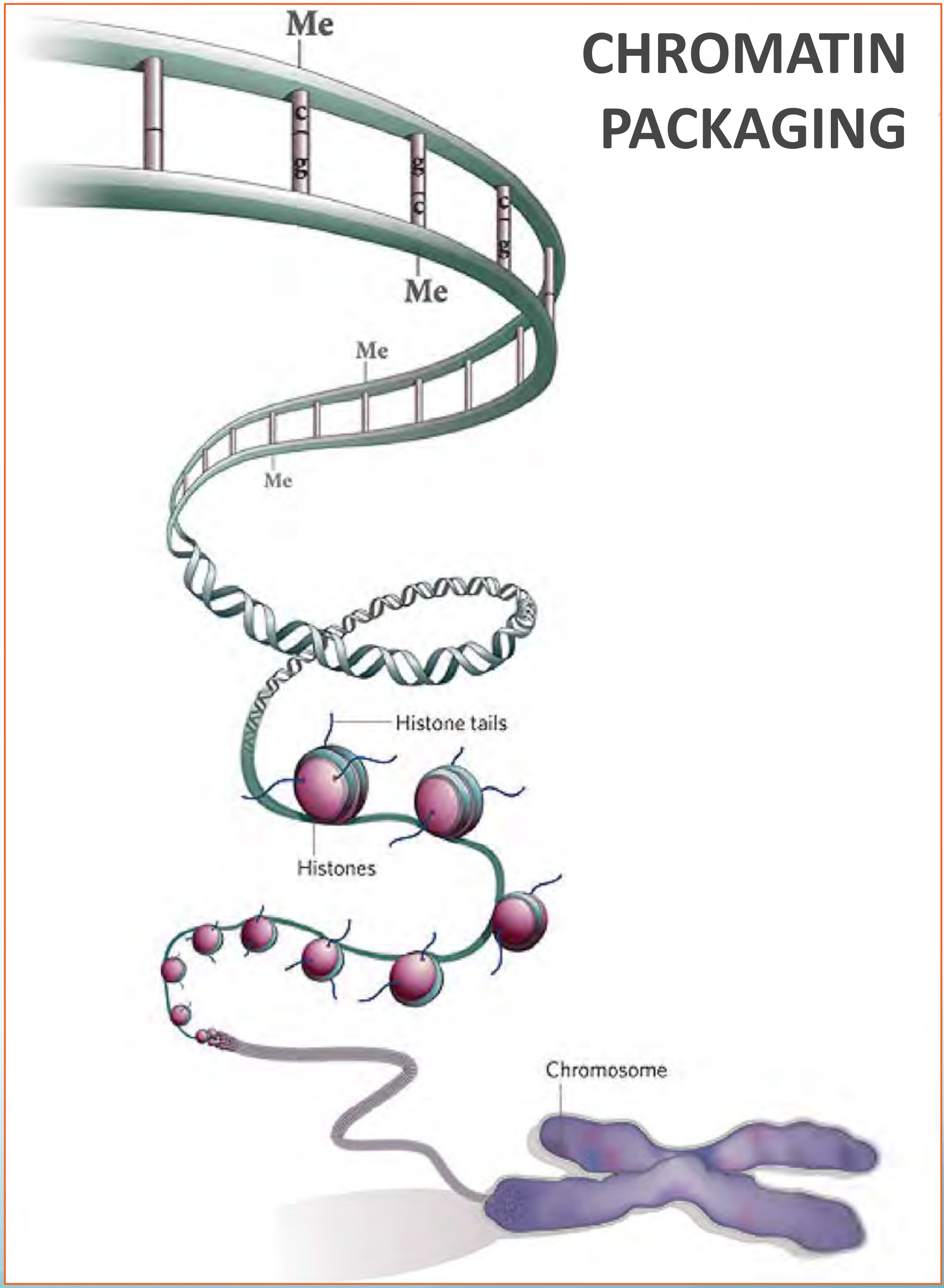
All of these cell types contain the same DNA.. so why do they look so different?



If DNA is the ‘hardware’, the epigenome is the ‘software’. It provides the instructions to regulate the genome

Epigenetic Marks

- Histone modifications
  - Acetylation
  - Methylation
- DNA methylation
- Non-coding RNAs
  - micro RNA (miRNA)

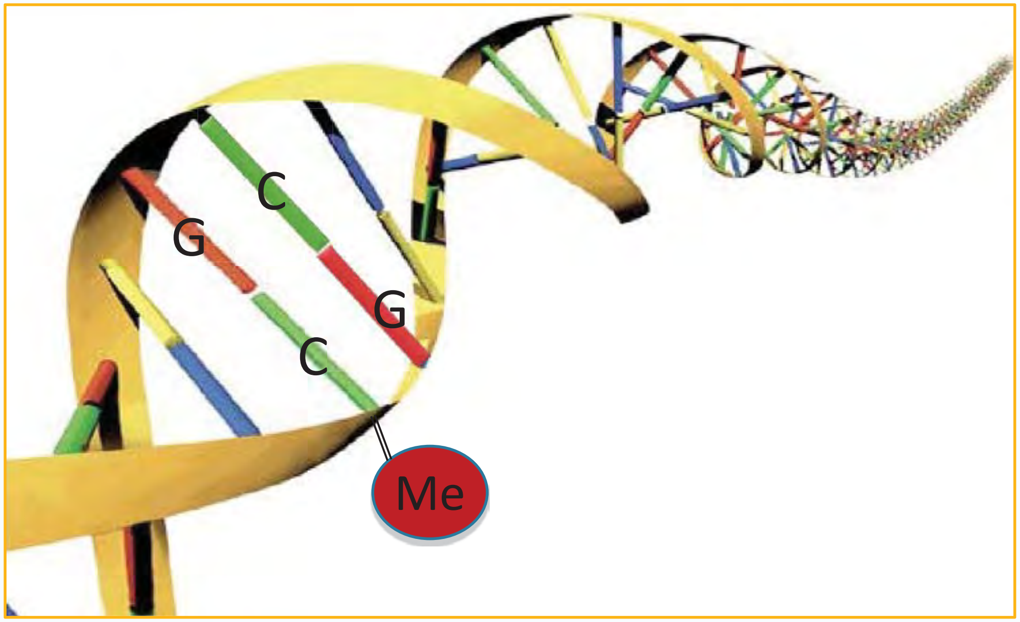


DNA Methylation

- Functions
- DNA methylation & the environment
- Epigenetic inheritance

DNA Methylation

- **Functions**
- DNA methylation & the environment
- Epigenetic inheritance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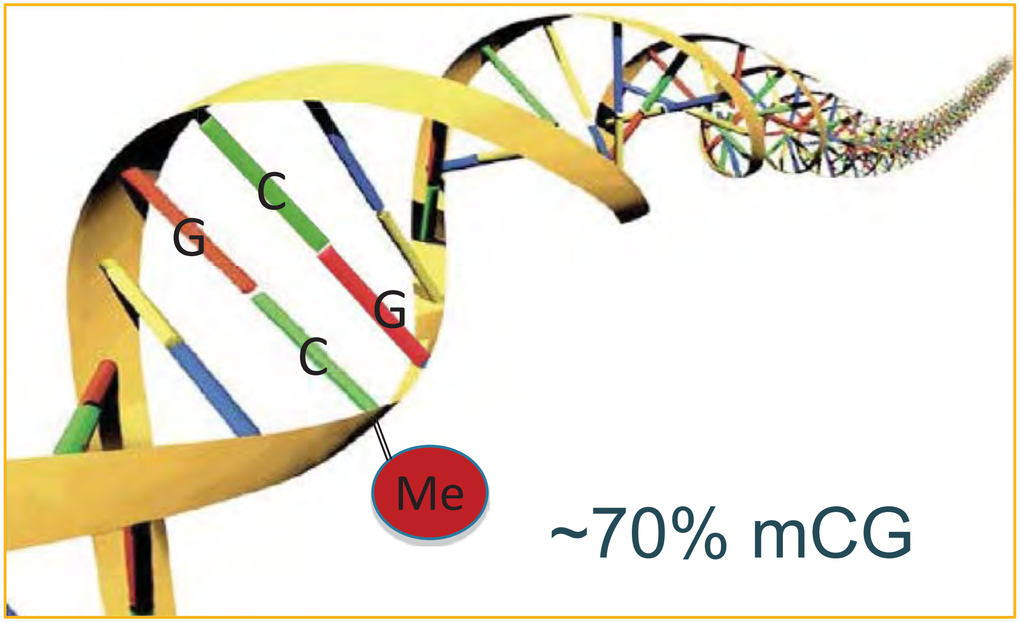
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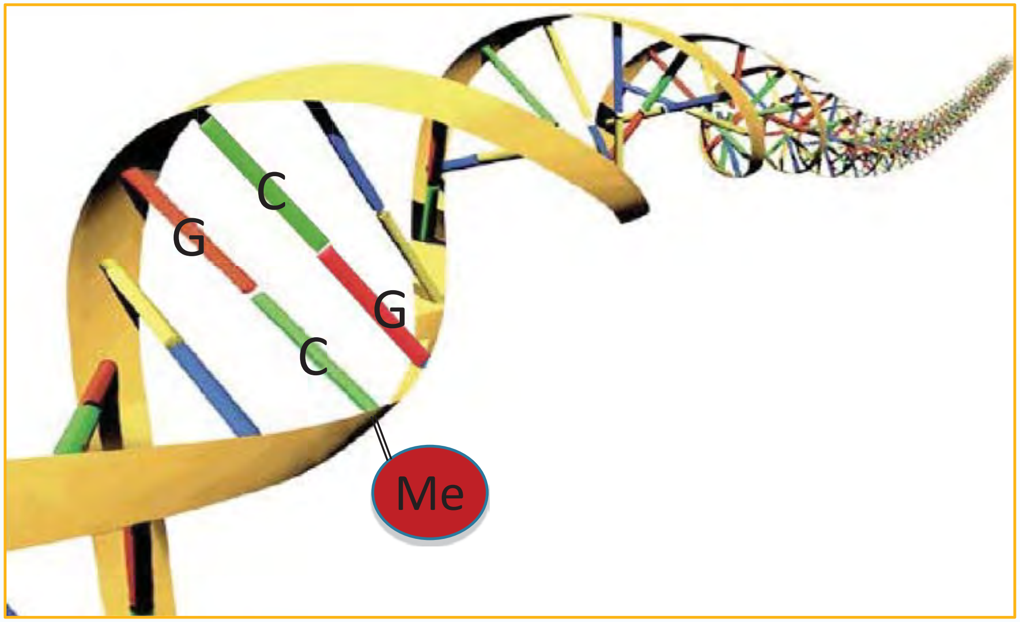
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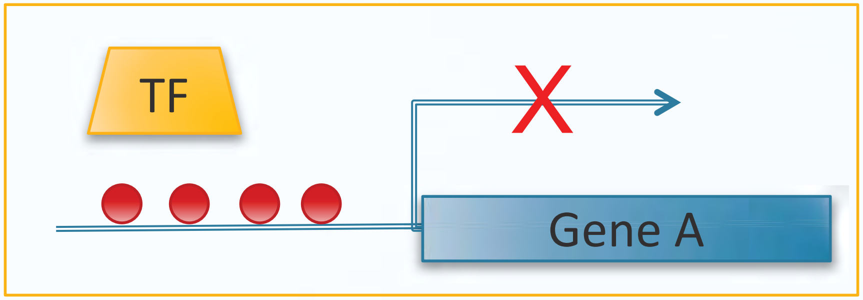
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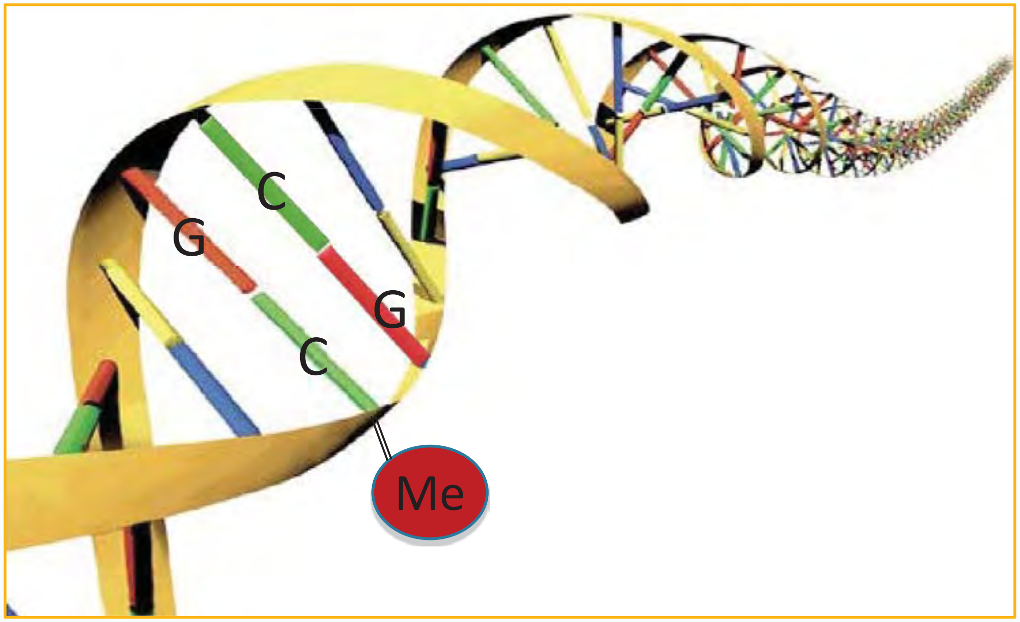
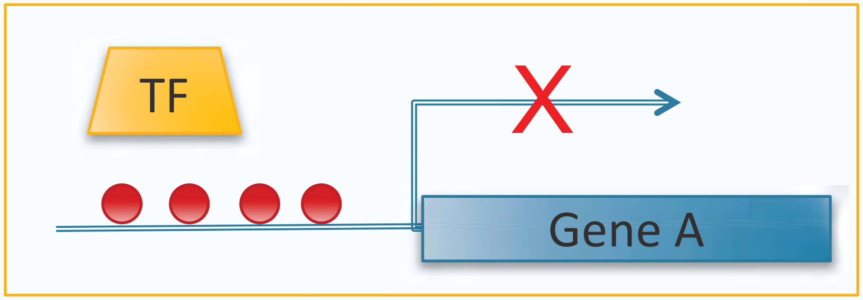
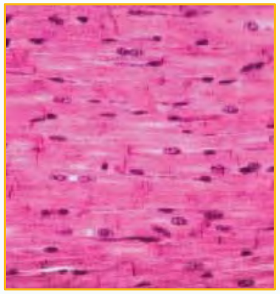
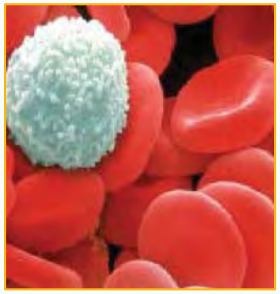
Attachment B









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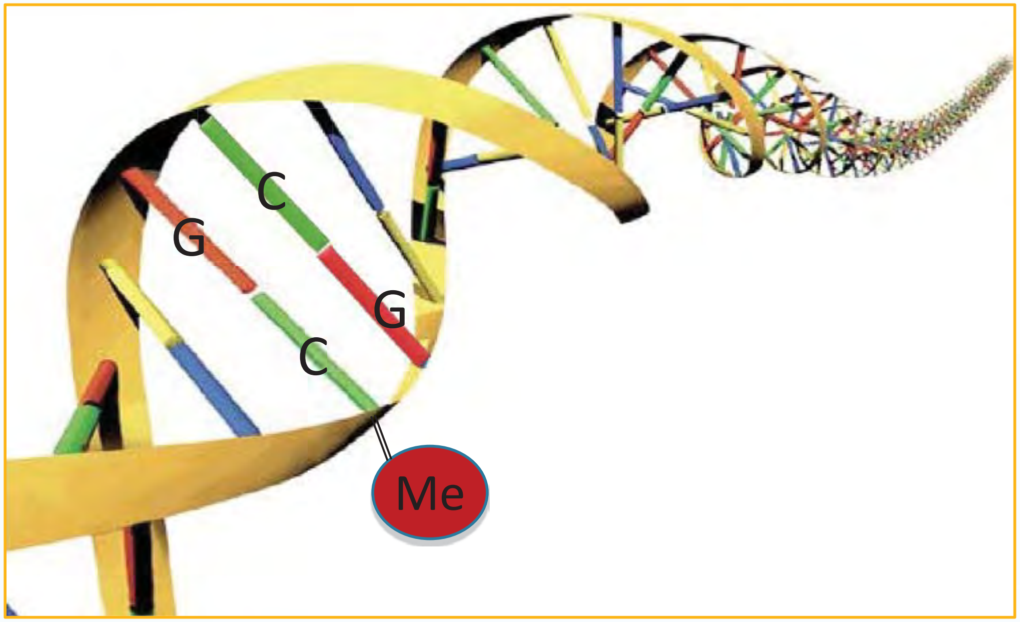

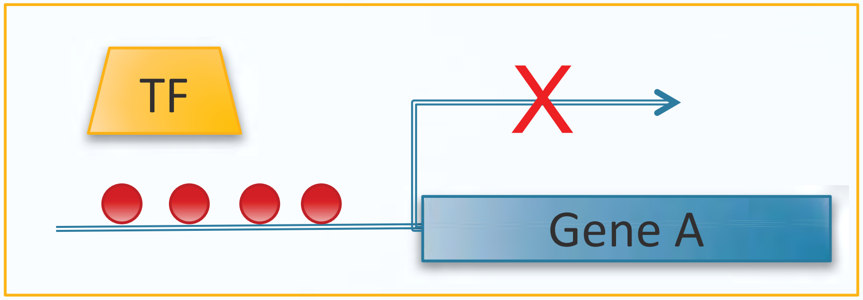

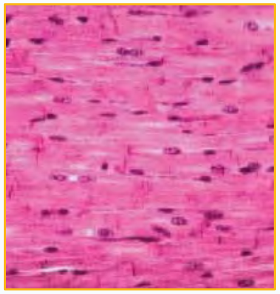

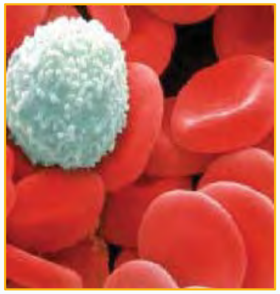

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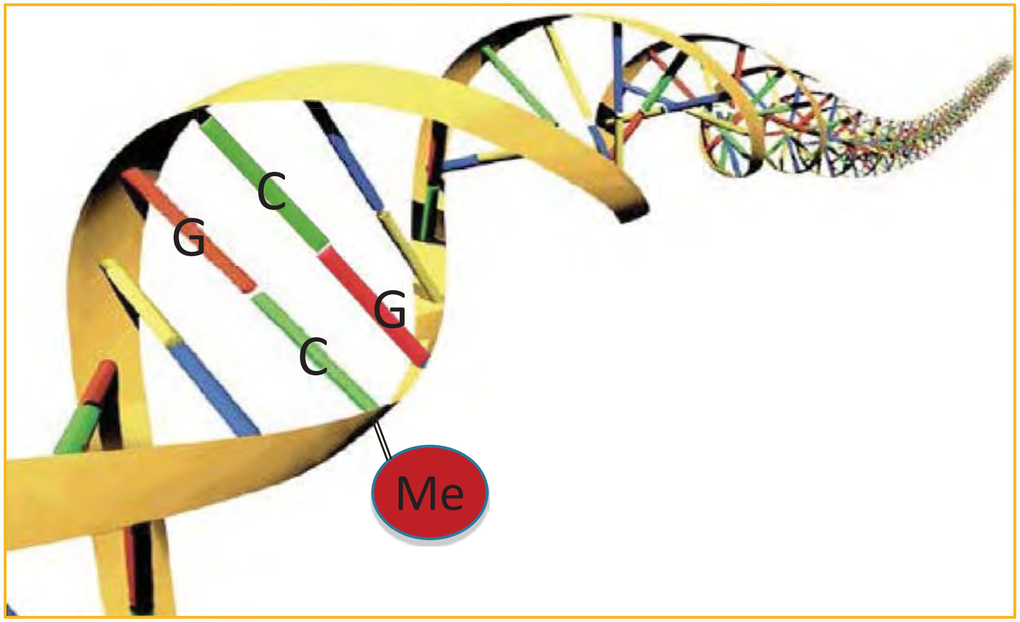

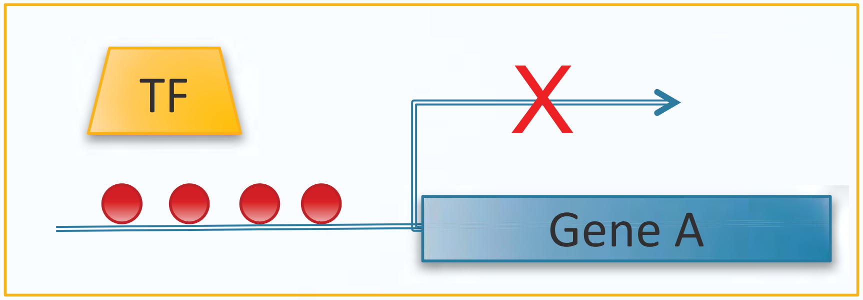

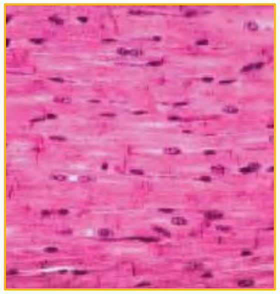

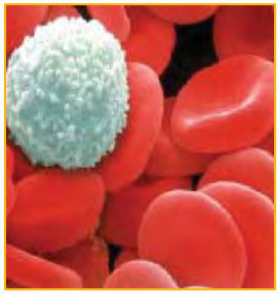

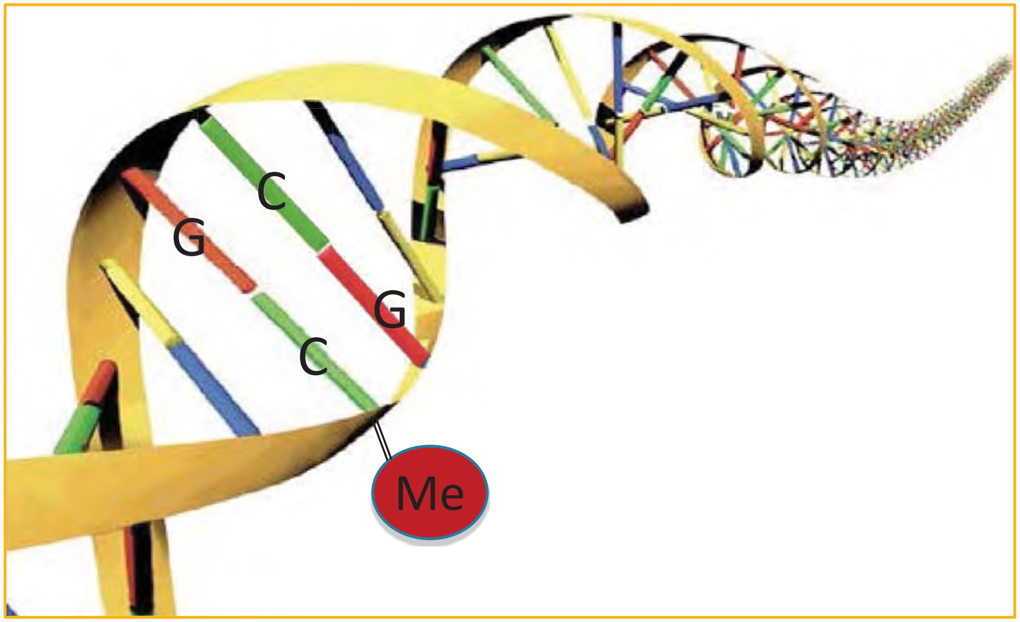
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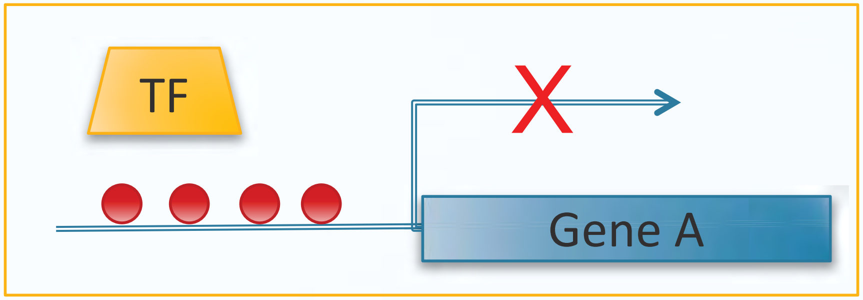
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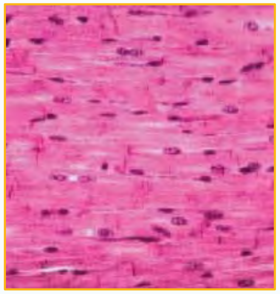

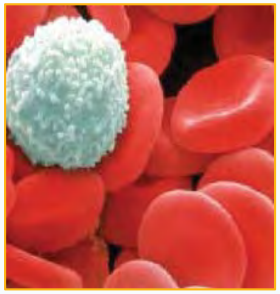


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gene


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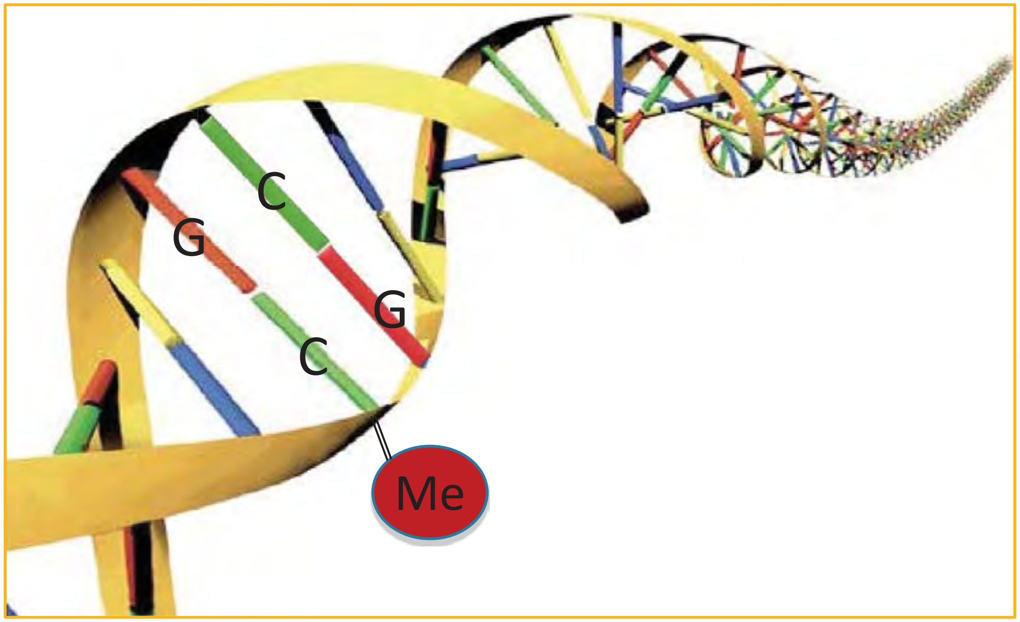
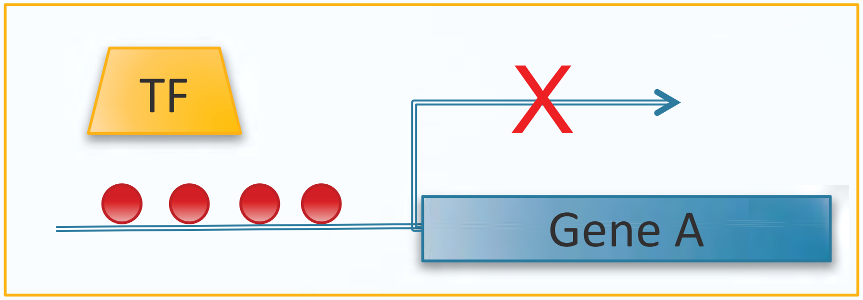
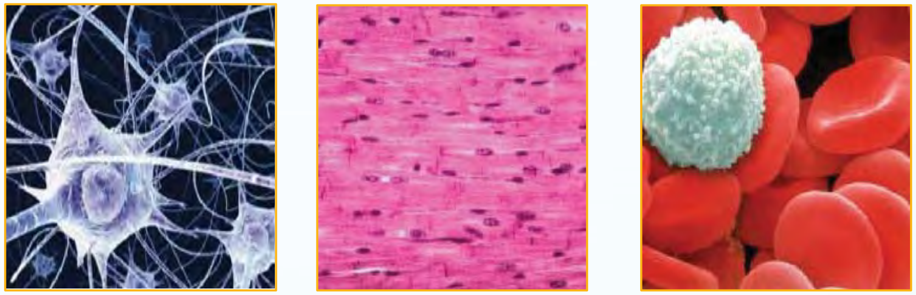
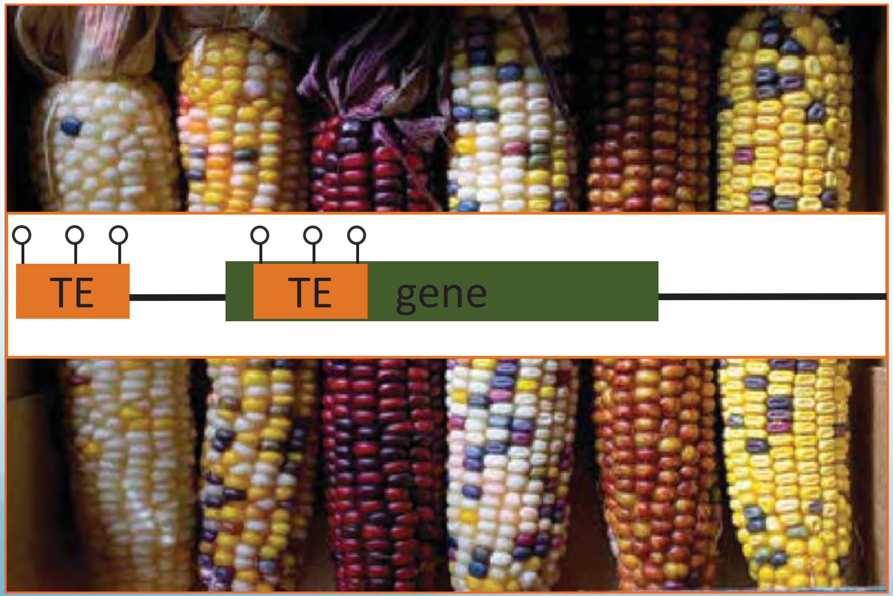
10.5
11.5
12.5
13.5
14.5
15.5
16.5
17.5
18.5
Neonate
Gestational Ages
in Days

Attachment B







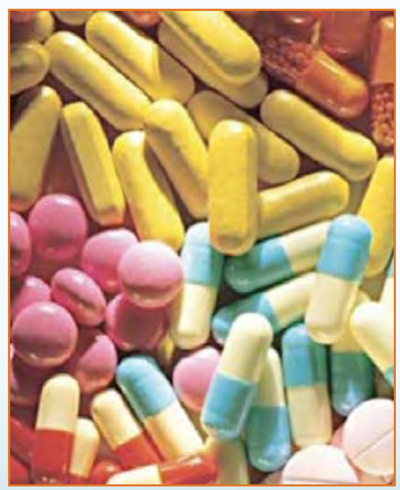


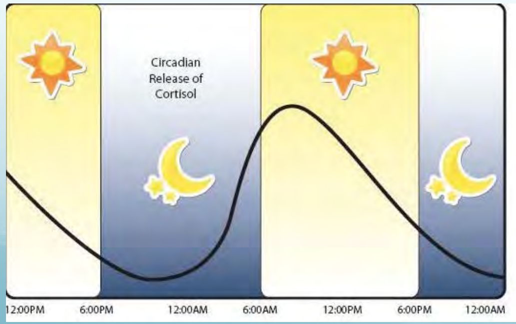
DNA Methylation

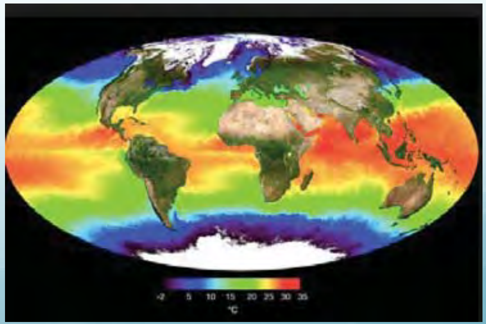
- Functions
- **DNA methylation & the environment**
- Epigenetic inheritance

DNA Methylation

- Many environmental factors have been shown to affect epigenetic marks such DNA methylation







Toxins

- Genetically identical female mice
- Different DNA methylation status of the Agouti gene
- Affected by toxins/diet

Source: Randy Jirtle

(Dolinoy et al., *PNAS*, 2007)

Temperature

- Sex determination in European sea bass is temperature dependent
- High temp early in development = more males
- Mechanism: Methylation of the aromatase gene

$$T \xrightarrow{\text{aromatase}} E2$$

(Navarro-Martin et al, *PLOS Genetics*, 2011)

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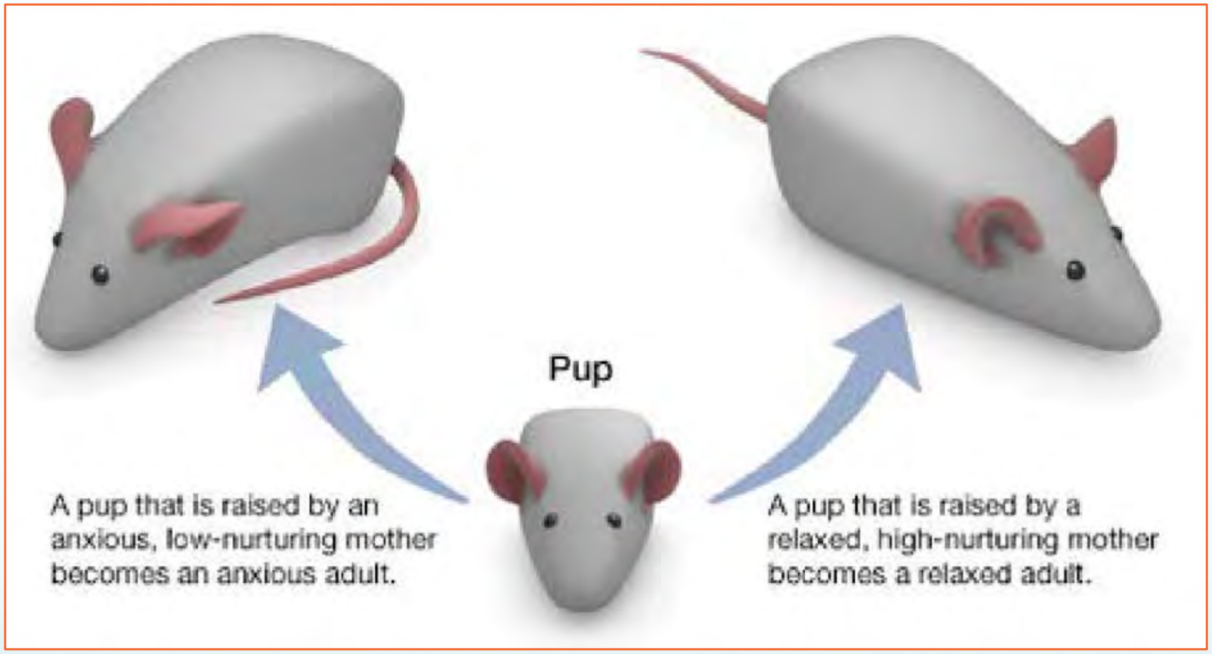
(Navarro-Martin et al, *PLOS Genetics*, 2011)

Behavior

- Licking/grooming behavior by rat mothers influences the DNA methylation status of the glucocorticoid receptor (a stress gene) in offspring



http://learn.genetics.utah.edu/content/epigenetics/rats/

(Weaver et al., *Nature Neuroscience*, 2004)

Nutrition – Dutch Hunger Winter

- Study the effects of developmental malnutrition by following women who were pregnant at this time
- Calorie restriction during early development (versus late development) had latent effects on adult health:
  - obesity
  - cardiovascular disease
  - insulin resistance
- DNA methylation differences in insulin-like growth factor gene

http://genomemag.com/epigenetics

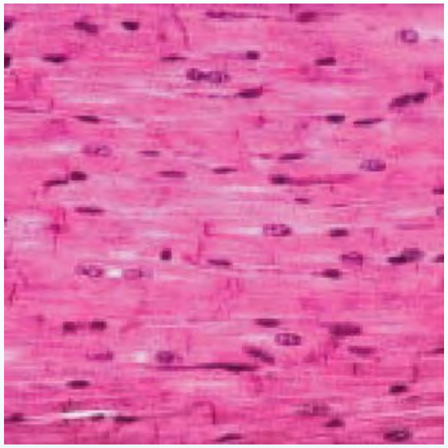
(Heijmans et al., *PNAS*, 2008)

DNA Methylation

- Functions
- DNA methylation & the environment
- **Epigenetic inheritance**

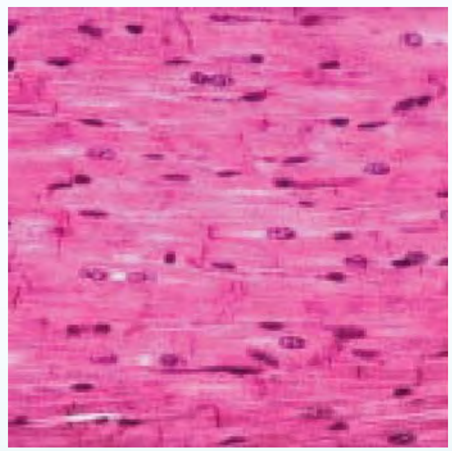
DNA methylation

- Epigenetic inheritance:

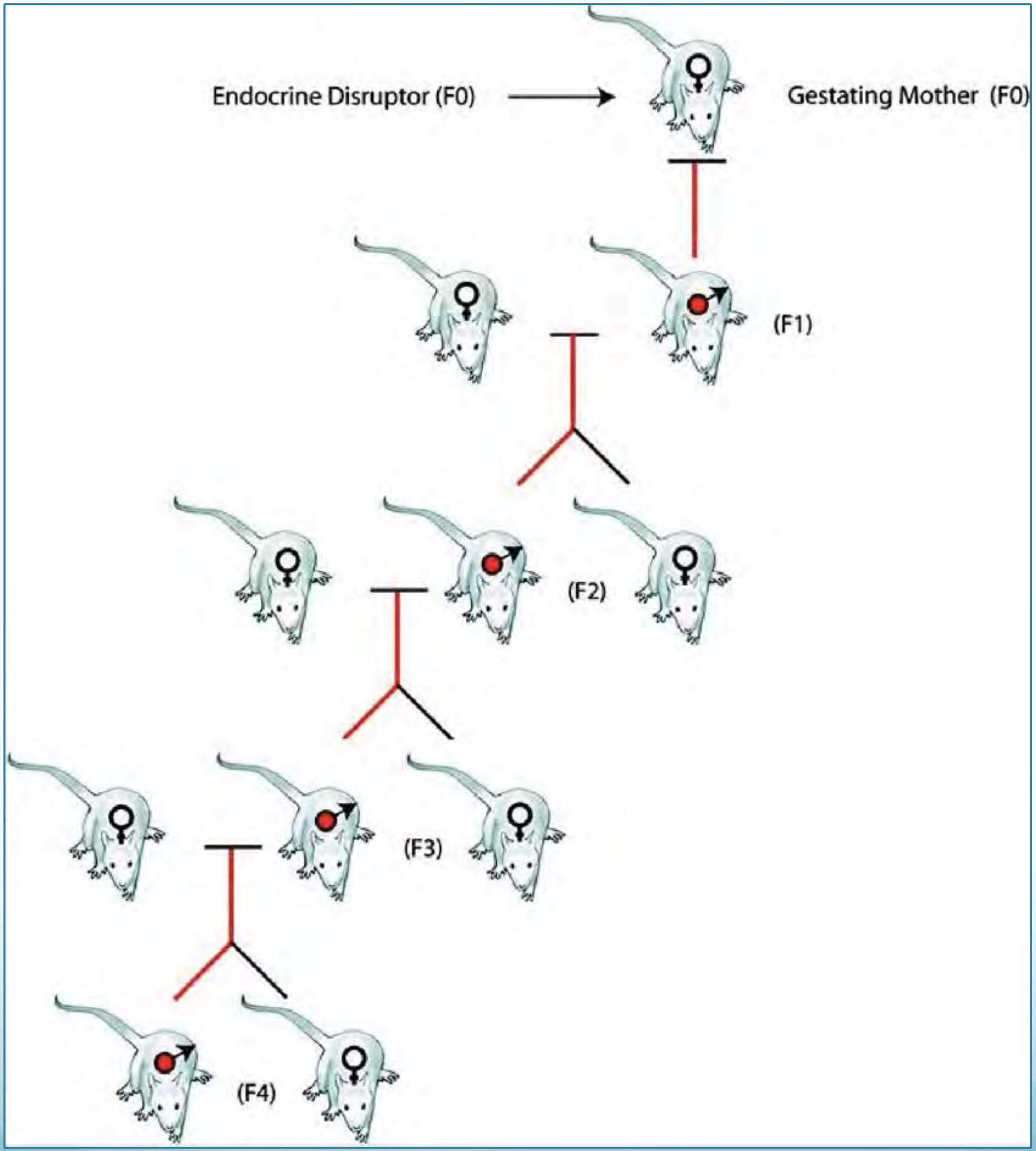




DNA methylation

- Epigenetic inheritance:
  - Mitotic inheritance
  - Meiotic (transgenerational) inheritance



Transgenerational Epigenetic Inheritance: mammals



(Skinner 2007)

Attachment B

Transgenerational Epigenetic Inheritance: half-smooth tongue sole

ZW female

ZZ male

Transgenerational Epigenetic Inheritance: half-smooth tongue sole

NORMAL TEMPERATURE

ZW female

ZZ male

ELEVATED TEMPERATURE

Transgenerational Epigenetic Inheritance: half-smooth tongue sole

NORMAL TEMPERATURE

ZW female

ZZ male

ELEVATED TEMPERATURE

ZW pseudomale

Transgenerational Epigenetic Inheritance: half-smooth tongue sole

NORMAL TEMPERATURE

ZW female

x

ZZ male

ELEVATED TEMPERATURE

ZW pseudomale

Attachment B

Transgenerational Epigenetic Inheritance: half-smooth tongue sole

NORMAL TEMPERATURE

ZW female

ZZ male

x

ELEVATED TEMPERATURE

ZW pseudomale

NORMAL TEMPERATURE (F1)

Transgenerational Epigenetic Inheritance: half-smooth tongue sole

NORMAL TEMPERATURE

ZW female

ZZ male

x

ELEVATED TEMPERATURE

ZW pseudomale

→

NORMAL TEMPERATURE (F1)

ZW pseudomale

Transgenerational Epigenetic Inheritance: half-smooth tongue sole

NORMAL TEMPERATURE

ZW female

ZZ male

x

ELEVATED TEMPERATURE

ZW pseudomale

→

NORMAL TEMPERATURE (F1)

ZW pseudomale

- Environment early in development changes phenotype, not genotype
- Phenotype is epigenetically inherited in the absence of environmental signal

DNA Methylation

- Functions
- DNA methylation & the environment
- Epigenetic inheritance

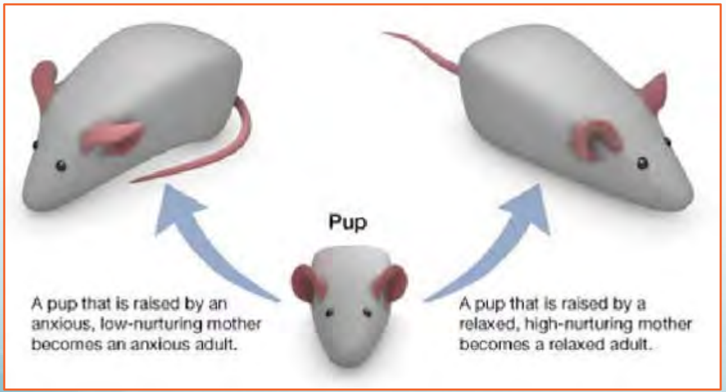
DNA Methylation

Environmentally-induced epigenetic changes are more likely to be persistent/heritable when exposure occurs during early development

DNA Methylation

<u>Environmentally-induced</u> epigenetic changes are more likely to be persistent/heritable when exposure occurs during <u>early development</u>

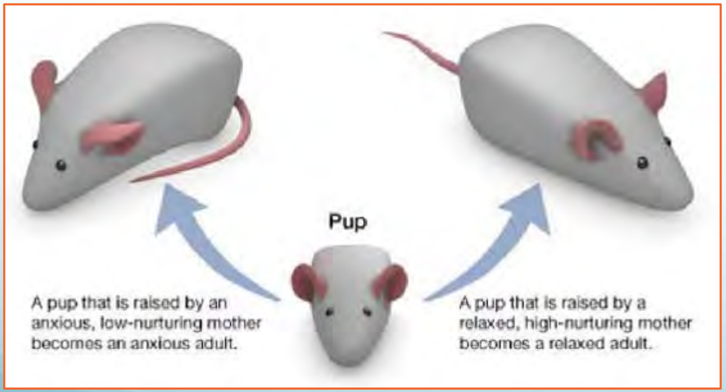
Adaptive:



DNA Methylation

<u>Environmentally-induced</u> epigenetic changes are more likely to be persistent/heritable when exposure occurs during <u>early development</u>

Adaptive:



Maladaptive:

Epigenetics: relevance to hatchery practices

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- Salmon and steelhead reared in a hatchery are phenotypically different than wild fish

Epigenetics: relevance to hatchery practices

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- Possible mechanisms include:
  - Hatchery induced selection
  - Environmentally-induced, heritable, epigenetic change
  - Both

Epigenetics: relevance to hatchery practices

- Salmon and steelhead reared in a hatchery are phenotypically different than wild fish
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  - **Environmentally-induced, heritable, epigenetic change**
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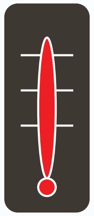
Epigenetics: relevance to hatchery practices

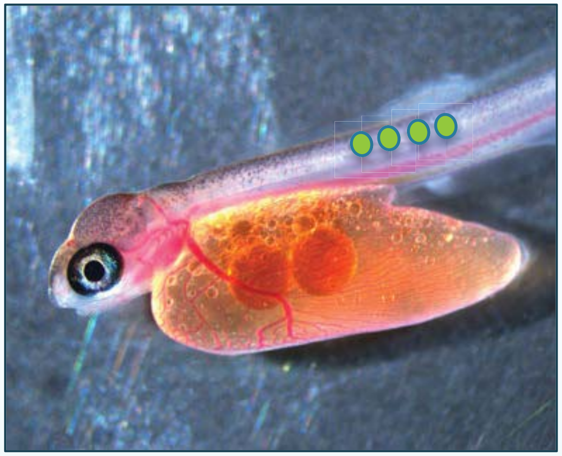
<u>Environmentally-induced</u> epigenetic changes are more likely to be persistent/heritable when exposure occurs during <u>early development</u>

Epigenetics: relevance to hatchery practices

photoperiod



temperature



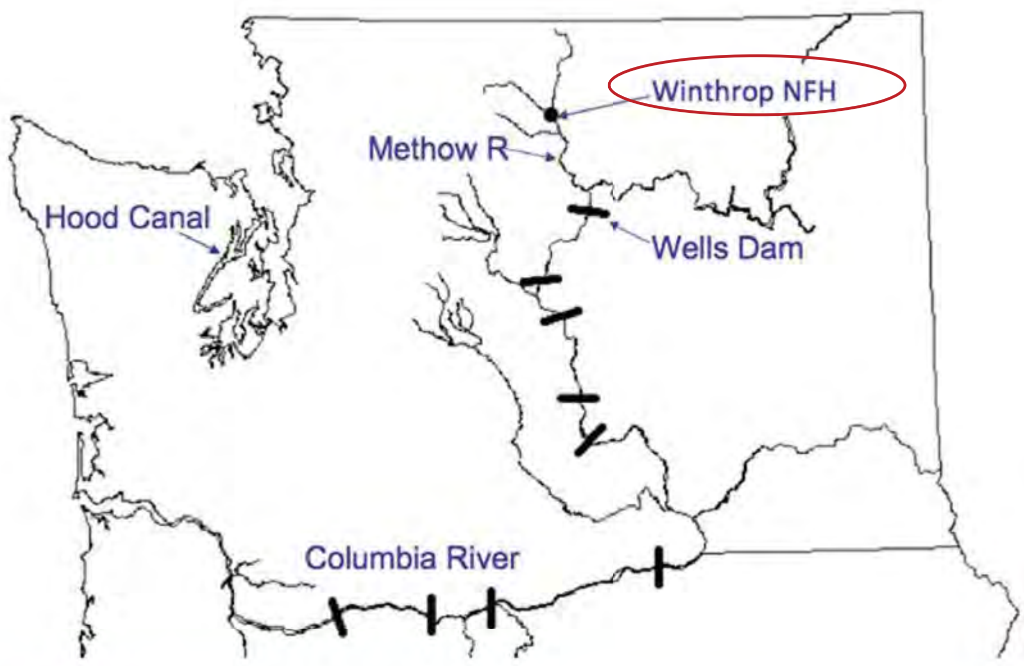
Water chemistry (pH, organics, toxins, O2)

Olfactory cues

Nutrients (yolk and exogenous food)

Steelhead & Epigenetics

Are there discernible epigenetic differences between hatchery and wild origin steelhead?



Steelhead & Epigenetics

- Returning adult fish were collected in 2014
- Identified as hatchery or natural origin
- Collected sperm and blood

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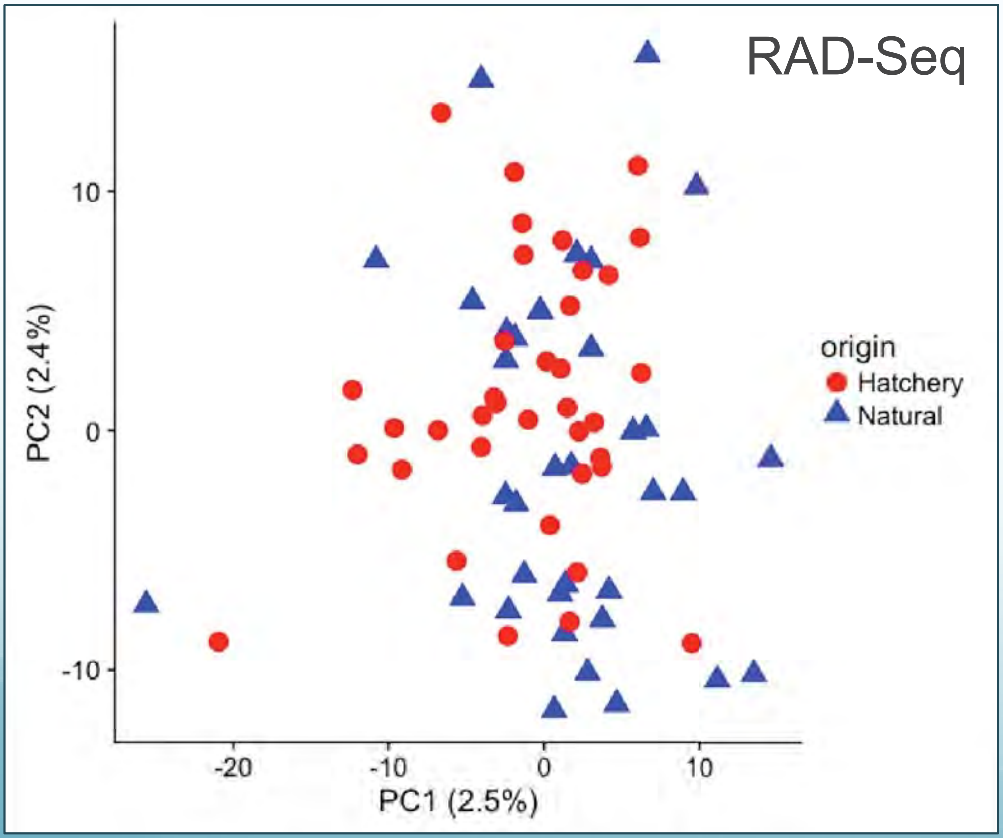


Approach

- DNA methylation analysis
  - Red Blood Cells (RBC)
  - Sperm

Results: RRBS

- Measured over 112,000 100bp regions in the genome
- Steelhead have a heavily methylated genome
  - 86% of CG are methylated in RBC
  - 94% of CG are methylated in Sperm

Attachment B

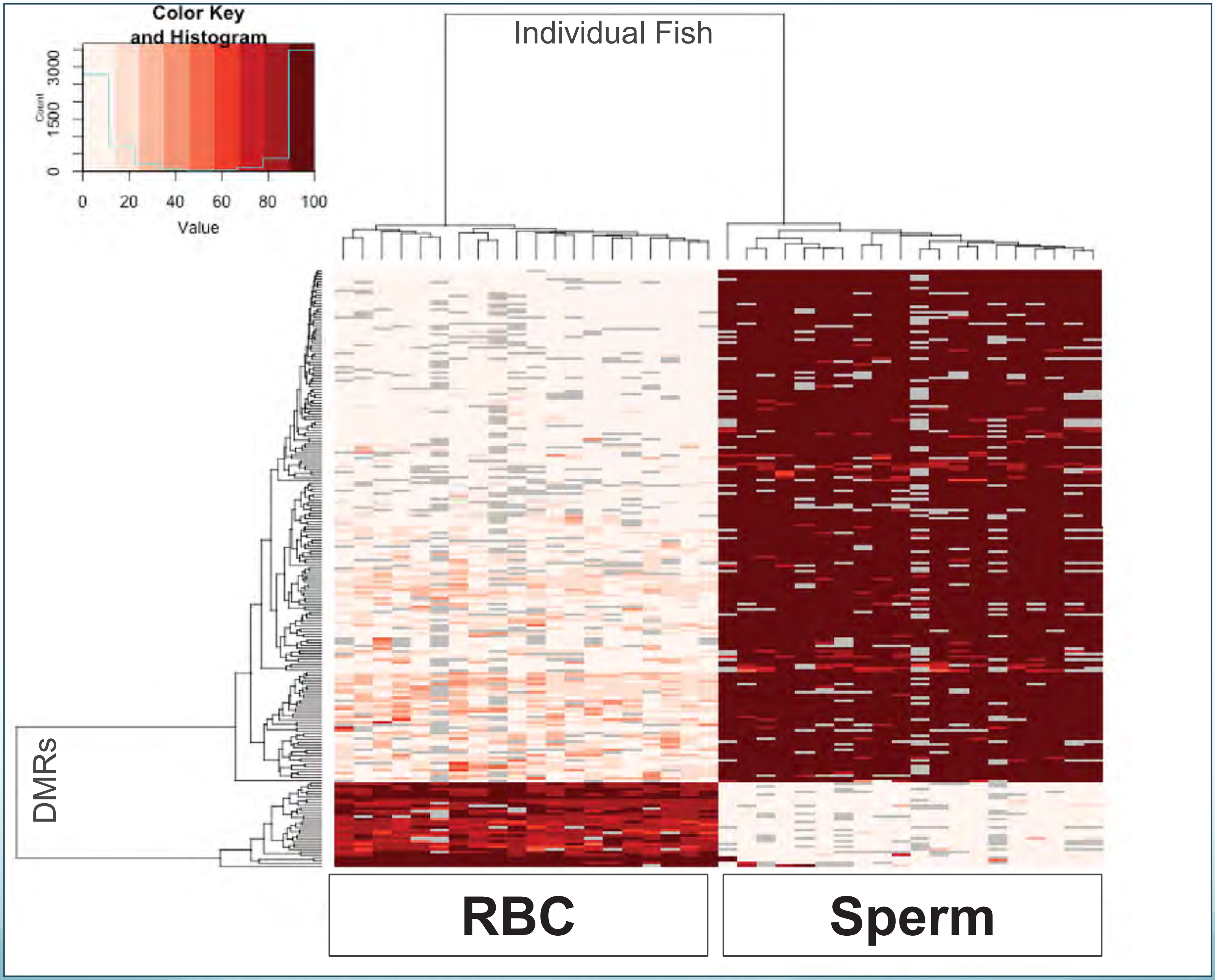
Cell-type Specific Methylation

Cell-type Specific Methylation

- Differentially methylated regions* (DMRs) *region = average % methylation over 100bp
  - 3633 DMRs >20% difference in methylation
  - 218 DMRs >75% difference in methylation

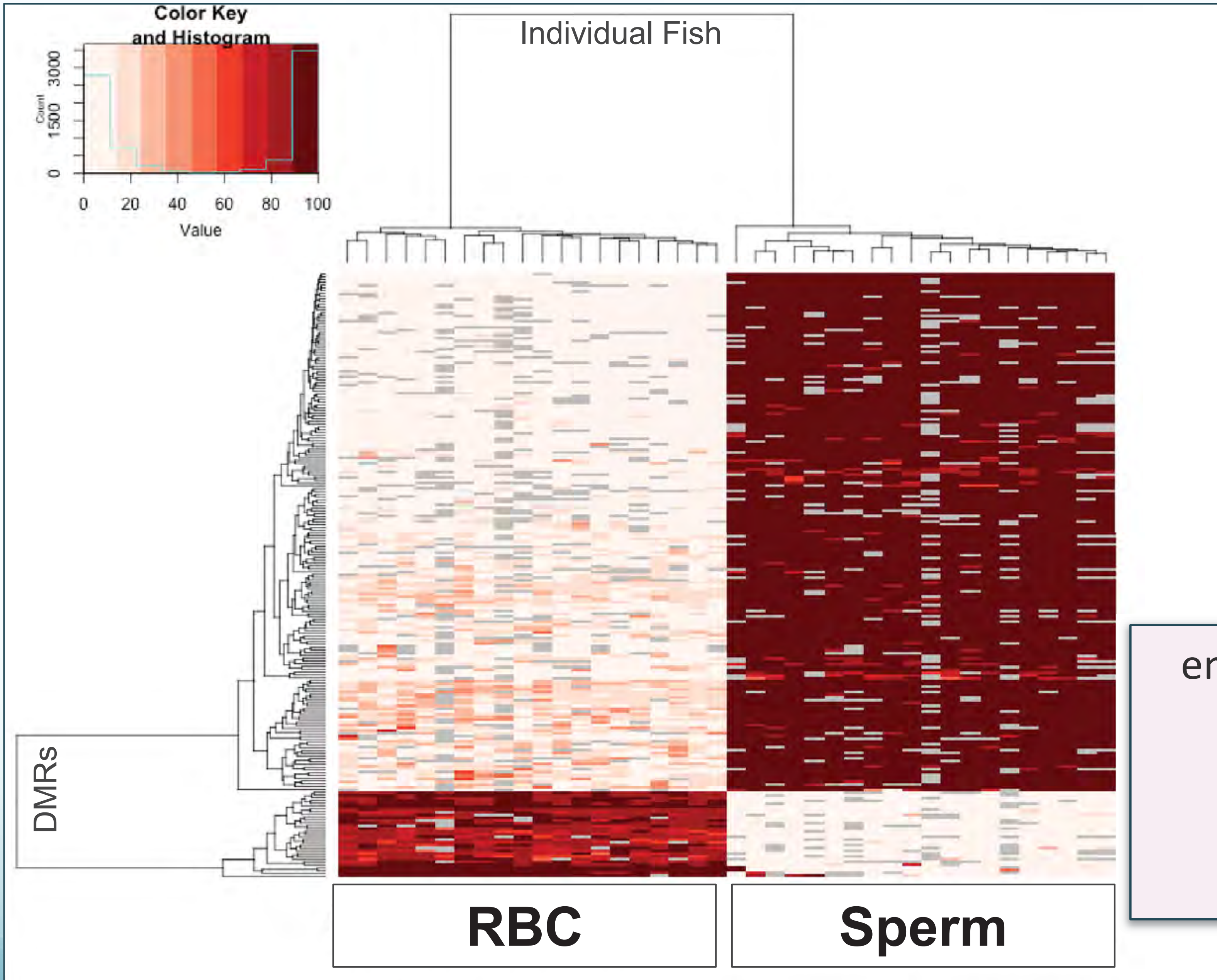
Attachment B

Cell-type Specific Methylation



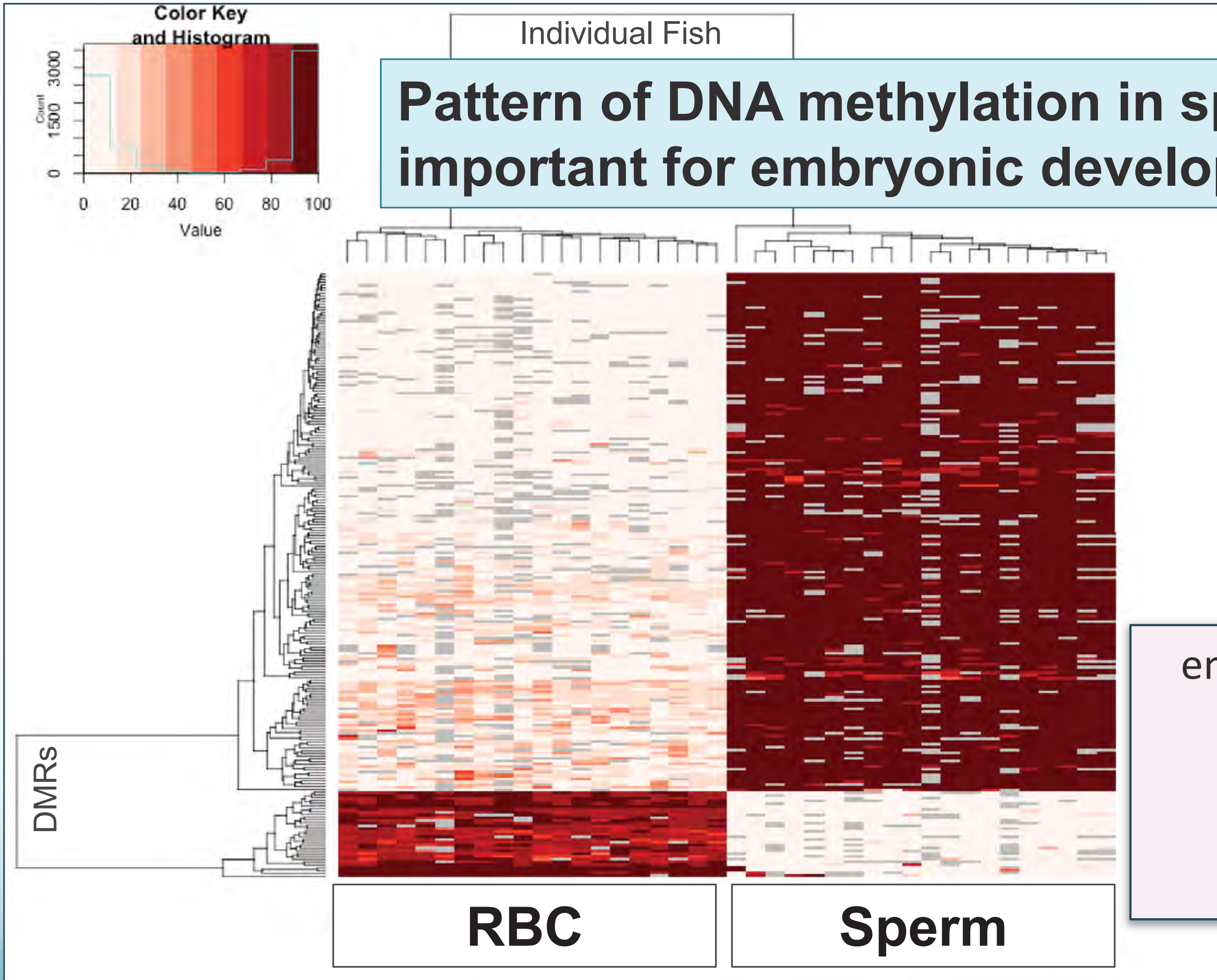
Attachment B

Cell-type Specific Methylation



embryonic genes:
oct4
hox3a
foxe4

Cell-type Specific Methylation



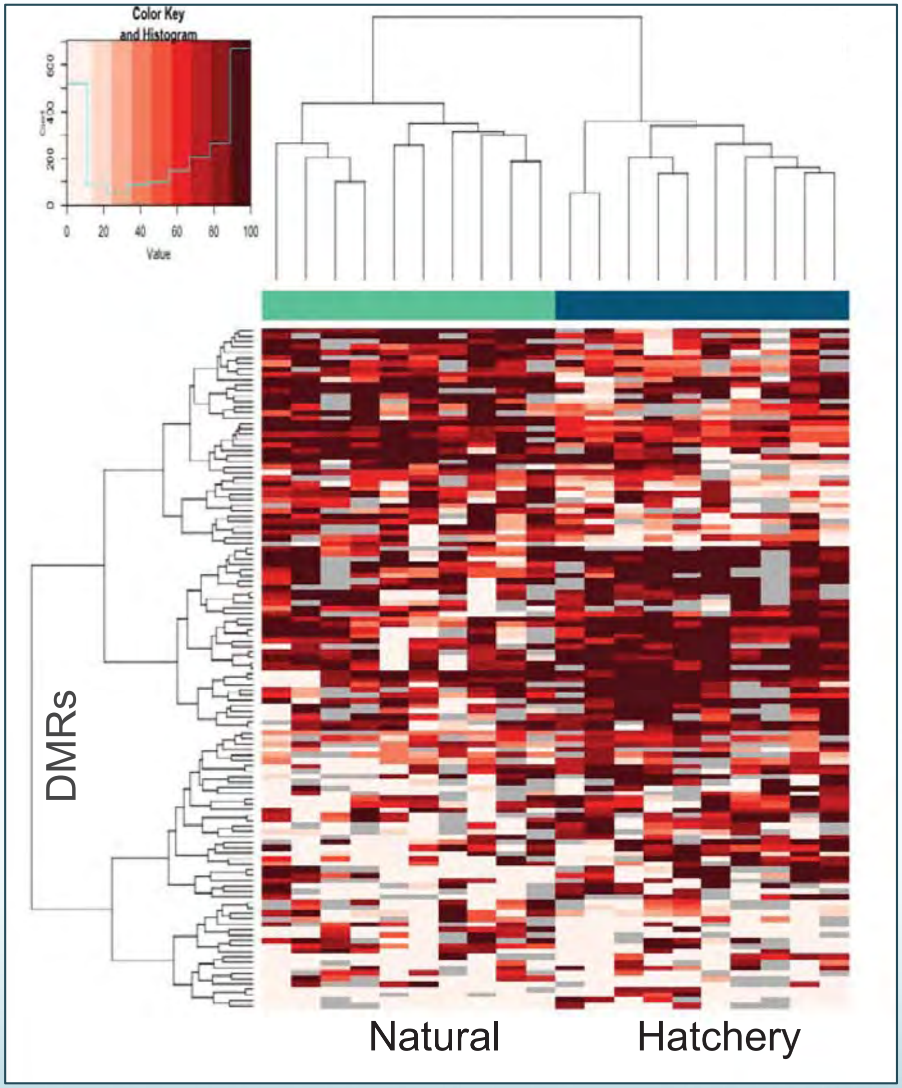
Pattern of DNA methylation in sperm is important for embryonic development

embryonic genes:
oct4
hox3a
foxe4

Origin-Specific Methylation

- Differential methylation between hatchery and natural origin fish
  - 101 origin-specific DMRs in RBC
  - 125 origin-specific DMRs in sperm
  - 22 DMRs overlap between tissues

Origin Specific Methylation



Sperm

Summary

There are differences in DNA methylation between natural and hatchery-origin steelhead

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- How do these DNA methylation changes affect gene expression and ultimately phenotype?

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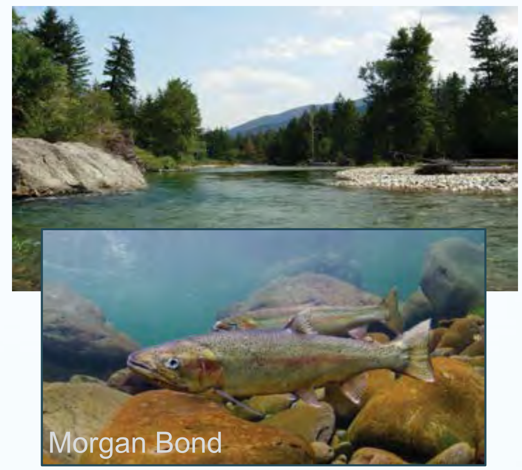
Summary

There are differences in DNA methylation between natural and hatchery origin steelhead

- How do these DNA methylation changes affect gene expression and ultimately phenotype?
- Which environmental parameters are influencing DNA methylation?
- How are epigenetic variation and genetic variation interrelated?
- Are environmentally-induced epigenetic changes transgenerationally inherited?

Concluding Remarks

- Epigenetics can help organisms *retain* (*and potentially pass on*) information about their environment.



- Epigenetics is an emerging tool to help understand how the environment affects phenotype in hatchery-reared fish, which could aid in minimizing heritable fitness loss in these populations.

Acknowledgements

UW SAFS

Graham Young

NOAA – Northwest Fisheries Science Center

Krista Nichols

Penny Swanson

Barry Berejikian

Chris Tatara

Mollie Middleton

Jon Dickey

Giles Goetz

Winthrop National Fish Hatchery:

Mathew Cooper (USFWS)

Chris Pasley (USFWS-WNFH)

Michael Humling (USFWS-WNFH)

Methodology and Bioinformatic Support

Melinda Baerwald (UC Davis)

Serge McGraw (University of Montreal)

Funding Sources:

NOAA

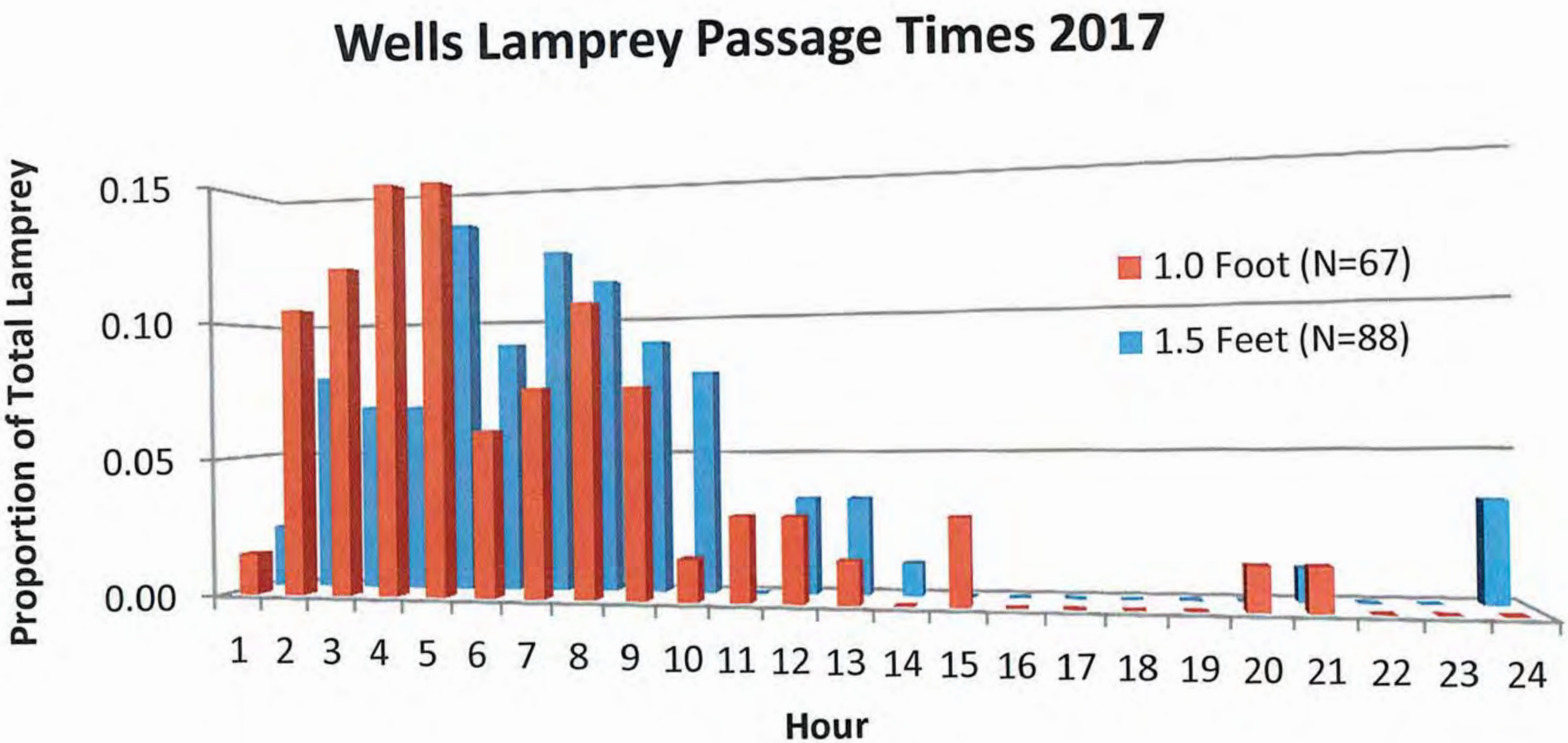
Bonneville Power Admin. (#1993-056)

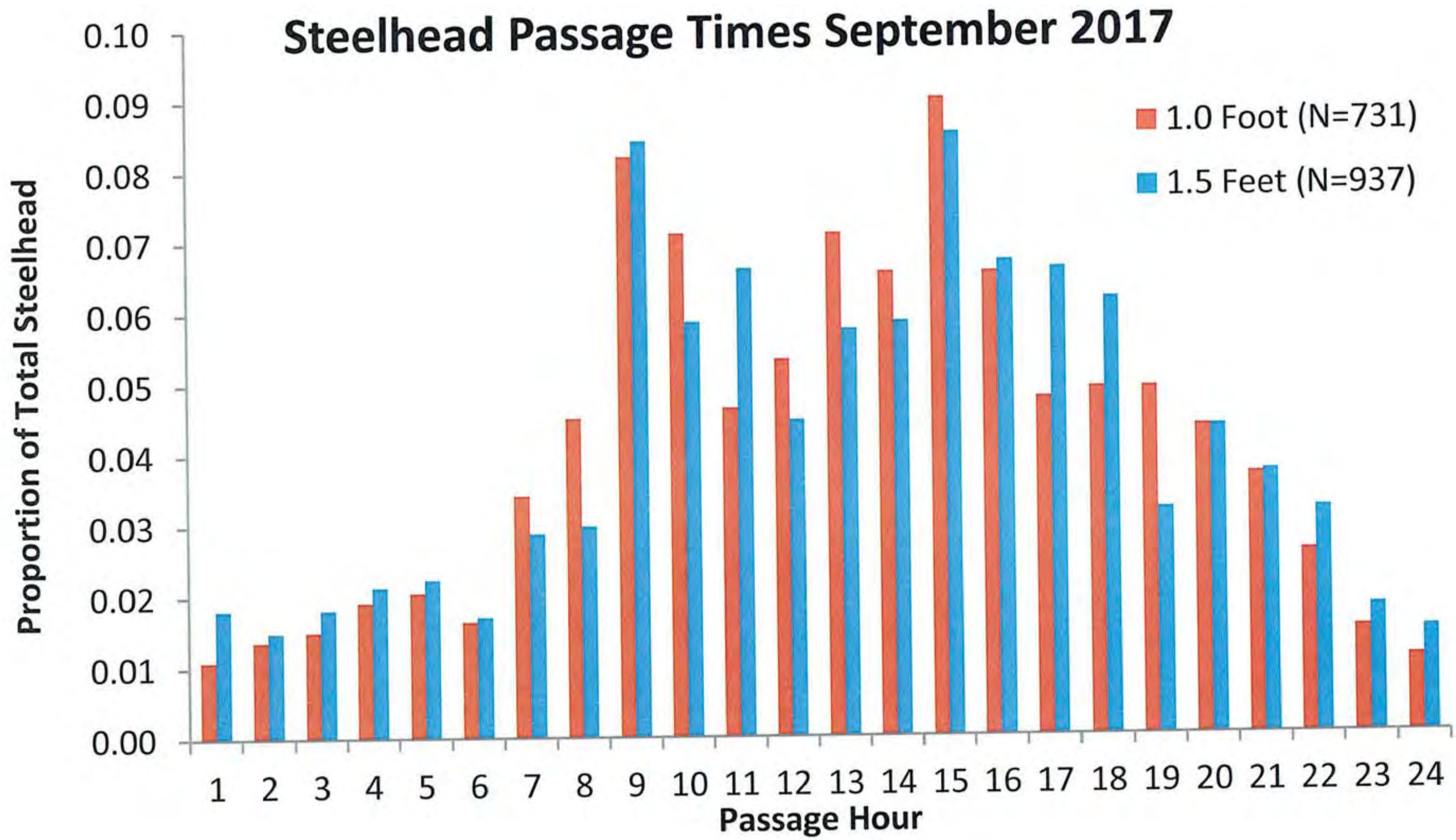
Next Steps: Controlled Experiment

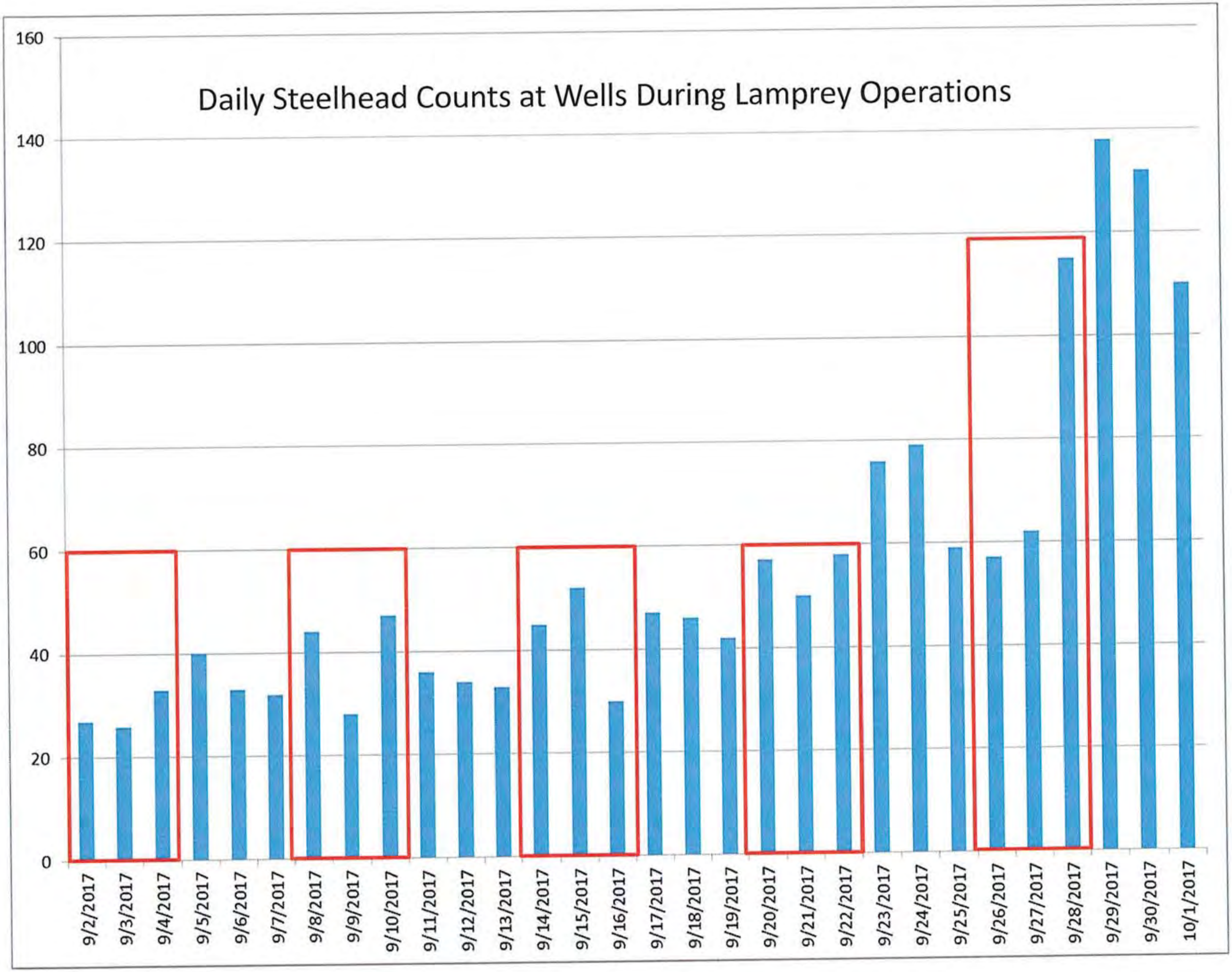
Hatchery Tanks

Artificial Stream

Any epigenetic differences will be due to early rearing environment


Wells Lamprey Passage Times 2017
Proportion of Total Lamprey
0.15
0.10
0.05
0.00
1.0 Foot (N=67)
1.5 Feet (N=88)
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Hour


Steelhead Passage Times September 2017
1.0 Foot (N=731)
1.5 Feet (N=937)
Proportion of Total Steelhead
0.10
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Passage Hour


Daily Steelhead Counts at Wells During Lamprey Operations
160
140
120
100
80
60
40
20
0
9/2/2017
9/3/2017
9/4/2017
9/5/2017
9/6/2017
9/7/2017
9/8/2017
9/9/2017
9/10/2017
9/11/2017
9/12/2017
9/13/2017
9/14/2017
9/15/2017
9/16/2017
9/17/2017
9/18/2017
9/19/2017
9/20/2017
9/21/2017
9/22/2017
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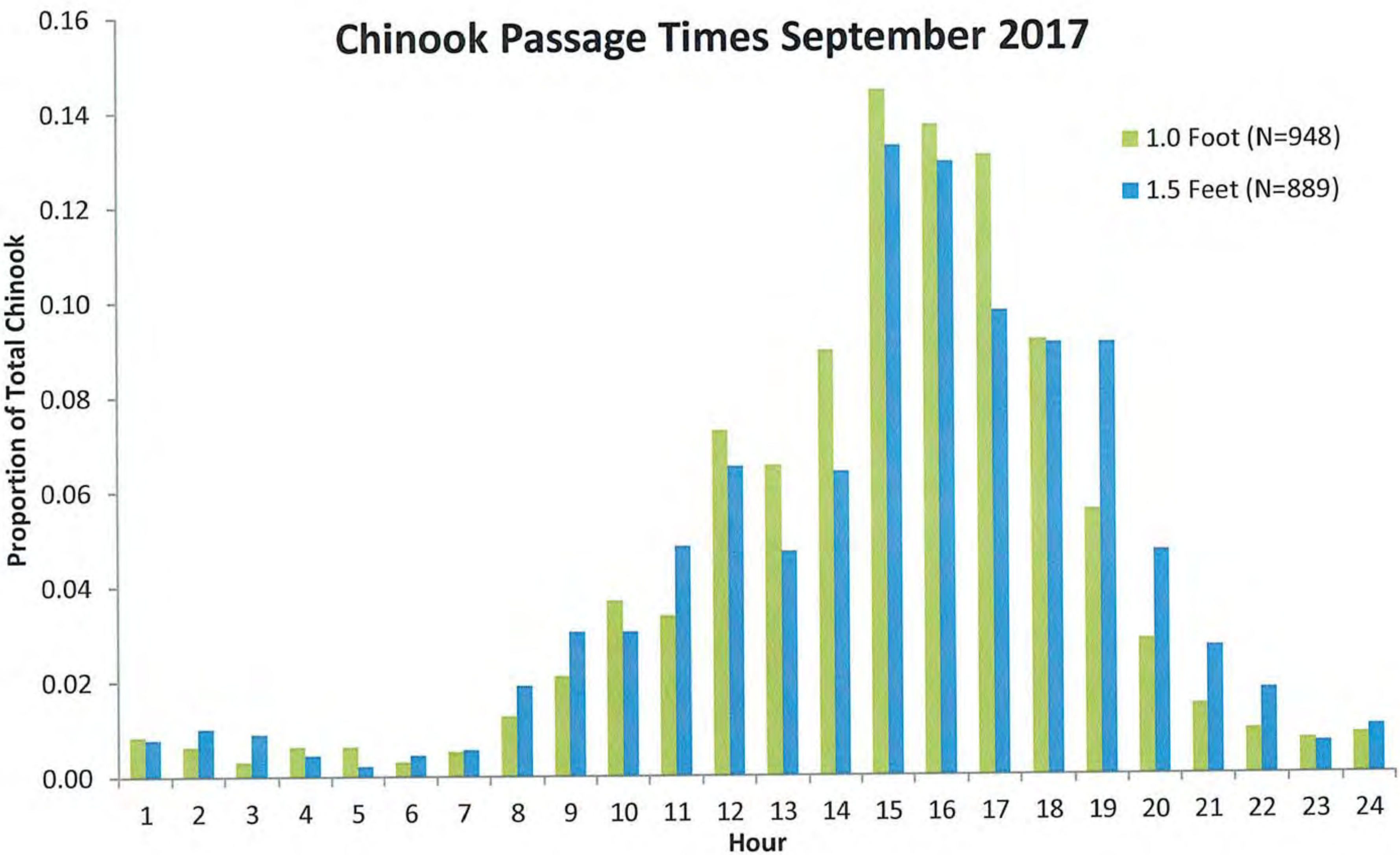
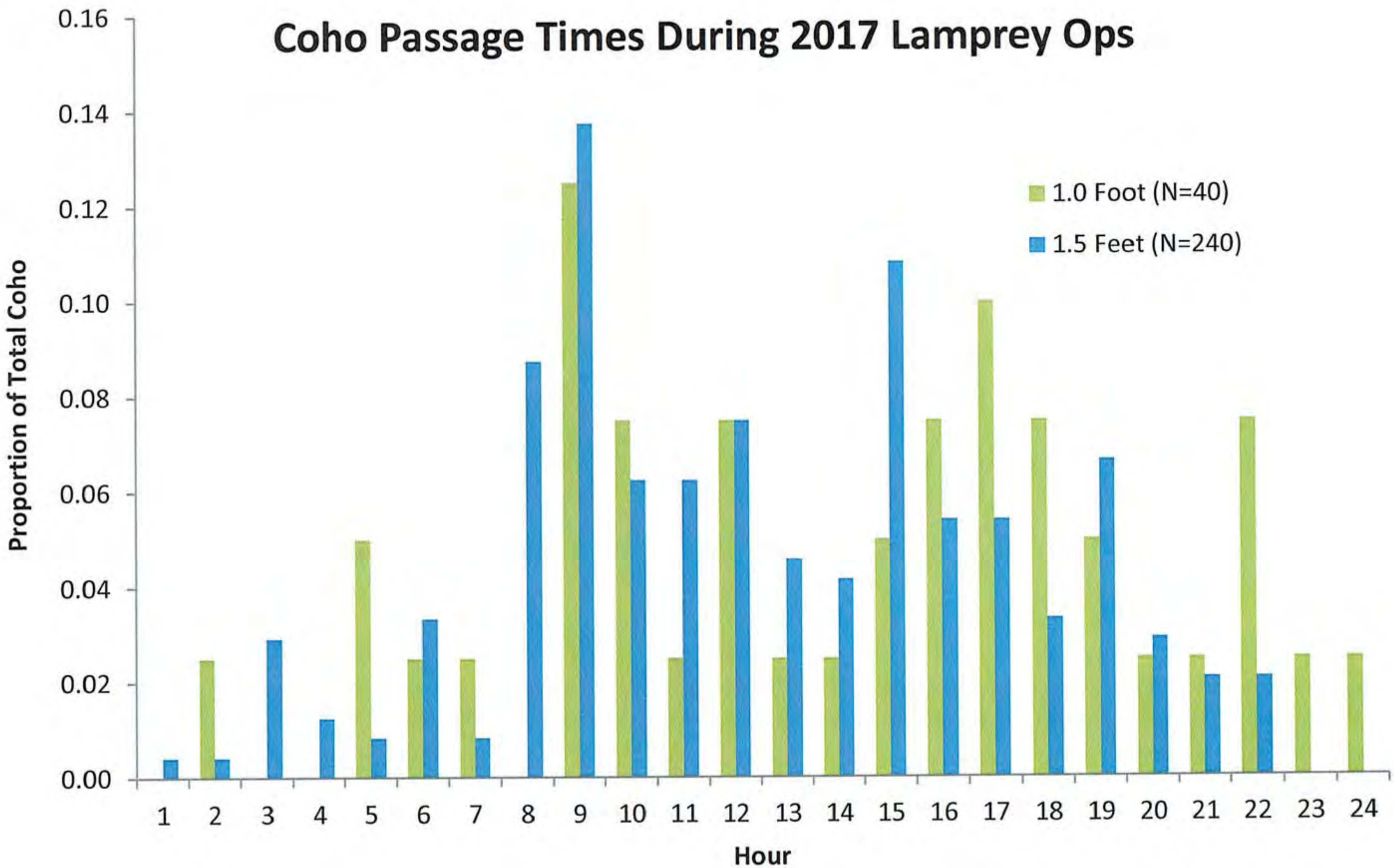
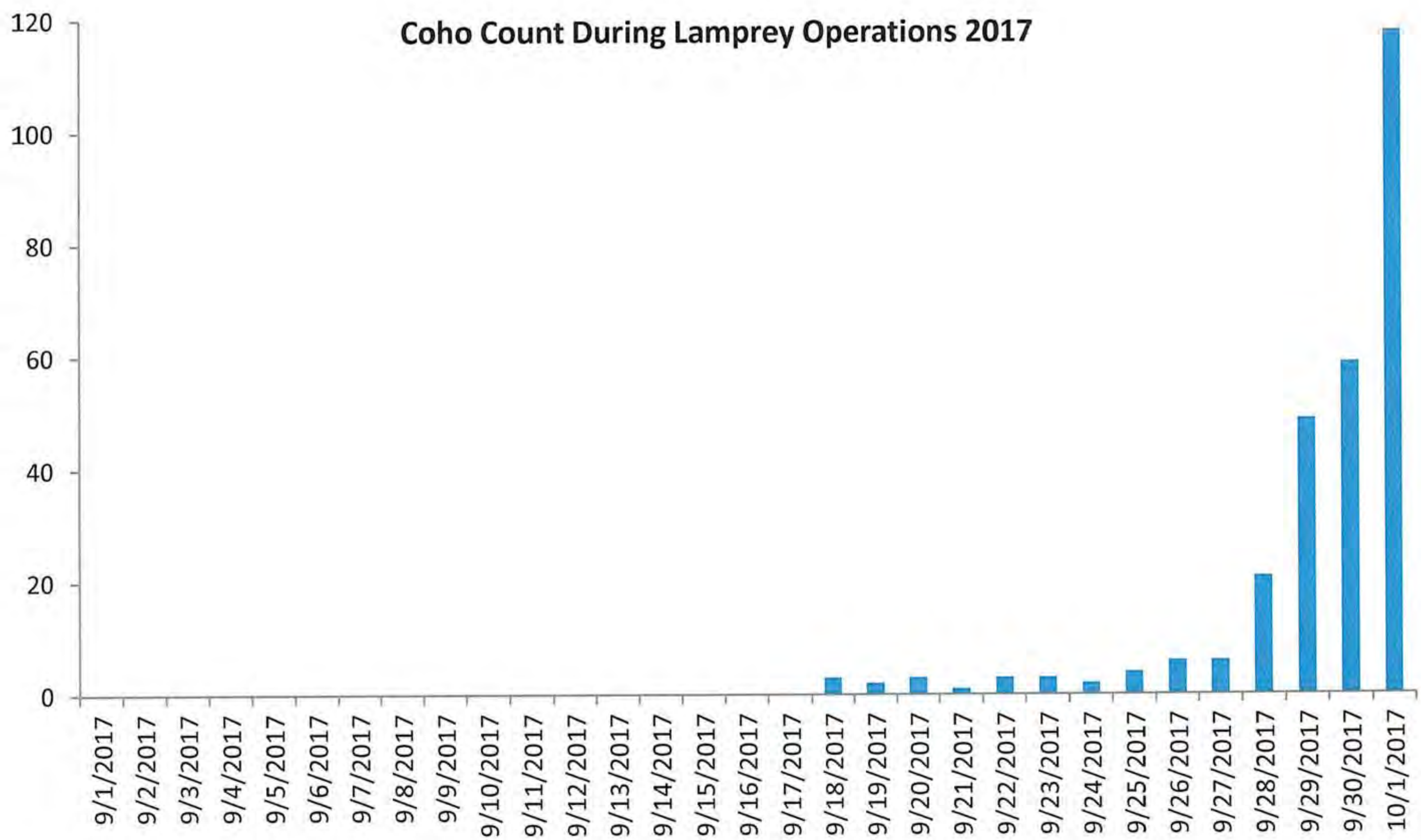
9/29/2017
9/30/2017
10/1/2017



Chinook Passage Times September 2017
1.0 Foot (N=948)
1.5 Feet (N=889)
Proportion of Total Chinook
Hour
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0.00
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24


Coho Passage Times During 2017 Lamprey Ops
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0.00
Proportion of Total Coho
1.0 Foot (N=40)
1.5 Feet (N=240)
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Hour


Coho Count During Lamprey Operations 2017
120
100
80
60
40
20
0
9/1/2017
9/2/2017
9/3/2017
9/4/2017
9/5/2017
9/6/2017
9/7/2017
9/8/2017
9/9/2017
9/10/2017
9/11/2017
9/12/2017
9/13/2017
9/14/2017
9/15/2017
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9/25/2017
9/26/2017
9/27/2017
9/28/2017
9/29/2017
9/30/2017
10/1/2017

DRAFT

Analysis of Proportion of Outmigration Affected by Bypass Operations at Wells Dam in 2017

Prepared for:

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Prepared by:

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23 October 2017

Introduction

This analysis summarizes the outmigration that has been monitored at the juvenile sampling facility at Rocky Reach Dam or detected at the Rocky Reach Bypass PIT-tag detector for five stocks of salmonids (Coho salmon, yearling and subyearling Chinook salmon, steelhead, and sockeye salmon) for the period 2006-2017. The proportions of each stock covered by the bypass operations at Wells Dam can be estimated using daily counts at Rocky Reach Dam, adjusting for the travel time from Wells to Rocky Reach dams. Table 1 has the average travel times based on Douglas PUD's 2010 PIT-tag study for yearling Chinook salmon, and acoustic-tag studies for steelhead and sockeye salmon. Due to a dearth of PIT-tag or acoustic-tag studies performed with subyearling Chinook, travel time was assumed to be 2 days. Coho travel time was assumed to match that of yearling Chinook, and preliminary PIT-tag data appears to validate this assumption (Appendix, Table A1).

Table 1: Average travel times from Wells tailrace to Rocky Reach Dam, based on study results or assumptions of similarity to surrogate species.

Stock	Travel time
Yearling Chinook salmon	5 days
Subyearling Chinook salmon	2 days
Steelhead	2 days
Sockeye salmon	2 days
Coho salmon	5 days

Plots of the annual cumulative proportion of the outmigration for spring migrants (yearling Chinook, steelhead, sockeye, and coho), and subyearling Chinook in the summer had fairly consistent start and end dates at Rocky Reach (Figure 1). The timing of bypass operations for the spring outmigration at Wells from 2004 through 2011 was from 00:00 April 12th through 24:00 June 13th of each year for the "spring" spill season, and from 00:00 June 14th through 24:00 August 26th for the "summer" spill season. For 2012 and beyond, the Wells Habitat Conservation Plan (HCP) Coordinating Committee approved the modification of the timing of bypass operations at Wells Dam as follows: bypass operations commenced at 00:00 on April 9th and continued through 24:00 on August 19th. This current timing of bypass operations will continue annually, unless modified as a result of future investigations that demonstrate an inadequacy of these dates at providing bypass passage for ≥95% of the migrations of both spring- and summer-migrating Plan Species at Wells Dam.

Results

The proportions of passage during the Wells bypass operations in 2017 were 99.85% for yearling Chinook salmon, 100% for steelhead, 99.99% for sockeye salmon, 100% for coho salmon, and 99.59% for subyearling Chinook salmon. The 2017 results for all monitored species were all consistent with historical trends, 2006–2017 (Table 2).

To assess the effectiveness of the selected start date for bypass operations, Table 3 compares the start date for bypass operations each year with the date on which the 5th percentile of the cumulative yearling Chinook salmon outmigration passed Wells Dam that year. For yearling Chinook salmon in 2017, the start date for bypass operations was 8 days earlier than necessary to achieve the HCP standard of providing bypass passage for ≥95% of the migration.

Similarly, Table 4 compares the actual termination date for bypass operations with the date on which bypass operations covered 95% of the subyearling Chinook salmon outmigration. In each year, an earlier termination of bypass operations would have been possible without jeopardizing the achievement of the HCP standard of providing a bypass route for ≥95% of outmigrating subyearling Chinook salmon. For subyearling Chinook salmon in 2017, the termination of bypass operations at midnight on August 19 was 13 days later than required to achieve the HCP standard of providing bypass passage for ≥95% of the migration.

Table 2. Total proportion of each stock's migration affected by bypass operations (spring, summer) at Wells Dam, based on travel times from Wells Dam to Rocky Reach Dam, the cumulative proportion of the annual migration of each stock at Rocky Reach, and the start and stop dates of Wells bypass operations, 2006-2017.

	Proportion passed	**Annual migration proportion**					
Spring Outmigration	**Yearling Chinook Salmon**	2006	2007	2008	2009	2010	2011
	prior to spring Bypass Ops period	0.0259	0.0551	0.0025	0.0116	0.0067	0.0085
	during spring Bypass Ops period	0.9559	0.9154	0.9972	0.9827	0.9917	0.9910
	during summer Bypass Ops period	0.0182	0.0296	0.0002	0.0056	0.0016	0.0005
	after Bypass Ops period	0	0	0	0	0	0
	Total Covered by Bypass Ops	**0.9741**	**0.9449**	**0.9975**	**0.9884**	**0.9933**	**0.9915**
		2012	2013	2014	2015	2016	**2017**
	prior to spring Bypass Ops period	0.0004	0.0171	0.0169	0.0012	0.0028	**0.0015**
	during spring Bypass Ops period	0.9996	0.9823	0.9829	0.9983	0.9929	**0.9962**
	during summer Bypass Ops period	0.0001	0.0006	0.0003	0.0004	0.0043	**0.0023**
	after Bypass Ops period	0	0	0	0	0	**0**
	Total Covered by Bypass Ops	**0.9996***	**0.9829**	**0.9831[+]**	**0.9988**	**0.9972[+]**	**0.9985[+]**
	Steelhead	2006	2007	2008	2009	2010	2011
	prior to spring Bypass Ops period	0.0101	0.0066	0.0009	0.0019	0.0045	0.0190
	during spring Bypass Ops period	0.9762	0.9887	0.9901	0.9965	0.9763	0.9513
	during summer Bypass Ops period	0.0137	0.0042	0.0089	0.0016	0.0188	0.0297
	after Bypass Ops period	0	0.0004	0.0001	0	0.0004	0
	Total Covered by Bypass Ops	**0.9899**	**0.9930**	**0.9990**	**0.9981**	**0.9951**	**0.9810**
		2012	2013	2014	2015	2016	**2017**
	prior to spring Bypass Ops period	0.0014	0.0079	0.0021	0.0029	0.0022	**0**
	during spring Bypass Ops period	0.9885	0.9847	0.9817	0.9602	0.9892	**0.9968**
	during summer Bypass Ops period	0.0101	0.0074	0.0158	0.0367	0.0085	**0.0032**
	after Bypass Ops period	0	0	0.0004	0.0002	0.0001	**0**
	Total Covered by Bypass Ops	**0.9986**	**0.9921**	**0.9975**	**0.9969**	**0.9977**	**1.0000[+]**
	Sockeye Salmon	2006	2007	2008	2009	2010	2011
	prior to spring Bypass Ops period	0	0	0	0	0	0
	during spring Bypass Ops period	0.9984	0.9998	0.9972	0.9957	0.9992	0.9923
	during summer Bypass Ops period	0.0016	0.0001	0.0028	0.0043	0.0008	0.0077
	after Bypass Ops period	0	0	0	0	0	0
	Total Covered by Bypass Ops	**1.0000**	**0.9999**	**1.0000**	**1.0000**	**1.0000**	**1.0000**
		2012	2013	2014	2015	2016	**2017**
	prior to spring Bypass Ops period	0	0	0	0	0	**0**
	during spring Bypass Ops period	0.9995	0.9990	0.9999	0.9994	1.0000	**0.9990**
	during summer Bypass Ops period	0.0005	0.0009	0.0001	0.0006	0	**0.0009**
	after Bypass Ops period	0	0.0001	0	0.0001	0	**0**
	Total Covered by Bypass Ops	**1.0000**	**0.9999**	**1.0000**	**0.9999***	**1.0000**	**0.9999***

***Proportions not summing to 1 are due to round-off error. +Proportion estimated using only releases above Wells Dam.**

Table 2. (continued).

	Proportion passed	Annual migration proportion					
Spring Outmigration	**Coho Salmon**		2013	2014	2015	2016	**2017**
	prior to spring Bypass Ops period		0.0001	0.0001	0.0004	0.0024	**0**
	during spring Bypass Ops period		0.9934	0.9991	0.9891	0.9962	**0.9977**
	during summer Bypass Ops period		0.0065	0.0007	0.0105	0.0013	**0.0023**
	after Bypass Ops period		0	0	0	0	**0**
	Total Covered by Bypass Ops		**0.9999**	**0.9999**	**0.9996**	**0.9976**	**1.0000**
Summer Outmigration	**Subyearling Chinook Salmon**	2006	2007	2008	2009	2010	2011
	prior to spring Bypass Ops period	0	0	0	0	0	0
	during spring Bypass Ops period	0.1894	0.2136	0.1266	0.1029	0.5212	0.5628
	during summer Bypass Ops period	0.8077	0.7847	0.8620	0.8882	0.4723	0.4331
	after Bypass Ops period	0.0029	0.0017	0.0113	0.0089	0.0064	0.0041
	Total Covered by Bypass Ops	**0.9971**	**0.9983**	**0.9887**	**0.9911**	**0.9936**	**0.9959**
		2012	2013	2014	2015	2016	**2017**
	prior to spring Bypass Ops period	0	0	0	0	0	**0**
	during spring Bypass Ops period	0.5871	0.1670	0.3529	0.0745	0.3349	**0.3238**
	during summer Bypass Ops period	0.4059	0.8263	0.6151	0.9252	0.6636	**0.6721**
	after Bypass Ops period	0.0070	0.0067	0.0320	0.0003	0.0016	**0.0041**
	Total Covered by Bypass Ops	**0.9930**	**0.9933**	**0.9680**	**0.9997**	**0.9984**	**0.9959**

Table 3. A comparison of the actual start date for bypass operations at Wells Dam for the last ten years versus the date on which the 5th percentile of the yearling Chinook salmon migration passed Wells Dam that year, 2008-2017. Operations begin at 00:01 for the date listed in column 2. "Proportion bypass ops would have covered" indicates the proportion of the migration that would have been provided a bypass passage route had bypass operations started at 00:01 on the date that the 5th percentile of the migration passed Wells Dam (column 5). "Bypass start date timing" (column 8) indicates whether the bypass start date was earlier or later than the date on which the 5th percentile of the yearling Chinook migration passed Wells Dam, and by how many days.

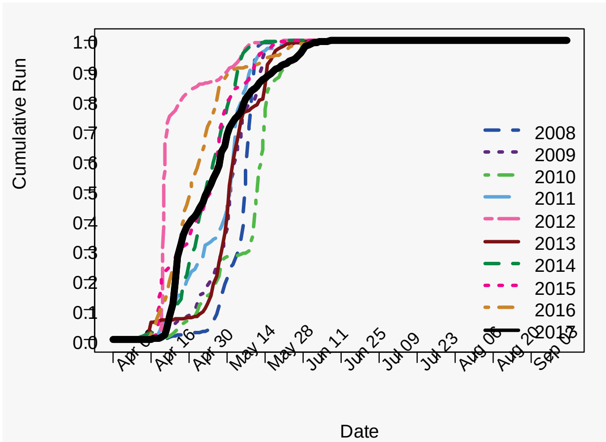
Migration Year	Actual bypass start date	Cumulative proportion passed before 00:01	Proportion Covered by Bypass Ops	Date on which the 5th percentile passed	Cumulative proportion passed before 00:01	Proportion bypass ops would have covered	Bypass start date timing
2008	April 12	0.0025	0.9975	May 3	0.0406	0.9594	21 days early
2009	April 12	0.0116	0.9884	April 19	0.0436	0.9564	7 days early
2010	April 12	0.0067	0.9933	April 22	0.0410	0.9590	10 days early
2011	April 12	0.0085	0.9915	April 15	0.0446	0.9554	3 days early
2012	April 9	0.0004	0.9996	April 15	0.0115	0.9885	6 days early
2013	April 9	0.0171	0.9829	April 10	0.0240	0.9760	1 day early
2014	April 9	0.0169	0.9831	April 16	0.0386	0.9614	7 days early
2015	April 9	0.0012	0.9988	April 13	0.0210	0.9790	4 days early
2016	April 9	0.0028	0.9972	April 12	0.0380	0.9620	3 days early
2017	April 9	0.0015	0.9985	April 17	0.0428	0.9572	8 days early

Table 4. A comparison of the actual stop date for bypass operations at Wells Dam for the last ten years, versus the stop date necessary to have covered at least 95% of the subyearling Chinook salmon outmigration that year. Operations are assumed to end at 24:00 for the date listed.

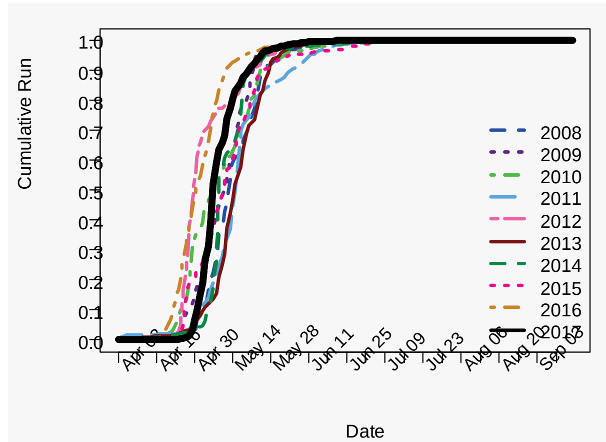
Migration Year	Actual bypass stop date	Cumulative proportion passed by 24:00 of actual stop date	Date on which the 95% standard was achieved	Cumulative proportion passed by 24:00 of the date on which the 95% standard was achieved	Bypass ended this many days after the 95% standard was achieved
2008	August 26	0.9887	August 19	0.9502	7
2009	August 26	0.9911	August 22	0.9709	4
2010	August 26	0.9936	August 10	0.9537	16
2011	August 26	0.9959	July 25	0.9528	32
2012	August 19	0.9930	July 29	0.9502	22
2013	August 19	0.9933	August 7	0.9592	12
2014	August 19	0.9696	August 15	0.9524	4
2015	August 19	0.9997	July 19	0.9559	31
2016	August 19	0.9984	July 28	0.9554	22
2017	August 19	0.9959	August 6	0.9533	13

Figure 1. Passage dates at Rocky Reach Dam for spring and summer migrating stocks, 2008-2017. Cumulative proportions are based on the expanded counts obtained from sampling daily from 1 April – 31 August (or through 4 September in 2008 and 15 September in 2014).

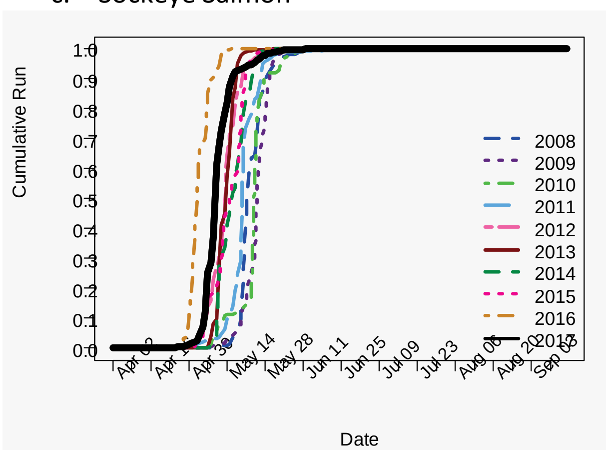
a. Yearling Chinook Salmon



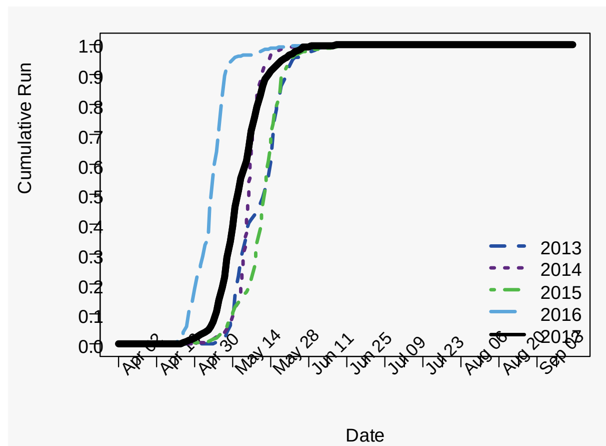
b. Steelhead



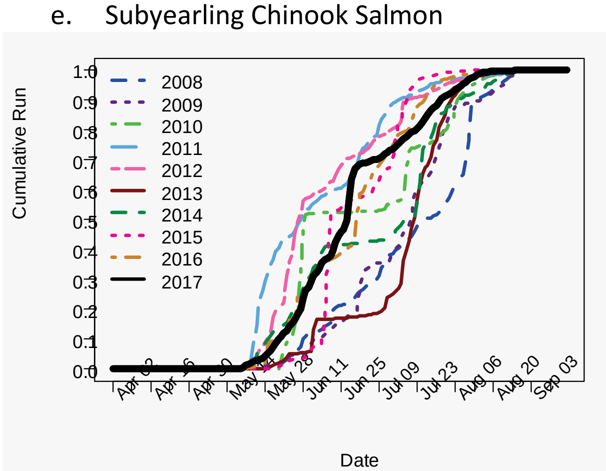
c. Sockeye Salmon



d. Coho Salmon



e. Subyearling Chinook Salmon



Appendix

This is the second year of the availability of PIT-tag detections at Wells Dam (WEJ), with 269 unique tag codes identified. These comprised 114 Chinook Salmon, 27 Coho Salmon, 127 Steelhead, and 1 Sockeye Salmon. As these numbers are too few to estimate any credible survival estimates, Table A1 summarizes the number of detections and estimated travel times between Wells and Rocky Reach Dam. It is hoped that future runs will be detected at higher numbers to enable a more detailed correction to the outmigration distribution estimated for Wells Dam.

Table A1. Travel Time summary for detected PIT-tagged fish at both Wells and Rocky Reach PIT-tag detectors in 2017.

			Travel Time (days)	
Run Species	Detected at Wells Dam	Detected at Rocky Reach Dam	Mean (SE)	Range
Yearling Chinook	114	21	6.7 (1.8)	1.3 – 29.0
Coho	27	11	5.4 (0.8)	2.2 - 10.0
Steelhead	127	41	1.9 (0.2)	0.8 - 6.6
Sockeye	1	0		

FINAL

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ANCHOR QEA

Memorandum

To: Wells, Rocky Reach, and Rock Island HCP Coordinating Committees

Date: January 25, 2018

From: John Ferguson, HCP Coordinating Committees Chairman

cc: Kristi Geris

Re: Final Minutes of the December 12, 2017 HCP Coordinating Committees Meeting

The Wells, Rocky Reach, and Rock Island Hydroelectric Projects Habitat Conservation Plan (HCP) Coordinating Committees met at the Grant PUD Office in Wenatchee, Washington, on Tuesday December 12, 2017, from 10:00 a.m. to 12:00 p.m. Attendees are listed in Attachment A to these meeting minutes.

Action Item Summary

- Kristi Geris will coordinate with Tracy Hillman and will notify the HCP Coordinating Committees of the date the HCP Hatchery Committees plan to tour the new Wells Fish Hatchery (tentatively scheduled for spring 2018; Item II-C).
- Chelan PUD will provide the Final 2017 Rock Island and Rocky Reach Fish Spill Program Report to Kristi Geris for distribution to the HCP Coordinating Committees (Item II-C). *(Note: Lance Keller provided the final report to Geris following the HCP Coordinating Committees meeting on December 12, 2017, which Geris distributed to the HCP Coordinating Committees on December 13, 2017.)*
- The Rock Island HCP Coordinating Committee will submit edits, comments, or indication of no comments on the Application for Non-Capacity Amendment for Coyote Dunes, to Jeff Osborn (Chelan PUD) and Lance Keller (and copy Kristi Geris) no later than December 15, 2017 (Item III-B). *(Note: all Rock Island HCP Coordinating Committee representatives responded to Chelan PUD by December 14, 2017.)*
- Kristi Geris will resend the email detailing the Application for Non-Capacity Amendment for Coyote Dunes for review, to the Rock Island HCP Coordinating Committee (Item III-B). *(Note: this email was re-distributed to the HCP Coordinating Committees by Geris on December 13, 2017.)*
- Lance Keller will verify internally that Chelan PUD has addressed cultural resource impacts, if any, associated with the Application for Non-Capacity Amendment for Coyote Dunes (Item III-B). *(Note: Keller verified that Chelan PUD has initiated the appropriate actions regarding addressing potential cultural resource impacts associated with this amendment, as explained in an email distributed to the HCP Coordinating Committees by Keller following the meeting on December 12, 2017, and by Kristi Geris on December 13, 2017.)*

- Douglas PUD will further review run-timing data for wild and hatchery yearling Chinook salmon with regard to Wells Dam bypass operation dates, and will report back to the HCP Coordinating Committees (Item IV-B).
- The Wells HCP Coordinating Committee will submit edits and comments on the Draft 2017 Wells Dam Passage Dates Analysis to Tom Kahler no later than January 5, 2018 (Item IV-B).
- Douglas PUD will provide a matrix outlining the pros and cons for potential study species to use in the Douglas PUD 2020 Survival Verification Study (including such details as species selection, release location, and tag type), for further discussion and decision in January 2018 (Item IV-C). *(Note: Tom Kahler provided this matrix to Kristi Geris on January 17, 2018, which Geris distributed to the HCP Coordinating Committees that same day.)*
- The HCP Coordinating Committees meeting on January 23, 2018, will be held in-person at the Grant PUD Wenatchee Office in Wenatchee, Washington (Item V-A).

Decision Summary

- There were no HCP Decision Items approved during today's meeting.

Agreements

- There were no HCP Agreements discussed during today's meeting.

Review Items

- A second Draft 2017 Wells Dam Passage Dates Analysis was distributed to the HCP Coordinating Committees by Kristi Geris on December 7, 2017. The draft analysis is available for review with edits and comments due to Tom Kahler by January 5, 2018 (Item IV-B).
- An Application for Non-Capacity Amendment for Coyote Dunes was distributed to the Rock Island HCP Coordinating Committee by Kristi Geris on November 15, 2017. The application is available for a 30-day review period with edits, comments, or indication of no comments, due to Jeff Osborn and Lance Keller (with a copy to Geris) by December 15, 2017 (Item III-B). *(Note: all Rock Island HCP Coordinating Committee representatives responded to Chelan PUD by December 14, 2017.)*
- The Draft 2017 Wells Post-Season Bypass Report (including the appended Draft 2017 Wells Dam Passage Dates Analysis) was distributed to the Wells HCP Coordinating Committee by Kristi Geris on December 29, 2017. The draft report is available for a 60-day review period, with edits and comments due to Tom Kahler by February 27, 2018.

- The Draft 2018 Wells Dam Gas Abatement Plan and Bypass Operating Plan was distributed to the Wells HCP Coordinating Committee by Kristi Geris on January 16, 2018. The draft plan is available for review with edits and comments due to Tom Kahler by February 12, 2018.
- The Draft 2018 Wells HCP Action Plan was distributed to the Wells HCP Coordinating Committee by Kristi Geris on January 22, 2018. The draft plan is available for a 30-day review period, with edits and comments due to Tom Kahler by February 21, 2018.
- The Draft 2017 Rocky Reach Juvenile Fish Bypass System Report, Draft 2017 Rock Island Smolt and Gas Bubble Trauma Evaluation Report, Draft 2018 Rocky Reach Juvenile Fish Bypass System Operations Plan, Draft 2018 Rock Island Bypass Monitoring Plan, and Draft 2018 Rock Island and Rocky Reach Action Plan were distributed to the Rocky Reach and Rock Island HCP Coordinating Committees by Kristi Geris on January 22, 2018. The draft documents are available for a 30-day review period, with edits and comments due to Lance Keller by February 21, 2018.

Finalized Documents

- The Final 2017 Rocky Reach and Rock Island Fish Spill Program Report, which was approved by the Rocky Reach and Rock Island HCP Coordinating Committees during the HCP Coordinating Committees meeting on October 24, 2017, was distributed to the HCP Coordinating Committees by Kristi Geris on December 13, 2017 (Item II-C).
- The Final Douglas PUD 2016 Pikeminnow Program Annual Report, which was approved by the Wells HCP Coordinating Committee after no disapprovals were received prior to the 60-day review deadline on May 29, 2017, was distributed to the HCP Coordinating Committees by Kristi Geris on December 29, 2017.
- The Final 2016 Rock Island Smolt Monitoring Program and Gas Bubble Trauma Report, Final 2016 Rock Island and Rocky Reach Pikeminnow Control Program Summary Report, and Final 2017 Rock Island Bypass Monitoring Plan were distributed to the HCP Coordinating Committees by Kristi Geris on January 5, 2018. The Rocky Reach and Rock Island HCP Coordinating Committees approved these documents after no disapprovals were received prior to the 30-day review deadline on February 22, 2017.
- The Final 2017 Rocky Reach Juvenile Fish Bypass System Operations Plan was distributed to the HCP Coordinating Committees by Kristi Geris on January 5, 2018. The Rocky Reach HCP Coordinating Committee approved the plan after no disapprovals were received prior to the 30-day review deadline on March 20, 2017.

I. HCP Tributary and Hatchery Committees Update

John Ferguson suggested Tracy Hillman provide the HCP Tributary and Hatchery Committees update prior to discussing today’s other agenda items, to accommodate Hillman’s travel schedule.

A. HCP Tributary and Hatchery Committees Update (Tracy Hillman)

Tracy Hillman updated the HCP Coordinating Committees on the following actions and discussions that occurred during the HCP Hatchery Committees meeting on November 15, 2017:

- *Coho Salmon Statement of Agreement*: The Rocky Reach and Rock Island HCP Hatchery Committees approved the Statement of Agreement (SOA) regarding Chelan PUD's coho salmon obligation, which includes methodology for meeting the obligation. This version, however, does not include a funding arrangement with the Yakama Nation (YN), which will be determined in a separate SOA following further coordination with the YN and the Colville Confederated Tribes (CCT).
- *Steelhead Program Surplus Brood Year 2017*: Douglas PUD indicated that their steelhead program has an excess of about 7,600 fish in the Twisp River program, an excess of about 87,000 in the Columbia River program, and a shortage of about 27,000 fish in the Methow River program. Following discussion, the Wells HCP Hatchery Committee agreed to: 1) release all Twisp River No Net Impact and inundation program steelhead on-station at time of release; 2) release all Methow River inundation program fish on-station at time of release; 3) retain the approximately 210,000 Columbia River Safety Net program fish on-station for release; 4) release the target of 160,000 Columbia River Safety Net program fish, plus a surplus to make up the shortfall in the Methow River inundation program release, for a total release of about 339,000 fish or less; and 5) remove additional surplus fish from the Columbia River Safety Net program and release in non-anadromous waters under direction of the Washington Department of Fish and Wildlife (WDFW).
- *Wells and Methow Fish Hatcheries Transition*: Douglas PUD has fully staffed both the Wells and Methow fish hatcheries. As of November 15, 2017, the transition was on track to be completed within 90 days. Douglas PUD hired a veterinarian, and is also working to finalize all other paperwork and responsibilities.
- *Summer Chinook Salmon Spawning Update*: Douglas PUD indicated the full program egg take was acquired, with a possible surplus. Hatchery staff collected an additional 18 females during an outbreak of columnaris, and the Yakima River restoration program also helped to spawn fish.
- *National Marine Fisheries Service Consultation Update*: The National Marine Fisheries Service (NMFS) received the official initiation of consultation request for the unlisted programs in the upper Columbia River, and will be responding with letters of sufficiency to the applicants. Also, the Draft Upper Columbia River Summer/Fall and Fall Chinook Salmon Biological Opinion (BiOp) will go to General Counsel for review, and then to the applicants for review. Finishing this BiOp by the end of the year is a priority.
- *U.S. Fish and Wildlife Service Bull Trout Consultation Update*: The U.S. Fish and Wildlife Service (USFWS) is working on the BiOp for the batch of Wenatchee subbasin programs, and hopes to

obtain signatures this week. USFWS is also making progress on the Methow River steelhead consultation, which was anticipated to be complete by the end of November 2017. Finally, USFWS received additional information for the unlisted programs in the upper Columbia River, which will inform the effects analysis. The schedule for completing a letter of concurrence depends on when NMFS is able to initiate consultation.

- *Draft Hatchery Monitoring and Evaluation Plan for PUD Hatchery Programs, 2017 Update*: The HCP Hatchery Committees approved the Hatchery Monitoring and Evaluation Plan for PUD Hatchery Programs, 2017 Update, as revised. The approved plan has been shared with the Upper Columbia Salmon Recovery Board (UCSRB) and Independent Scientific Advisory Board (ISAB). The HCP Hatchery Committees also shared the final plan with those conducting on-the-ground hatchery monitoring.
- *Timeline of Changes in Hatchery Programs*: The HCP Hatchery Committees are preparing and reviewing timelines of major hatchery program changes to help inform statistical analyses for the statistical and comprehensive reports. This has been completed for spring Chinook salmon, and focus will now shift to summer Chinook and sockeye salmon, and steelhead,
- *Upper Columbia Salmon Recovery Board Hatchery Summary Report*: Greer Maier (UCSRB) presented on "Integrated Recovery," and discussed the UCSRB's Draft Hatchery Summary Report. HCP Hatchery Committees representatives and other reviewers provided comments on the draft summary report, and UCSRB is currently reviewing and addressing those comments. UCSRB hopes to obtain approval of the summary report during their meeting on December 31, 2017. The next step for UCSRB is to prepare summary reports for hydropower and harvest. John Ferguson asked about the status of the ISAB report summarizing their review of the status of upper Columbia River spring Chinook salmon, and Tom Kahler said the report will be available in March 2018.
- *Next meeting*: The next meeting of the HCP Hatchery Committees will be on January 17, 2018.

Hillman updated the HCP Coordinating Committees on the following actions and discussions that occurred during the HCP Tributary Committees meeting on November 9, 2017:

- *Frazer Creek – Lazy K Property Appraisal Project*: The HCP Tributary Committees received a Small Projects Program Application from Methow Salmon Recovery Foundation to appraise the value of a 20-acre parcel along Frazer Creek in the Methow River basin. Acquiring the property would allow stream restoration in a site where the 2017 flood plugged a culvert causing the stream to cut deep gullies through the property. The total cost of the project is about $1,400, which only covers coordination with the landowner and appraiser, and billing and administration work. The HCP Tributary Committees elected not to fund the appraisal, because most of the property does not border the stream and restoring this site would have little biological benefit.

- *Upper Beaver Creek – Anderson Property Appraisal Project*: The HCP Tributary Committees received another Small Projects Program Application from Methow Salmon Recovery Foundation to appraise the value of a 1.6-acre parcel along Beaver Creek in the Methow River basin. Acquiring the property would allow stream restoration in a site where the 2017 flood avulsed through the Anderson property and damaged the County road. The cost of the project is about $1,400, which only covers coordination with the landowner and appraiser, and billing and administration work. After receiving additional information from the sponsor, the HCP Tributary Committees elected not to fund the appraisal, because the Committees were uncomfortable acquiring the property without an analysis of the vulnerability of the road from the stream.
- *PRESENTATION: Chelan River Restoration*: Steve Hays (Chelan PUD) presented on the Chelan River Restoration project, which was funded by Chelan PUD. Hays discussed riverine conditions before hydropower development, requirements under the first two licenses, and objectives and agreements under the most recent license. Hays played a video which showed the evolution of the river during the restoration process and how it changed. He then described Chelan PUD's robust monitoring program and discussed results. He concluded by stating the restoration work has created high quality habitat, which is being used by salmonids, including cutthroat trout.
- *PRESENTATION: Effectiveness of Enhancement Projects*: Hillman provided a presentation on the effectiveness of tributary habitat enhancement projects, which is based on a report Hillman and his coauthors (Phil Roni [Cramer Fish Sciences] and Jen O'Neal [Natural Systems Design]) prepared for the Bonneville Power Administration (BPA). The report addresses six policy-level questions about the success of enhancement actions, and was used as part of the Federal Columbia River Power System BiOp. Well-over 1,000 pieces of literature were reviewed and 617 reports met the criteria for relevance. The report focused on identifying characteristics of successful projects and also reasons why some failed. Hillman concluded by providing recommendations for enhancement work in the future.
- *Sponsorship Request*: The UCSRB asked the HCP Tributary Committees about helping sponsor the Upper Columbia Science Conference. Each HCP Tributary Committee agreed to donate $1,000 to the conference, which identifies the HCP Tributary Committees as "Gold Sponsors."
- *Next meeting*: The next meeting of the HCP Tributary Committees will be on January 11, 2018.

II. Welcome

A. Review Agenda (John Ferguson)

John Ferguson welcomed the HCP Coordinating Committees and reviewed the agenda. Ferguson asked for any additions or changes to the agenda. The following revisions were requested:

- Lance Keller added the Application for Non-Capacity Amendment for Coyote Dunes.
- Tom Kahler added a Wells Dam fishway maintenance update.

B. Meeting Minutes Approval (John Ferguson)

The HCP Coordinating Committees reviewed the revised draft October 24, 2017 meeting minutes. Kristi Geris said there was one outstanding comment when the revised minutes were distributed, under Douglas PUD's Draft 2017 Wells Dam Passage Dates Analysis discussion. Geris said the comment was about the new location of the lower Methow River passive integrated transponder (PIT)-tag array, which Mike Tonseth later clarified has been moved from river mile 1.2 to 5. Geris said all other comments and revisions received from members of the Committees were incorporated into the revised minutes. HCP Coordinating Committees members present approved the October 24, 2017 meeting minutes, as revised.

C. Last Meeting Action Items (John Ferguson)

Action items from the HCP Coordinating Committees conference call on October 24, 2017, and follow-up discussions, were as follows. *(Note: italicized text corresponds to agenda items from the meeting on October 24, 2017):*

- *Kristi Geris will coordinate with Tracy Hillman and will notify the HCP Coordinating Committees of the date the HCP Hatchery Committees plan to tour the new Wells Fish Hatchery (tentatively scheduled for early 2018; Item II-C).*
  Geris said Hillman indicated the HCP Hatchery Committees decided to postpone the tour until later next year. Geris said although no date was set, it will likely occur next spring. This action item will be carried forward.
- *Kristi Geris will locate the presentation, "Potential to improve the conservation benefits of steelhead hatcheries," presented by Barry Berejikian (National Oceanic and Atmospheric Administration [NOAA] Northwest Fisheries Science Center) during the HCP Hatchery Committees meeting on October 18, 2017, and will distribute the presentation to the HCP Coordinating Committees (Item III-A).*
  Geris distributed Berejikian's presentation to the HCP Coordinating Committees on October 26, 2017.

- *Douglas PUD will: 1) incorporate comments received on the Transition Plan for Wells and Methow Fish Hatcheries, and provide the updated plan to Kristi Geris for distribution to the HCP Coordinating Committees; 2) either incorporate sections of the Memorandum of Understanding (MOU) into the transition plan or distribute the MOU to the HCP Coordinating Committees; and 3) check on the status of the Operations Plan (Item IV-B).*
  Sections of the MOU were incorporated into the final transition plan, and Tom Kahler provided the final plan to Geris on November 7, 2017, which Geris distributed to the HCP Coordinating Committees that same day.
- *Douglas PUD, in coordination with Richard Townsend (Columbia Basin Research), will incorporate wild yearling Chinook salmon passage data for 2017 into the corrected Draft 2017 Wells Dam Passage Dates Analysis (Item IV-C).*
  Data were incorporated, as discussed, and an updated analysis was distributed to the HCP Coordinating Committee by Kristi Geris on December 7, 2017. This will be further discussed during today's meeting.
- *Douglas PUD, in coordination with Richard Townsend, will include wild yearling Chinook salmon passage data for all years of analyses in an addendum to the Draft 2017 Wells Dam Passage Dates Analysis (Item IV-C).*
  This will be discussed during today's meeting.
- *Douglas PUD will provide a proposal on which study species to use for the Douglas PUD 2020 Survival Verification Study for the Wells HCP Coordinating Committee to consider, and will convene a conference call for discussion, if necessary (Item IV-D).*
  This will be discussed during today's meeting.
- *Chelan PUD will provide the Final 2017 Rock Island and Rocky Reach Fish Spill Program Report to Kristi Geris for distribution to the HCP Coordinating Committees (Item V-A).*
  This action item will be carried forward. (Note: Lance Keller provided the final report to Geris following the HCP Coordinating Committees meeting on December 12, 2017, which Geris distributed to the HCP Coordinating Committees on December 13, 2017.)
- *Chelan PUD will provide a written list of the repairs planned for the Rocky Reach Dam fish ladders during the 2017/2018 winter maintenance outage, and 2014 passage data, for Rocky Reach HCP Coordinating Committee consideration and vote via email (Item V-D).*
  Keller provided the list of repairs and 2014 passage data to Kristi Geris following the meeting on October 24, 2017, which Geris distributed to the HCP Coordinating Committees on October 25, 2017.
- *Chad Jackson will provide an official Washington Department of Fish and Wildlife (WDFW) HCP Hatchery Committees Representation Designation Letter to Kristi Geris for the administrative record (Item VI-A).*

Jackson provided this letter to Geris on November 6, 2017, which Geris distributed to the HCP Coordinating Committees and to Sarah Montgomery [Anchor QEA] for distribution to the HCP Hatchery Committees that same day.

- *Kristi Geris will coordinate with Denny Rohr (Priest Rapids Coordinating Committee [PRCC] Facilitator) and the PRCC regarding rescheduling the HCP Coordinating Committees meeting in December 2017 (Item VI-B).*
  Geris coordinated with Rohr, who indicated the PRCC plans to meet on December 13, 2017; therefore, the HCP Coordinating Committees meeting on December 26, 2017, has been rescheduled to December 12, 2017.

III. Chelan PUD

A. Rocky Reach and Rock Island Adult Fishway Maintenance Updates (Lance Keller)

Lance Keller reviewed maintenance updates at Rock Island Dam and Rocky Reach Dam, as follows:

<u>Rock Island Dam</u>

Right Ladder

Keller said the right ladder at Rock Island Dam was taken offline for annual winter maintenance on December 4, 2017. He said a fish rescue was conducted in the upper fishway that same day, and in the lower fishway on December 6, 2017. He said all fish were successfully rescued and released in a healthy state. He reviewed species that were recovered across both efforts, as follows:

Species	Stage/length	Clip	Count	Condition	PIT-tag
rainbow/steelhead	juvenile	ad-present	51	NR	No
		ad-clipped	4	NR	No
	12 inches	ad-clipped	2	NR	No
	14 inches	ad-clipped	2	NR	No
	20 inches	ad-present	1	NR	No
Chinook salmon	juvenile	ad-present	20	NR	No
	adult	ad-present	5	NR	No
		ad-clipped	1	NR	No
redside shiner	NR	NA	2	NR	No
bull trout	8 inches	NA	1	Excellent	No
	10 inches	NA	1	Excellent	Yes

Notes:
ad = adipose
NA = not applicable
NR = not reported
PIT = passive integrated transponder

Keller noted that the one PIT-tagged bull trout was listed as orphan. He also noted there were no mortalities encountered. John Ferguson asked where the rescued fish were released, and Keller said rescued fish are released in the Rock Island Dam forebay.

Left Ladder

Keller said the left ladder at Rock Island Dam will be taken offline for annual winter maintenance on December 18, 2017.

Middle Ladder

Keller said the middle ladder at Rock Island Dam will be taken offline for annual winter maintenance when either the right or left fish ladder is returned to service. He noted that this year, the middle ladder will be the shortest ladder outage at Rock Island Dam.

Keller said all fishways at Rock Island Dam should be back to service by mid-February 2018. He said this is earlier than the usual end of February return to service date.

Rocky Reach Dam

Keller recalled that the Rocky Reach HCP Coordinating Committee agreed to Chelan PUD's request to begin the 2017/2018 winter maintenance work period at Rocky Reach Dam, 3 weeks earlier than usual to allow more time to complete required work. Keller said as agreed, the upper adult fish ladder at Rocky Reach Dam was taken offline for annual winter maintenance on December 11, 2017. He said a fish rescue was conducted in the upper ladder that same day, while the lower ladder remained watered with entrances open. He reviewed species that were recovered from the upper ladder, as follows:

<table>
<tr><th>Species</th><th>Stage/length</th><th>Clip</th><th>Count</th><th>Condition</th><th>PIT-tag</th></tr>
<tr><td rowspan="2">rainbow/steelhead</td><td rowspan="2">juvenile</td><td>ad-present</td><td>54</td><td>NR</td><td>No</td></tr>
<tr><td>ad-clipped</td><td>9</td><td>NR</td><td>No</td></tr>
<tr><td rowspan="2">Pacific lamprey</td><td rowspan="2">adult</td><td>NA</td><td>232</td><td>NR</td><td>No</td></tr>
<tr><td>NA</td><td>2</td><td>NR</td><td>Yes</td></tr>
<tr><td>whitefish</td><td>NR</td><td>NA</td><td>34</td><td>NR</td><td>No</td></tr>
</table>

Notes:
ad = adipose
NA = not applicable
NR = not reported
PIT = passive integrated transponder

Keller said, considering the large Pacific lamprey run this year, crews were prepared to encounter a large number of Pacific lamprey, and 234 fish is the most encountered in a long time. He said two Pacific lamprey were PIT-tagged with full-duplex tags, which Keller suspects are from the adult PIT-tagging effort Steve Hemstrom is conducting in coordination with the Rocky Reach Fish Forum. Keller said all 234 Pacific lamprey were released to a calm, quiet area in the Rocky Reach Dam forebay.

Ferguson noted the ongoing translocation efforts lead by Ralph Lampman (YN) and in association with the Douglas PUD Aquatic Settlement Work Group. Ferguson suggested Chelan PUD coordinate with Lampman about possibly using Pacific lamprey from fish rescues for translocation efforts upstream of Wells Dam. Keller said he believes Lampman is aware of annual fish rescue numbers. Keller said Chelan PUD would want to continue releasing PIT-tagged fish in the Rocky Reach Dam forebay for monitoring and evaluation purposes; however, Chelan PUD may be open to ideas for non-PIT-tagged fish. Keller said similar to Rock Island Dam, there were also no mortalities encountered at Rocky Reach Dam.

Keller said the lower ladder will be dewatered in the coming days. He reiterated that all weirs in the lower fishway remained fully submerged while dewatering the upper fishway, so fish will not become stranded and are able to exit the fishway. Kirk Truscott asked about the logistics of dewatering the upper fishway, but not the lower. Keller said the upper fishway exits are closed and the water drains via gravity to a level equal to the current tailwater elevation, with the lower ladder and all weirs remaining fully submerged. He said the water elevation in the lower fishway will follow the tailrace elevation until the entrance gates are deployed and the remaining water is pumped from the lower fishway, at which point crews are present for the lower fishway fish rescue. Truscott also asked if the number of clipped and non-clipped O. mykiss (*Oncorhynchus mykiss*) were similar to other years. Keller said there seemed to be more resident fish versus migrating. He added that crews did interrogate every fish for PIT tags.

B. Application for Non-Capacity Amendment for Coyote Dunes (Lance Keller)

Lance Keller said Kristi Geris notified the Rock Island HCP Coordinating Committee on November 15, 2017, that an Application for Non-Capacity Amendment for Coyote Dunes is available for a 30-day review period, with edits and comments due to Jeff Osborn by December 15, 2017. Keller also asked that Rock Island HCP Coordinating Committee representatives submit indication of no comments, if this is the case, in order to create a complete consultation record to submit to the Federal Energy Regulatory Commission. Geris said she will resend the email detailing the Application for Non-Capacity Amendment for Coyote Dunes for review, to the Rock Island HCP Coordinating Committee. *(Note: this email was re-distributed to the HCP Coordinating Committees by Geris on December 13, 2017,* *and all Rock Island HCP Coordinating Committee representatives responded to Chelan PUD by December 14, 2017.)*

Keller said the proposal is for two changes to the Olds Bridge recreation site, which is the area south of "north end bridge" (Odabashian Bridge) in Wenatchee, Washington. He said changes include: 1) changing the name of the site to "Coyote Dunes Natural Area"; and 2) adjusting the area of the site and designating the site to be a passive recreation area on approximately 26 acres of land owned by Chelan PUD.

Kirk Truscott asked if the amendment includes moving dirt. Keller said no, there will be some restoration in the uplands, but there will be no in-water work. Keely Murdoch asked if a cultural resource survey is needed or has been conducted. Keller said to his knowledge, Chelan PUD has reviewed and addressed the requirements associated with cultural resources. Murdoch said she asked because for the YN, someone other than her needs to review and approve actions related to cultural resources. Keller said he will verify internally that Chelan PUD has addressed cultural resource impacts, if any, associated with the Application for Non-Capacity Amendment for Coyote Dunes. *(Note: Keller verified that Chelan PUD has initiated the appropriate actions regarding addressing potential cultural resource impacts associated with this amendment, as explained in an email distributed to the HCP Coordinating Committees by Keller following the meeting on December 12, 2017, and by Kristi Geris on December 13, 2017.)*

C. Integrated Recovery Technical Advisory Team (Greer Maier)

Greer Maier said she is the Science Program Manager at UCSRB (the Board). Maier said she has been with the Board since 2007, when the Upper Columbia Spring Chinook Salmon and Steelhead Recovery Plan was written. She said part of this recovery plan is to determine what recovery strategies can be integrated across all four H's (habitat, harvest, hydropower, and hatcheries), how to achieve recovery by creating partnerships, and how the Board can help facilitate positive change. She said this effort started with developing the Habitat Summary Report in 2014, where information was gathered to date on habitat restoration efforts. She said next, the Hatchery Summary Report was developed, which will hopefully be approved next week. She said now, focus is shifting to the Hydropower Summary Report. She said part of this process is understanding who is involved (in hydropower).

Maier said the Integrated Recovery Technical Advisory Team (IRTAG) was convened 5 years ago to review and provide input on these summary reports. She said the IRTAG meets twice per year in Wenatchee, Washington. She said it is optimal to have at least one representative present from each Mid-Columbia PUD (Grant, Chelan, and Douglas PUDs), and she said it has also been helpful to have Keely Murdoch and Casey Baldwin present to represent the YN and the CCT, respectively.

Maier said this effort starts with these background summaries, or summary reports. She said next comes shared learning, presentations at Board meetings, and then open discussions about the issues and how the Board can play a role in coming up with solutions and obtaining funding. She said, however, these summary reports for all four H's need to be complete before the subsequent discussions can start.

Tom Kahler asked if UCSRB would also report on the Federal Columbia River Power System (i.e., fish passage and survival at the federal projects). Maier said yes, as well as BPA, WDFW, and USFWS. She said she has also been in touch with Grant PUD and the PRCC.

John Ferguson asked if the Board has formally requested representation. Maier said the request is fairly informal, and is essentially what she is doing today. Kahler said he has been elected to represent Douglas PUD. Lance Keller said he was elected to represent Chelan PUD. Maier said the first meeting will be in early spring 2018.

Ferguson asked about the regulatory context of the recovery plan. He asked, what requirement does the recovery plan meet, what authority does this plan have, and how does it affect ongoing programs? Maier said the plan is advisory and all participation is voluntary. She said this effort is supported by specific salmon recovery funds. She said there is political value with the Board, but there is also interest in pursuing how to contribute in other arenas. She said the recovery plan has also been adopted by NOAA, but is voluntary. She said the plan also affects obtaining permits in terms of status of species.

Maier said she would like to touch base with the HCP Coordinating Committees again, when the process is further down the road. She said a copy of the Hatchery Summary Report was provided to the HCP Hatchery Committees for review and comment. She said this is an open process, that she wants accurate information, and asks for everyone to participate so the process has everyone involved.

Kirk Truscott asked, considering various workloads, can chapters be distributed as they are completed instead of all at once (entire draft document). Maier said the document is written all at once, not iteratively; however, she can work on distributing sections separately, or can try parsing out the information.

Ferguson asked about the schedule for the Hydropower Summary Report. Maier said efforts for this report will be ramping up in February or March 2018, which is when the first meeting might be scheduled. She said she hopes to identify people contributing to this report by January 2018. She said she also hopes to have a draft report by spring 2018, and finish the report by the end of 2018. She said this might be a bit ambitious considering the other reports took 2 to 3 years to complete.

IV. Douglas PUD

A. Wells Dam Fishway Maintenance Update (Tom Kahler)

Tom Kahler reviewed maintenance updates at Wells Dam, as follows:

West Fishway

Kahler said dewatering of the west fishway at Wells Dam (ladder and collection gallery) for annual winter maintenance has been postponed because unforeseen problems delaying the necessary replacement of a walkway over the AWS intakes in the tailrace have prevented the installation of the bulkheads in those intakes. He said dewatering was initially supposed to take place on the morning of December 5, 2017; however, it will now take place the week of December 18, 2017. *(Note: the west fishway was taken out of service for annual maintenance on the morning of December 27, 2017.)*

Kahler said installation of the bulkheads in the fish-pump intakes in the forebay was completed on the afternoon of December 5, 2017, in preparation for the fish rescue through the entire fishway. He said, therefore, the ladder is in operation; however, the AWS attraction flow to the collection gallery is not. Therefore, there is very little head differential at the fishway entrance, but flow from the ladder into the collection gallery will attract fish already in the gallery, and any fish using the ladder will be able to exit.

Kahler recalled at Wells Dam, major versus routine maintenance is alternated between fishways each year. He said this year, the west fishway will receive the more extensive maintenance.

East Fishway

Kahler said the east fishway at Wells Dam will be taken offline for annual winter maintenance once the west fishway is complete. He said this year, only routine maintenance will be performed on the east fishway. He guessed the fishway will be dewatered in late-January 2018, and should return to service a couple of weeks after.

Kirk Truscott asked, historically, if a large number of whitefish are typically rescued from the Wells Dam fishways. Kahler said yes, both Mountain and Lake whitefish. He said operators started pulsing water through the upper ladder in preparation for the fishway outage, which whitefish do not appear to like and so they move out.

B. 2017 Wells Dam Passage Dates Analysis (Tom Kahler)

Tom Kahler said a corrected Draft 2017 Wells Dam Passage Dates Analysis was distributed to the HCP Coordinating Committees by Kristi Geris on October 23, 2017. The draft analysis was available for a 30-day review period, with edits and comments due to Kahler by November 22, 2017. Kahler said per his action item from the HCP Coordinating Committees meeting on October 24, 2017, to incorporate wild migrants only, a second version of the corrected Draft 2017 Wells Dam Passage Dates Analysis (Attachment B) was distributed to the HCP Coordinating Committees by Geris on December 7, 2017. Kahler said he already identified edits needed to the text of this latest version; however, the edits will not change the data.

Kahler said based on this analysis, when considering wild yearling Chinook salmon migrants only, there is quite a difference compared to the combined (hatchery and wild) run. He said, for example, Table 5 of Attachment B demonstrates how the yearling Chinook salmon wild-only sample sizes are disproportionate to the run at large sample sizes. He added that wild yearling Chinook salmon migrate approximately 2 weeks earlier compared to hatchery fish. He said some fish managers also expect the freshets to shift (occur earlier) over time if climate change continues. He said if this happens, hatchery releases may also need shifting. *(Note: Jim Craig noted a typo in Table 5 under wild only PIT tags in 2015, which Kahler said he will correct in the next iteration of this document.)*

Kahler said, however, the same is not true for subyearling Chinook salmon, as shown in Table 7 of Attachment B. He said here, the wild PIT-tagged and hatchery groups are not so different from one another. Kirk Truscott noted that for subyearling Chinook salmon, wild fish typically emigrate later than hatchery fish.

John Ferguson asked what these new data mean in terms of a path forward. Kahler said the Wells HCP standard says nothing about parsing out wild versus hatchery fish; therefore, yes, the Wells Project met the standard. He said, however, he believes the intent of the HCP was not to systematically under-protect.

Truscott reviewed Table 6 of Attachment B. He noted that about 14% of wild spring Chinook salmon did not receive protection under spill in 2013 and 2015. He caveated that those years were moderate-to-low water years. He also noted in 2014, about 18% of wild spring Chinook salmon did not receive protection under spill, which he believes is a fairly healthy portion of the wild run. Ferguson asked, considering the small sample size, are those numbers being skewed by 1 or 2 fish? He asked if more needs to be understood about when these fish start migrating to understand the importance of the data. Kahler said this is something Douglas PUD is concerned about and would like to investigate more. He said in 2017, spill was provided for 92.92% of the wild run; however, Wells Dam was spilling a lot of water beginning mid-March, and it is not as though those fish passing before April 9 were not provided protection. He said Douglas PUD is interested in better understanding the shape of the wild spring Chinook salmon distribution.

Truscott said based on these PIT tag data (detections at Rocky Reach Dam with the assumed 5-day travel time to Wells Dam), spring Chinook salmon are beginning to migrate before the Twisp River screw trap is operational. Kahler said Charlie Snow's (WDFW) crew also started electrofishing and tagging in the tributaries sometime around 2012 to 2014, and Kahler is unsure of what the mix is between screw trap and electrofishing. Ferguson asked if the new PIT-tag detector in spillbay 2 at Wells Dam can be used to verify the assumed 5-day travel time between Wells and Rocky Reach dams. Kahler said this analysis is ongoing, as described on page 12 of Attachment B; however, not many fish have been detected at both Wells and Rocky Reach dams. He said the issue is when there is so much spill most fish do not pass via that spillbay with PIT-tag detection.

Kahler said Douglas PUD will further review run-timing data for wild and hatchery yearling Chinook salmon with regard to Wells Dam bypass operation dates, and will report back to the HCP Coordinating Committees. Ferguson asked if changing the bypass operation dates at Wells Dam will need to be memorialized in an SOA, and Kahler said this is correct. Craig noted that hatchery managers will also need to know ahead of time to adjust their programs, as needed.

Kahler said Douglas PUD is still accepting comments on the Draft 2017 Wells Dam Passage Dates Analysis. The Wells HCP Coordinating Committee will submit edits and comments on the draft analysis to Kahler no later than January 5, 2018.

Truscott said he appreciates Douglas PUD's willingness to look into these passage dates further.

C. Douglas PUD 2020 Survival Verification Study - Study Species (Tom Kahler)

Tom Kahler said he has not yet developed a proposal on which study species to use for the Douglas PUD 2020 Survival Verification Study. He said the most practical approach would be to use yearling summer Chinook salmon. He said with summers there is no Endangered Species Act issue, and this species does not have the same level of concern for straying. He recalled the last survival verification study consisted of 15 replicate releases of 667 yearling Chinook salmon at the mouth of the Okanogan River; 2,000 in the Methow River; and 2,667 in the Wells Dam tailrace. He said based on more current data, this split may change. He said all study fish were PIT-tagged. He said Douglas PUD may just propose to repeat the same study methods.

John Ferguson asked if there will be enough adult returns, and Kahler said he believes precision was met before. Kirk Truscott asked about releasing at the mouth of the Okanogan River, noting that Project effects reach farther upstream than just at the mouth. Kahler said the Wells HCP specifically states a release will be at the mouth. Truscott said inundation reaches up 11 miles, and he knows a lot of non-indigenous fish are present in the inundation zone.

Keely Murdoch said for clarification, when this topic was last discussed Kahler mentioned YN reluctance for using coho salmon for a study species; however, after further discussions with colleagues the YN would be supportive of using coho salmon if the Wells HCP Coordinating Committee chooses to do so. Kahler said Douglas PUD is also open to using coho salmon; however, Douglas PUD's proposal would still be for yearling summer Chinook salmon. Ferguson asked if using coho salmon will change releases. Kahler said yes, because there are no Okanogan River coho salmon. He said using coho salmon may be simpler. He said in terms of Project effects, there have been four studies using yearling Chinook salmon (2 studies) and steelhead (2 studies), but no coho salmon. He said consistency helps to fully understand effects, but he acknowledged there are also several other considerations.

Truscott recalled during the HCP Coordinating Committees meeting on October 24, 2017, there was discussion about using PIT tags versus acoustic tags. Truscott said it seems Douglas PUD prefers PIT tags. Ferguson recalled that the Wells HCP requires testing for delayed mortality, which cannot be evaluated using acoustic tags. Truscott said he is suggesting acoustic tags because then the sample size can be lower and spring Chinook salmon can be used to evaluate how they differ from yearling summer Chinook salmon. Kahler said Douglas PUD is wary of using acoustic tags. Lance Keller recalled that in in 2004, Chelan PUD conducted a PIT- versus acoustic-tag comparative study, and for the Rock Island Dam project there was no difference based on a side-by-side analysis. Scott Carlon said he favors acoustics because of the ability to evaluate behavioral data. He also asked Truscott if he is referring to using hatchery spring Chinook salmon, and Truscott said this is correct. Kahler added that historically, Douglas PUD has not needed to use acoustic tags because there has been no need to determine route-specific survival at Wells Dam.

Kahler said a decision needs to be made in time for drafting the annual Broodstock Collection Protocols. He said this is needed by February 2018 at the latest, but January 2018 is more practical. Ferguson suggested that Douglas PUD provide a matrix outlining the pros and cons for potential study species to use in the Douglas PUD 2020 Survival Verification Study (including such details as species selection, release location, and tag type), for further discussion and decision in January 2018. *(Note: Kahler provided this matrix to Kristi Geris on January 17, 2018, which Geris distributed to the HCP Coordinating Committees that same day.)*

V. HCP Administration

A. Next Meetings

The next scheduled HCP Coordinating Committees meeting is on January 23, 2017, to be held in-person at the Grant PUD Wenatchee Office in Wenatchee, Washington.

John Ferguson said he will be unable to attend in-person; however, he will call into the meeting.

The February 27 and March 27, 2018 meetings will be held by conference call or in-person at the Grant PUD Wenatchee Office in Wenatchee, Washington, as is yet to be determined.

VI. List of Attachments

Attachment A	List of Attendees
Attachment B	Draft 2017 Wells Dam Passage Dates Analysis (version 2)

Attachment A
List of Attendees

Name	Organization
John Ferguson	Anchor QEA, LLC
Kristi Geris	Anchor QEA, LLC
Tracy Hillman††	BioAnalysts
Lance Keller*	Chelan PUD
Alene Underwood†	Chelan PUD
Greer Maier[0]	Upper Columbia Salmon Recovery Board
Tom Kahler*	Douglas PUD
Scott Carlon*†	National Marine Fisheries Service
Jim Craig*	U.S. Fish and Wildlife Service
Chad Jackson*	Washington Department of Fish and Wildlife
Kirk Truscott*	Colville Confederated Tribes
Keely Murdoch*	Yakama Nation

Notes:
* Denotes HCP Coordinating Committees member or alternate
† Joined by phone
†† Joined by phone for the HCP Tributary and Hatchery Committees Update
0 Joined for Chelan PUD's Integrated Recovery Technical Advisory Team agenda item

Analysis of Proportion of Outmigration Affected by Bypass Operations at Wells Dam in 2017

Prepared for:

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7 December 2017

1. Introduction

This analysis summarizes the outmigration timing that has been monitored at the juvenile sampling facility at Rocky Reach Dam or detected at the Rocky Reach Bypass PIT-tag detector for five stocks of salmonids (Coho salmon, yearling and subyearling Chinook salmon, steelhead, and sockeye salmon) for the period 2012-2017. The proportions of each stock covered by the bypass operations at Wells Dam can be estimated using daily counts at Rocky Reach Dam, adjusting for the travel time from Wells to Rocky Reach dams. Table 1 has the average travel times based on Douglas PUD's 2010 PIT-tag study for yearling Chinook salmon, and acoustic-tag studies for steelhead and sockeye salmon. Since there are no PIT-tag or acoustic-tag studies measuring travel times of subyearling Chinook, travel time was assumed to be 5 days, which is approximately one-half of the median travel time (11 days) to Rocky Reach Dam of PIT-tagged wild subyearling Chinook released at the mouth of the Okanogan River in 2017. Coho travel time was assumed to match that of yearling Chinook, and preliminary PIT-tag data appears to validate this assumption (Appendix, Table A1).

Table 1: Average travel times from Wells tailrace to Rocky Reach Dam, based on study results or assumptions of similarity to surrogate species.

Stock	Travel time
Yearling Chinook salmon	5 days
Subyearling Chinook salmon	5 days
Steelhead	2 days
Sockeye salmon	2 days
Coho salmon	5 days

Plots of the annual cumulative proportion of the outmigration for spring migrants (yearling Chinook, steelhead, sockeye, and coho salmon), and subyearling Chinook salmon in the summer have fairly consistent start and end dates across years at Rocky Reach Dam (Figure 1). The timing of bypass operations at Wells Dam from 2012 through 2017 was from 00:00 April 9th through 24:00 on August 19th. This current timing of bypass operations will continue annually, unless modified as a result of future investigations that demonstrate an inadequacy of these dates at providing bypass passage for ≥95% of the migrations of both spring- and summer-migrating Plan Species at Wells Dam.

2. Results

2.1 Bypass coverage, 2012–2017

For each Plan Species, the proportions of migrations that passed during the Wells bypass operations in 2017 were 99.85% for yearling Chinook salmon (combined hatchery and wild), 100% for steelhead, 99.99% for sockeye salmon, 100% for coho salmon, and 99.70% for subyearling Chinook salmon (combined hatchery and wild). The 2017 results for all monitored Plan Species were consistent with historical trends, 2012–2017 (Table 2). However, evaluating the wild component of the yearling Chinook run revealed that the effectiveness of the annual start date for bypass operations was strongly influenced by the origin of the yearling Chinook used in the analysis (see Section 2.2).

Though Table 2 shows the annual estimated proportion of migration passing Wells Dam prior to, during, and post bypass operations required for fish passage, Tables 3 and 4 are presented to highlight the stocks that may be at risk of not achieving the 95% coverage (yearling Chinook salmon passage prior to bypass operations, and subyearling Chinook salmon passage post bypass operations).

To assess the effectiveness of the selected start date for bypass operations, Table 3 compares the start date for bypass operations each year with the date on which the 5th percentile of the cumulative yearling Chinook salmon outmigration passed Wells Dam that year. For yearling Chinook salmon (combined hatchery and wild) in 2017, the start date for bypass operations was 8 days earlier than necessary to achieve the HCP standard of providing bypass passage for ≥95% of the migration. However, for wild only, the start date for bypass operations was 3 days late (see Section 2.2).

Similarly, Table 4 compares the actual termination date for bypass operations with the date on which bypass operations covered 95% of the subyearling Chinook salmon outmigration. In each year, an earlier termination of bypass operations would have been possible without jeopardizing the achievement of the HCP standard of providing a bypass route for ≥95% of outmigrating subyearling Chinook salmon. For combined hatchery and wild subyearling Chinook salmon in 2017, the termination of bypass operations at midnight on August 19 was 13 days later than required to achieve the HCP standard of providing bypass passage for ≥95% of the migration.

Table 2. Total proportion of each stock's migration affected by bypass operations at Wells Dam, based on travel times from Wells Dam to Rocky Reach Dam, the cumulative proportion of the annual migration of each stock at Rocky Reach, and the start and stop dates of Wells bypass operations, 2012-2017. Hatchery and wild-origin PIT-tagged releases above Wells Dam are included for both yearling and subyearling Chinook for the years 2012-2017.

	Proportion passed	Annual migration proportion					
Spring Outmigration	**Yearling Chinook Salmon+**						
	Hatchery & Wild:	2012	2013	2014	2015	2016	**2017**
	prior to Bypass Ops period	0.0022	0.0026	0.0055	0.0026	0.0032	**0.0017**
	during Bypass Ops period	**0.9978**	**0.9974**	**0.9945**	**0.9974**	**0.9968**	**0.9983**
	after Bypass Ops period	0	0	0	0	0	**0**
	Wild Only:	2012	2013	2014	2015	2016	**2017**
	prior to Bypass Ops period	0.0438	0.1386	0.1823	0.1402	0.1897	**0.0708**
	during Bypass Ops period	**0.9562**	**0.8614**	**0.8177**	**0.8598**	**0.8103**	**0.9292**
	after Bypass Ops period	0	0	0	0	0	**0**
	Steelhead	2012	2013	2014	2015	2016	**2017**
	prior to Bypass Ops period	0.0014	0.0079	0.0021	0.0029	0.0022	**0**
	during Bypass Ops period	**0.9986**	**0.9921**	**0.9975**	**0.9969**	**0.9977**	**1.0000**
	after Bypass Ops period	0	0	0.0004	0.0002	0.0001	**0**
	Sockeye Salmon	2012	2013	2014	2015	2016	**2017**
	prior to Bypass Ops period	0	0	0	0	0	**0**
	during Bypass Ops period	**1.0000**	**0.9999**	**0.9999**	**1.0000**	**1.0000**	**0.9999**
	after Bypass Ops period	0	0.0001	0	0.0001	0	**0**
	Coho Salmon		2013	2014	2015	2016	**2017**
	prior to Bypass Ops period		0.0001	0.0001	0.0004	0.0024	**0**
	during Bypass Ops period		**0.9999**	**0.9999**	**0.9996**	**0.9976**	**1.0000**
	after Bypass Ops period		0	0	0	0	**0**
Summer Outmigration	**Subyearling Chinook Salmon+**						
	Hatchery & Wild:	2012	2013	2014	2015	2016	**2017**
	prior to Bypass Ops period	0	0	0	0	0	**0**
	during Bypass Ops period	**0.9639**	**0.9885**	**0.9611**	**1.0000**	**1.0000**	**0.9970**
	after Bypass Ops period	0.0361	0.0115	0.0389	0	0	**0.0030**
	Wild Only:	2012	2013	2014	2015	2016	**2017**
	prior to Bypass Ops period	0	0	0	0	0	**0**
	during Bypass Ops period	**0.9639**	**0.9885**	**0.9611**	**1.0000**	**1.0000**	**0.9957**
	after Bypass Ops period	0.0361	0.0115	0.0389	0	0	**0.0043**

+Proportion estimated using only PIT-tagged releases above Wells Dam.

Table 3. A comparison of the actual start date for bypass operations at Wells Dam for the last 10 years versus the date on which the 5th percentile of the PIT-tagged yearling Chinook salmon migration passed Wells Dam that year, 2012-2017. Operations begin at 00:01 for the date listed in column 2. “Proportion bypass operations would have covered” indicates the proportion of the migration that would have been provided a bypass passage route had bypass operations started at 00:01 on the date that the 5th percentile of the migration passed Wells Dam (column 5). “Bypass start date timing” (column 8) indicates whether the bypass start date was earlier or later than the date on which the 5th percentile of the yearling Chinook migration passed Wells Dam, and by how many days.

Migration Year	Actual bypass start date	Cumulative proportion passed before 00:01	Proportion Covered by Bypass Ops	Date on which the 5th percentile passed	Cumulative proportion passed before 00:01	Proportion bypass ops. would have covered	Bypass start date timing
Hatchery & Wild							
2012	April 9	0.0022	0.9978	April 15	0.0269	0.9731	6 days early
2013	April 9	0.0026	0.9974	April 18	0.0405	0.9595	9 days early
2014	April 9	0.0055	0.9945	April 17	0.0277	0.9723	8 days early
2015	April 9	0.0026	0.9974	April 18	0.0381	0.9219	9 days early
2016	April 9	0.0032	0.9968	April 12	0.0410	0.9590	3 days early
2017	April 9	0.0017	0.9983	April 17	0.0493	0.9507	8 days early
Wild Only							
2012	April 9	0.0438	0.9562	April 10	0.0438	0.9562	1 day early
2013	April 9	0.1386	0.8614	April 4	0.0301	0.9699	5 days late
2014	April 9	0.1823	0.8177	April 5	0.0331	0.9669	4 days late
2015	April 9	0.1402	0.8598	April 2	0.0343	0.9657	7 days late
2016	April 9	0.1897	0.8103	April 2	0.0460	0.9540	7 days late
2017	April 9	0.0708	0.9292	April 6	0.0425	0.9575	3 days late

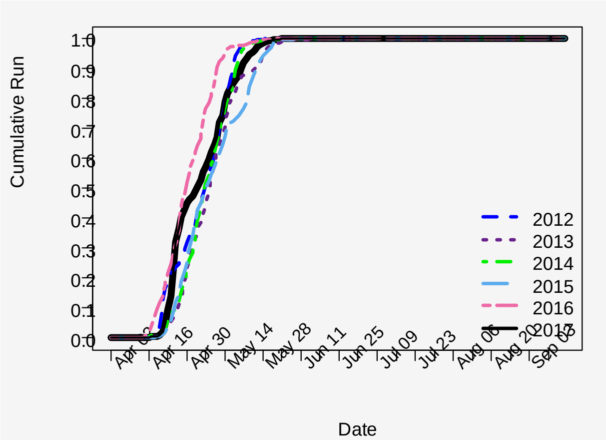
Table 4. A comparison of the actual stop date for bypass operations at Wells Dam for the last 6 years, versus the stop date necessary to have covered at least 95% of the subyearling Chinook salmon outmigration that year. Operations are assumed to end at 24:00 for the date listed.

Migration Year	Actual bypass stop date	Cumulative proportion passed by 24:00 of actual stop date	Date on which the 95% standard was achieved	Cumulative proportion passed by 24:00 of the date on which the 95% standard was achieved	bypass end date timing
Hatchery & Wild					
2012	August 19	0.9639	August 16	0.9518	3 days late
2013	August 19	0.9885	August 11	0.9515	8 days late
2014	August 19	0.9611	August 18	0.9555	1 day late
2015	August 19	1.0000	July 27	0.9506	23 days late
2016	August 19	1.0000	July 20	0.9531	30 days late
2017	August 19	0.9970	August 3	0.9533	16 days late
Wild Only					
2012	August 19	0.9639	August 16	0.9518	3 days late
2013	August 19	0.9885	August 11	0.9515	8 days late
2014	August 19	0.9611	August 18	0.9555	1 day late
2015	August 19	1.0000	August 1	0.9515	18 days late
2016	August 19	1.0000	July 24	0.9547	26 days late
2017	August 19	0.9957	August 5	0.9543	14 days late

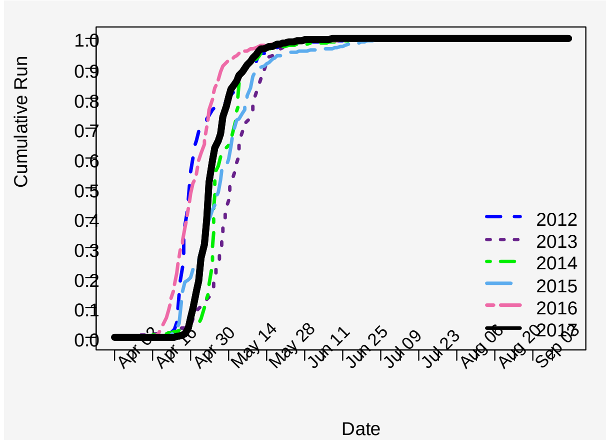
** PIT-tagged, wild-origin subyearling Chinook released above Wells Dam.*

Figure 1. Passage distributions at Rocky Reach Dam juvenile collection facility for spring and summer migrating stocks, 2012-2017. Cumulative proportions are based on the expanded counts obtained from daily sampling at Rocky Reach from 1 April – 31 August, except where PIT-tagged releases above Wells Dam were available (wild and hatchery yearling and subyearling Chinook).

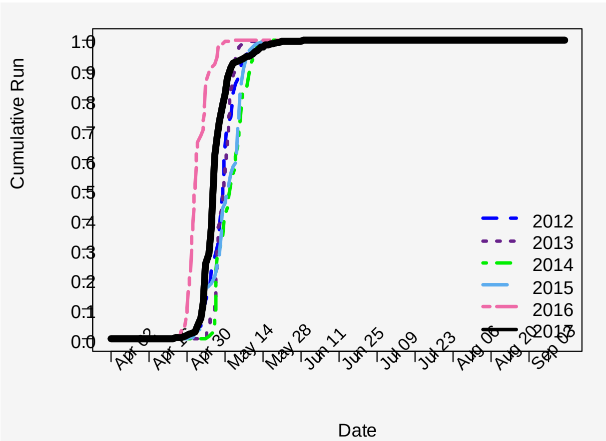
a. Yearling Chinook Salmon



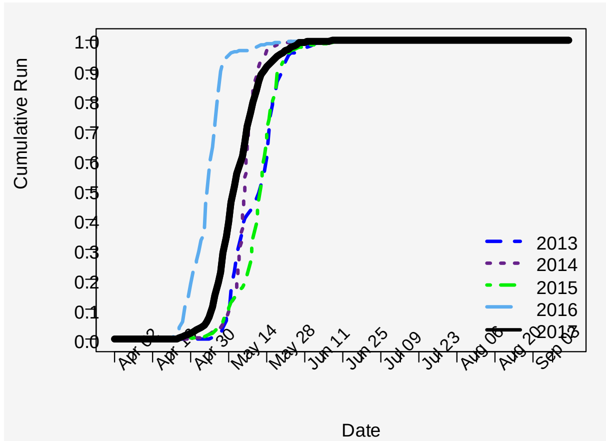
b. Steelhead



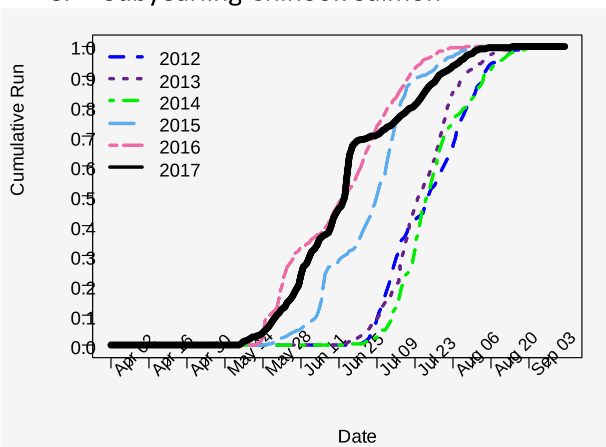
c. Sockeye Salmon



d. Coho Salmon



e. Subyearling Chinook Salmon



2.2 Comparing Migration Timing and Passage Proportions of PIT-tagged Hatchery and Wild-origin Yearling Chinook Released above Wells Dam

The yearling Chinook migration timing at Wells Dam was estimated using 1) the unadjusted daily counts of PIT-tagged fish released above Wells Dam; and 2) the unadjusted daily counts of PIT-tagged wild-origin fish released above Wells Dam. While wild yearling Chinook salmon are the preferable group to determine bypass coverage of the summer migration, it is also the smallest group, with each individual having a greater impact on passage proportion (Table 5). The number of hatchery yearling Chinook salmon is much larger, but passage timing is susceptible to hatchery release timing. For the six years that comparison of migration timing between PIT-tagged hatchery and wild-origin yearling Chinook released above Wells Dam is possible, wild PIT-tagged yearling Chinook salmon appear to outmigrate up to two weeks earlier than the hatchery-released yearling Chinook salmon (Figure 2).

With the observed differences in the passage timing of the hatchery and wild yearling Chinook salmon, bypass operations were not equally effective in covering ≥95% of the migrations (see Table 6). Bypass operations conveyed 99.9% to 100% of hatchery yearling Chinook salmon migrations in 2012–2017. In contrast, bypass operations at Wells Dam conveyed from 81.03% to 95.62% of the wild PIT-tagged yearling Chinook salmon migrations, achieving the ≥95% standard in only 2012.

Table 5. Total detections of yearling Chinook salmon at Rocky Reach Dam by year and group.

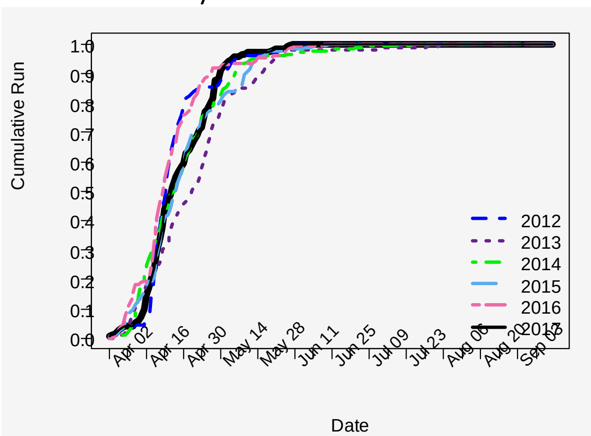
Group	2012	2013	2014	2015	2016	2017
Hatchery, Wild and Unknown PITs	3,539	9,439	5,850	16,793	11,810	10,370
Wild only PITs	137	166	181	3f21	174	212

Table 6. Comparison of migration timing of PIT-tagged hatchery and wild-origin yearling Chinook released above Wells Dam.

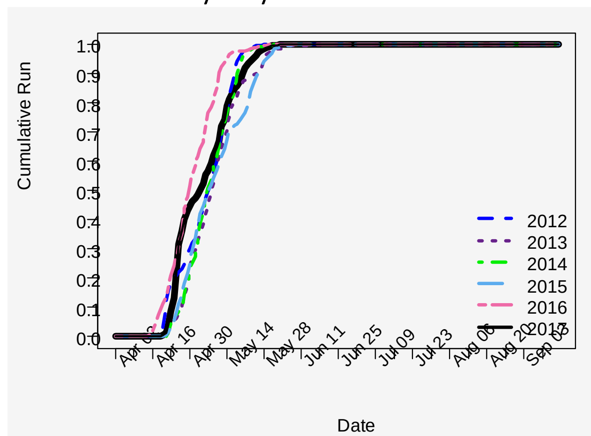
Proportion passed						
Hatchery:	2012	2013	2014	2015	2016	**2017**
prior to Bypass Ops period	0.0006	0.0002	0	0	0.0004	**0.0003**
during Bypass Ops period	**0.9994**	**0.9998**	**0.9998**	**0.9999**	**0.9996**	**0.9997**
after Bypass Ops period	0	0	0	0	0	**0**
Wild:	2012	2013	2014	2015	2016	**2017**
prior to Bypass Ops period	0.0438	0.1386	0.1823	0.1402	0.1897	**0.0708**
during Bypass Ops period	**0.9562**	**0.8614**	**0.8177**	**0.8598**	**0.8103**	**0.9292**
after Bypass Ops period	0	0	0	0	0	**0**

Figure 2. Comparison of Yearling Chinook migration timing at Wells Dam by rearing source a) wild origin only, b) hatchery only, and c) hatchery and wild origin.

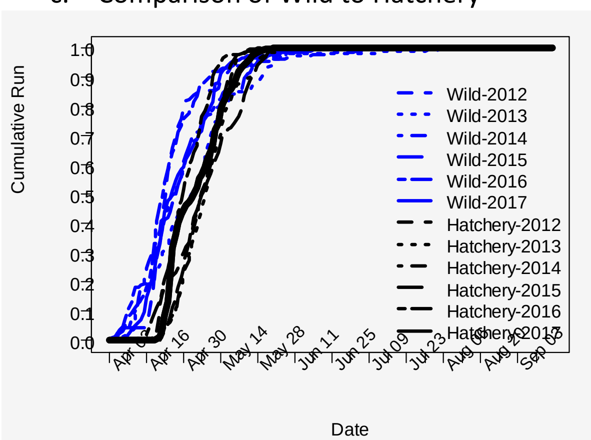
a. Wild only



b. Hatchery only



c. Comparison of Wild to Hatchery



2.3 Comparing Migration Timing and Passage Proportions of PIT-tagged Hatchery and Wild-origin Subyearling Chinook Released above Wells Dam

The subyearling Chinook migration timing at Wells Dam was estimated using 1) the unadjusted daily counts of PIT-tagged hatchery and wild fish released above Wells Dam; and 2) the unadjusted daily counts of PIT-tagged wild-origin fish released above Wells Dam. Each has the same caveats as the yearling Chinook salmon in regard to comparative migration sizes (Table 7). For the three years (2015–2017) that comparison of migration timing between PIT-tagged hatchery and wild-origin subyearling Chinook released above Wells Dam is possible, wild PIT-tagged subyearling Chinook salmon appear to outmigrate up to a month later than the hatchery-released subyearling Chinook salmon (Figure 3).

Despite differences in the passage timing of hatchery and wild subyearling Chinook salmon, bypass operations were effective in covering ≥95% of the migration for each (Table 8). Bypass operations covered 100% of the hatchery subyearling Chinook salmon in 2015–2017, and from 96.11% to 100% for PIT-tagged wild subyearling Chinook salmon. It therefore appears the timing of the bypass operations at Wells Dam is robust, conveying all segments of the subyearling Chinook salmon outmigration.

Table 7. Total detections of subyearling Chinook salmon at Rocky Reach Dam by year and group.

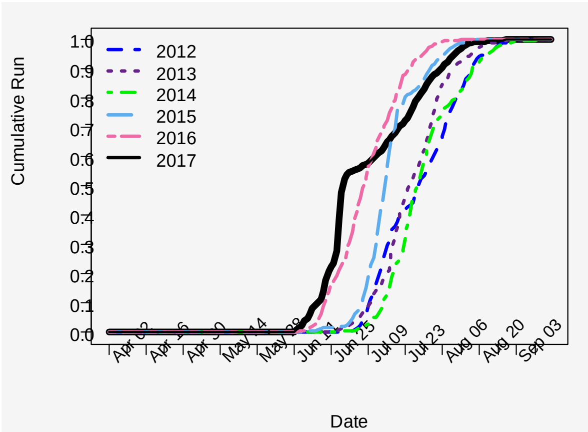
Group	2012	2013	2014	2015	2016	2017
Hatchery, Wild and Unknown PITs	913	1,998	899	1,052	2,303	5,308
Wild only PITs	913	1,998	899	577	1,413	3,701

Table 8. Comparison of migration timing of PIT-tagged hatchery and wild-origin subyearling Chinook released above Wells Dam. PIT-tagged hatchery releases started in 2015.

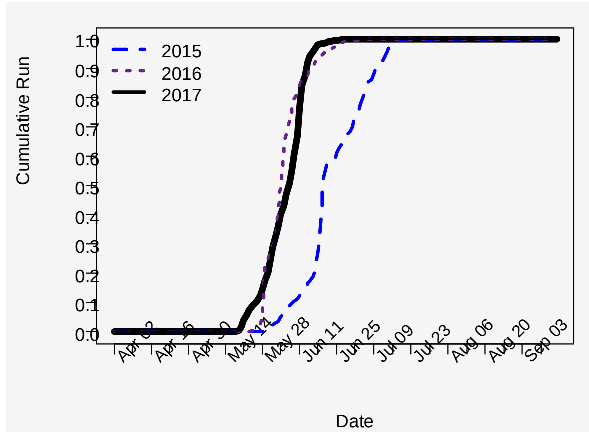
Proportion passed						
Hatchery:				2015	2016	**2017**
prior to Bypass Ops period				0	0	**0**
during Bypass Ops period				**1.0000**	**1.0000**	**1.0000**
after Bypass Ops period				0	0	**0**
Wild:	2012	2013	2014	2015	2016	**2017**
prior to Bypass Ops period	0	0	0	0	0	**0**
during Bypass Ops period	**0.9639**	**0.9885**	**0.9611**	**1.0000**	**1.0000**	**0.9957**
after Bypass Ops period	0.0361	0.0115	0.0389	0	0	**0.0043**

Figure 3. Comparison of Subyearling Chinook migration timing at Wells Dam by rearing source a) wild origin only, b) hatchery only, and c) hatchery and wild origin.

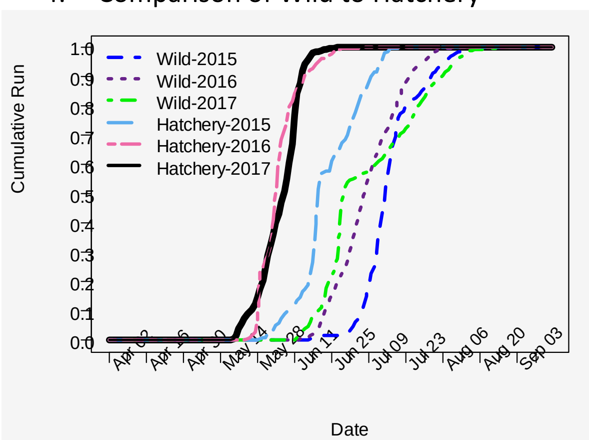
d. Wild only



e. Hatchery only



f. Comparison of Wild to Hatchery



3. Discussion

In 2017, when considering combined wild- and hatchery-origin fish, the bypass operations covered between 99.70% and 100% of the outmigrations of the five Plan Species at Wells Dam. These coverage rates in 2017 are typical of past performance, 2012–2016 (Table 2). Using PIT-tagged subyearling (i.e. 2015-2017) and yearling Chinook (i.e. 2012-2017) salmon, run timing of hatchery and wild fish were examined separately, (Tables 6 & 8). Evaluation of the migrations of the wild components of the Chinook outmigrations in 2017 revealed that the start date for bypass operations at Wells Dam failed to provide bypass operations for ≥95% of the migration of yearling Chinook, while the end date for bypass operations succeeded in providing bypass operations for ≥95% of the migration of subyearling Chinook. Expanding the evaluation of wild Chinook migrants to past years showed that the bypass termination date in use since 2012 was adequate for providing bypass operations for ≥95% of the migration of both hatchery and wild subyearling Chinook. However, the April 9 start date for bypass operations succeeded in providing bypass operations for ≥95% of the migration of wild PIT-tagged yearling Chinook in only 1 of 6 bypass seasons since 2012.

4. Appendix

Using Wells Dam PIT-tag Detections

2017 was the second year with available PIT-tag detections at Wells Dam (WEJ), with 269 unique tag codes identified. These comprised 114 Chinook salmon, 27 Coho salmon, 127 steelhead, and 1 sockeye salmon. As these numbers are too few to estimate any credible survival estimates, Table A1 summarizes the number of detections and estimated travel times between Wells and Rocky Reach Dam. It is hoped that future runs will be detected at higher numbers to enable a more detailed correction to the outmigration distribution estimated for Wells Dam. Results suggest the values in Table 1 are reasonable adjustments for travel time.

Table A1. Travel time summary for detected PIT-tagged fish at both Wells and Rocky Reach PIT-tag detectors in 2017.

			Travel Time (days)	
Run Species	Detected at Wells Dam	Detected at Rocky Reach Dam	Mean (SE)	Range
Yearling Chinook	114	21	6.7 (1.8)	1.3 – 29.0
Coho	27	11	5.4 (0.8)	2.2 - 10.0
Steelhead	127	41	1.9 (0.2)	0.8 - 6.6
Sockeye	1	0		

Appendix B
Habitat Conservation Plan Hatchery Committees 2017 Meeting Minutes and Conference Call Minutes

FINAL

720 Olive Way, Suite 1900
Seattle, Washington 98101
206.287.9130

ANCHOR QEA

Memorandum

To: Wells, Rocky Reach, and Rock Island HCPs Hatchery Committees

Date: February 16, 2017

From: Tracy Hillman, HCP Hatchery Committees Chairman

cc: Sarah Montgomery, Anchor QEA, LLC

Re: Final Minutes of the January 18, 2017, HCP Hatchery Committees Meeting

The Wells, Rocky Reach, and Rock Island Hydroelectric Projects Habitat Conservation Plans (HCPs) Hatchery Committees meeting was held at the Grant PUD office in Wenatchee, Washington, on Wednesday, January 18, 2017, from 9:00 a.m. to 12:30 p.m. Attendees are listed in Attachment A to these meeting minutes.

Action Item Summary

- Sarah Montgomery and Tracy Hillman will renumber the Hatchery Monitoring and Evaluation (M&E) Plan appendices and append them to the Hatchery M&E Plan (Item I-A). *(Note: this item is ongoing.)*
- Sarah Montgomery will add a summary table to the draft summary of the 5-Year Hatchery M&E Review process (Item I-A). *(Note: this item is ongoing.)*
- Keely Murdoch will research who is leading the Columbia River Inter-Tribal Fish Commission's (CRITFC's) parentage-based tagging effort in order to coordinate with Mclain Johnson (Washington Department of Fish and Wildlife [WDFW]) about genetic sampling (Item IV-E). *(Note: this item is ongoing.)*
- Justin Yeager and Brett Farman will discuss internally the Douglas PUD Twisp gamete request and provide National Marine Fisheries Services' (NMFS') vote to the Hatchery Committees (Item II-A). *(Note: Farman provided NMFS approval on January 27, 2017.)*
- Douglas PUD will review WDFW's white paper, "Twisp Steelhead Hatchery Broodstock Issues," which Sarah Montgomery distributed to the Hatchery Committees on January 18, 2017, and provide comments to Mike Tonseth (Item II-B).
- Greg Mackey will coordinate with Chelan and Grant PUDs to develop a statement of agreement (SOA) describing the components in the proposed Hatchery M&E Reporting Timeline, which Sarah Montgomery distributed to the Hatchery Committees on January 13, 2017 (Item IV-C). *(Note: Mackey sent the draft SOA to Montgomery on February 13, 2017, which she distributed to the Hatchery Committees.)*
- Hatchery Committees members will review the Upper Columbia Salmon Recovery Board (UCSRB) Draft Hatchery Report and provide edits and comments to Greer Maier (UCSRB) by

January 31, 2017, and invite Maier to discuss comments in person at an upcoming Hatchery Committees meeting (Item IV-D).

- McLain Johnson will revise the timeline for conducting genetic analysis for HCP program species incorporating suggestions provided during the Hatchery Committees January 18, 2017, meeting (Item IV-E).
- McLain Johnson and WDFW geneticists will perform a power analysis to inform genetic analysis intervals and intensity for HCP program species (Item IV-E).
- Todd Pearsons (Grant PUD) will write a white paper about factors affecting the brood year stray rates of hatchery fish and considerations for revising stray rate targets (Item IV-F). *(Note: Pearsons sent his paper, "Stray Rate Targets for Hatchery Programs" to Sarah Montgomery on February 6, 2017, which she distributed to the Hatchery Committees.)*

Decision Summary

- The Rocky Reach, Rock Island, and Wells Hatchery Committees approved Douglas PUD, Chelan PUD, and WDFW's request for gametes from four female and four male Twisp River hatchery-origin steelhead that WDFW will collect at the Twisp Weir in 2017 for use in pilot studies on egg-to-fry survival, as follows: Douglas PUD, Chelan PUD, WDFW, U.S. Fish and Wildlife Service (USFWS), Yakama Nation (YN), and Colville Confederated Tribes (CCT) approved on January 18, 2017; and NMFS approved via email on January 27, 2017.

Agreements

- The Hatchery Committees agreed they will hold back-to-back meetings with the Priest Rapids Coordinating Committee Hatchery Sub-Committee (PRCC HSC) at Grant PUD's Wenatchee, Washington, office, with the Hatchery Committees meeting from 9 a.m. to as late as 12:30 p.m., unless prevented by lengthy agenda items or logistical constraints. *(Note: this was discussed as a joint item during the PRCC HSC November 17, 2016, meeting.)*

Review Items

- Sarah Montgomery sent an email to the Hatchery Committees on January 18, 2017, notifying them the Chelan PUD 2017 Draft Action Plan is available for review, with comments due to Catherine Willard. *(Note: the hatchery portion of the Chelan PUD 2017 Draft Action Plan will be a decision item at the Hatchery Committees February 15, 2017, meeting.)*

Finalized Documents

- No documents have been finalized recently.

I. Welcome

A. Review Agenda, Review Last Meeting Action Items, and Approve the October 19, 2016, Meeting Minutes (Tracy Hillman)

Tracy Hillman welcomed the Hatchery Committees and asked for any additions or changes to the agenda. The following revisions were requested:

- Mike Tonseth added a discussion about the Twisp steelhead program.
- Tonseth added a joint item regarding the off-ladder adult fish trap (OLAFT) at Priest Rapids Dam.

The Hatchery Committees reviewed the revised draft October 19, 2016 meeting minutes. Sarah Montgomery said there are several outstanding comments to be discussed, which the Hatchery Committees reviewed and addressed. Hatchery Committees representatives present approved the draft October 19, 2016, meeting minutes, as revised.

Action items from the Hatchery Committees meeting on October 19, 2016, and follow-up discussions were addressed *(note: italicized text below corresponds to agenda items from the meeting on October 19, 2016)*:

- *Justin Yeager will check when the Yakama Nation (YN) most recently reviewed the Wenatchee steelhead draft Biological Opinion and provide that date to Keely Murdoch (Item I-A).*
  This item is complete.
- *The U.S. Fish and Wildlife Service (USFWS) will send a letter to the HCP Coordinating Committees describing changes in USFWS representation on the Hatchery Committees (Item II-A).*
  This item is complete. Jim Craig (USFWS) emailed a letter to Tracy Hillman describing this change on October 21, 2016.
- *Sarah Montgomery will assist USFWS in acquiring Hatchery Committees cc: email access for Michael Humling (USFWS; Item II-A).*
  This item is complete. Montgomery added Humling to the Hatchery Committees email cc: distribution list on October 20, 2016.
- *A subgroup led by Catherine Willard will convene to prepare a plan to outplant adult spring Chinook salmon in the Chewuch River (Item II-C).*
  Willard said the subgroup met on January 9, 2017, and the plan will be discussed today.
- *Keely Murdoch will research who is leading the Columbia River Inter-Tribal Fish Commission's (CRITFC) parentage-based tagging effort in order to coordinate with Mclain Johnson about genetic sampling (Item II-D).*
  This item is ongoing.

- *Mclain Johnson (Washington Department of Fish and Wildlife [WDFW]) will revise the timeline for conducting genetic analysis for HCP program species and send it to Sarah Montgomery for distribution to the Hatchery Committees (Item II-D).*
  This item will be discussed today.
- *The Hatchery Committees will review the timeline for conducting genetic analysis for HCP program species and provide additional questions to Johnson (Item II-D).*
  This item is ongoing.
- *Mike Tonseth will ask WDFW geneticists about a technical methodology for deciding analysis intervals (Item II-D).*
  This item will be discussed today.
- *Sarah Montgomery and Tracy Hillman will renumber the Hatchery Monitoring and Evaluation (M&E) Plan appendices and append them to the Hatchery M&E Plan (Item II-E).*
  This item is ongoing.
- *Todd Pearsons (Grant PUD) will distribute the paper by Ford et al. (2015) regarding brood year stray rates to the Hatchery Committees for review (Item II-E).*
  This item is complete. Pearsons sent the paper to Montgomery, which she forwarded to the Hatchery Committees on October 20, 2016, and it will be discussed today.
- *Catherine Willard will add a summary table to the draft summary of the 5-Year Hatchery M&E Review process (Item II-F).*
  This item is ongoing. Sarah Montgomery said she is working on it.
- *Craig Busack will discuss proportion of hatchery-origin spawners (pHOS) targets for Methow steelhead with Amilee Wilson (National Marine Fisheries Service [NMFS]), and follow up with the Hatchery Committees by October 21, 2016 (Item III-A).*
  This item is complete. Busack emailed Hatchery Committees representatives on October 21, 2016, stating the consultation has been transferred to Charlene Hurst (NMFS alternate), and Hurst and Busack will further discuss pHOS targets.
- *Sarah Montgomery will provide the WebEx phone number on the agenda for future Hatchery Committees meetings (Item V-B).*
  This item is complete. Montgomery added the WebEx phone number to the January 18, 2017, agenda.

II. Douglas PUD

A. Decision: Twisp Hatchery-origin Steelhead Gametes (Tom Kahler)

Tom Kahler shared a document titled, "Estimating steelhead egg-to-fry survival in the Twisp River: 2017 pilot study," which Sarah Montgomery distributed to the Hatchery Committees on January 6, 2017 (Attachment B). Kahler said Douglas PUD requests gametes from three female and three male Twisp hatchery-origin steelhead, which are surplus to broodstock and escapement needs, that WDFW will collect at the Twisp weir in spring 2017 for use in the egg-to-fry survival study. Mike Tonseth asked when the fish would be collected and where they would be held. Kahler said he does not have a definitive answer because Douglas PUD wants to get approval from the Hatchery Committees before working through logistics, but the tentative plan is to collect fish at the Twisp weir and hold them at Methow Fish Hatchery. Tonseth said WDFW and Chelan PUD are also working on a steelhead egg-to-fry survival study. Because there are no surplus adult steelhead in the Wenatchee River, WDFW and Chelan PUD are interested in sourcing eggs from another location and noted that no surplus adults are available at Wells Dam or other programs due to spawn timing. Tonseth asked what Douglas PUD plans to do with the balance of gametes that are not needed for the study, and said there is potential for WDFW and Chelan PUD to use the extra gametes. Kahler said the extra gametes would be disposed of, or Douglas PUD may consider egg-planting above an anadromous barrier. Tonseth asked to increase the gamete request to include collecting four female and four male Twisp hatchery-origin steelhead, so WDFW and Chelan PUD can utilize the unused gametes from the Douglas PUD study in their own study, which requires gametes from four female and four male steelhead. He said there would be extra gametes from the Douglas PUD study, which only requires 1,500 eggs, and collection of four female and four male steelhead. Doing this would meet requirements for both studies without targeting a separate collection location for the Chelan PUD study. Catherine Willard added that the spawn timing for steelhead in the Chelan River is late March to early April, and Kahler said steelhead spawn around April in the Twisp River. Greg Mackey said that WDFW could collect the two extra fish, assuming there are enough surplus hatchery-origin steelhead present.

Bill Gale asked if there will certainly be enough hatchery-origin steelhead at the Twisp weir to supply this request in addition to broodstock and pHOS needs. Gale also asked how this gamete request relates to the next discussion (Item II-B) regarding Twisp steelhead program broodstock issues. Tonseth said he thinks there will be enough hatchery-origin steelhead at the weir to meet all program needs plus this surplus gamete request. He said part of the discussion regarding Twisp steelhead program broodstock issues involves potentially reducing the pHOS target in the Twisp River from 0.5 to 0.3, which would make more hatchery steelhead available for surplus. Willard said Chelan PUD supports Tonseth's idea of coordinating the studies and adding two additional hatchery-origin steelhead (one female and one male) to the gamete request.

Justin Yeager asked if this gamete request would change any permitting that has been completed to date. Tonseth replied that it would not. Tonseth also clarified that for egg-to-fry survival studies, no progeny are released into the system; the eggs are put into boxes in gravel, and the boxes with fry are later removed.

Gale said a potential impact to bull trout is that the location of the boxes may overlap with bull trout redds. Mackey agreed that there is potential for overlap with bull trout spawning areas, but the chance is low because the boxes will be placed in the gravel in the Twisp River in the spring.

Tracy Hillman summarized that the gamete request is now for four females and four males, and the Wells Hatchery Committee is voting on the collection of gametes for use in Douglas PUD's egg-to-fry survival 2017 pilot study, and WDFW and Chelan PUD's related egg-to-fry survival study. Douglas PUD, WDFW, and the CCT voted yes. Keely Murdoch emphasized that the steelhead collected must be excess fish, and priority must be given to spawning, and YN voted yes. Gale emphasized that any potential issues with bull trout and permitting should be considered before the study is undertaken, and USFWS voted yes. Yeager said he and Brett Farman will discuss this internally and provide NMFS' vote via email. *(Note: Farman communicated NMFS' approval on January 27, 2017.)*

B. Twisp Steelhead Program Broodstock Issues

Mike Tonseth shared a document titled, "Twisp steelhead hatchery broodstock issues," which Sarah Montgomery distributed to the Hatchery Committees on January 18, 2017 (Attachment C). Tonseth said there is increasing concern about negative genetic effects to the Twisp River steelhead population due to continued operation of the Twisp River steelhead program. He said the current target number of Twisp River wild broodstock is small and, according to geneticists (Todd Seamons, WDFW), continued operation of the program will likely decrease the effective population size (Ne), termed a Ryman-Laikre effect, which has unacceptable long-term genetic risks. He said the Hatchery Committees should consider restructuring management of the Twisp River steelhead program and population. Currently, the population is being managed as a separate spawning aggregate, and the Twisp River is being used as a test basin to evaluate steelhead reproductive success, a wild-by-wild conservation approach, and pHOS management (currently 0.50), all possible because of the Twisp Weir and Twisp Acclimation Pond, as well as the intensive M&E performed in this river. He asked the Hatchery Committees to consider continuing to collect natural-origin adult steelhead at the Twisp Weir, which would be utilized in a USFWS Methow basin program (as opposed to a dedicated Twisp program), and the existing Douglas PUD Twisp program (48,000 steelhead) would be converted to a safety net program and targeted for release in the lower Methow River. He said continued releases of juvenile steelhead in the Twisp River are desired, but could come from a composite group from Winthrop National Fish Hatchery (NFH) which would increase and diversify the number of spawners used to produce juveniles for release. He said there are a lot of changes to discuss, but the most immediate issue for spring 2017 is reducing the Twisp hatchery pHOS escapement target from 0.5 to 0.3. He said WDFW has suggestions outlined in Attachment C for real-time genetic analysis that could be implemented in future years in order to increase the number of families represented in the Twisp River, but the focus for 2017 should be on increasing the effective population size by incorporating juveniles from Winthrop NFH's smolt program.

Tonseth said the broodstock collection numbers identified in the 2016 Broodstock Collection Protocols should still be targeted, but the fish would be transferred to Winthop NFH, and juveniles would be released in the lower Methow River. Greg Mackey suggested Tonseth coordinate with Todd Seamons (WDFW), Craig Busack, and Charlene Hurst to determine the potential genetic effects of these proposed changes. Mackey recalled that the Twisp River population is managed as a separate spawning aggregate because it has weak genetic differentiation from other populations. Mackey said the Twisp program may further exacerbate genetic drift by removing hatchery adult steelhead (without being able to know their familial origins), and the Hatchery Committees should consider a better program design and how Douglas PUD's mitigation requirements fit into the program design. He said Douglas PUD is required to provide 8,000 steelhead as No Net Impact (NNI) mitigation, which is the conservation core of the Twisp program, and the rest of the steelhead released satisfy inundation mitigation requirements. He said the inundation mitigation requirement may be more appropriately managed as a safety net or harvest program. Tonseth summarized that changing the Twisp program will require a lot of coordination and discussion over time, but the first items to settle are broodstock collection and 2017 releases, and WDFW proposes to join the Twisp and Winthrop steelhead programs with releases into the Twisp River and the Methow River. Keely Murdoch said truck planting can also be considered for those releases. Tonseth said truck planting is a good idea because it works well for steelhead and because acclimation and release location affect the distribution of fish (i.e., truck planting would result in wider distribution). Tonseth indicated that the JFP were considering release at Buttermilk Bridge, which is upstream of the Twisp Acclimation Pond, in order to encourage spatial distribution of hatchery origin spawners further upstream. Mackey added that evaluating the appropriate release number of steelhead should be a component of these discussions as well, in order to make the best use possible of wild broodstock.

Tonseth said the distribution of steelhead in the Twisp River and Methow River can be evaluated using passive integrated transponder (PIT) tags, and an analysis of releases in the lower Methow River over a 2- to 3-year period could inform the future of releases in the Methow basin, such as if some releases need to be moved out-of-basin. Mackey added that radical shifts in program implementation could affect permitting, and NMFS should definitely be involved in these discussions. Mackey said Douglas PUD will review WDFW's white paper, "Twisp Steelhead Hatchery Broodstock Issues" (Attachment C) and provide feedback to Tonseth.

Tracy Hillman mentioned the results from Mackey's steelhead proportionate natural influence (PNI) modeling work (discussed during the Hatchery Committees October 19, 2016 meeting) which members, especially the YN, questioned regarding the use of a pHOS of 0.3. Murdoch said YN had agreed to a pHOS of 0.5 and does not want to agree to anything more restrictive than they already have. In reference to Mike Tonseth's statement that pHOS would be adjusted from 0.50 to 0.30, Keely Murdoch stated that this was not discussed by the JFP. She said, based on past conversations, YN supports the concept of taking Twisp River natural-origin returns to Winthrop NFH as long as the progeny are released back into the Twisp River. Tonseth clarified that the desire to reduce pHOS from 0.5 to 0.3 starting in 2017 is because there was a collapse of the 1-salt return, and because the population is already small; during the next 2 years they would only be able to collect adults from one age class if the program were not mixed with the Winthrop program. He said WDFW is not advocating for changing pHOS targets for the entire basin, but for a short-term reduction in order to prevent impacts to the Twisp River steelhead effective population size.

Bill Gale said the Winthrop program obligations come from production tables in U.S. v. Oregon[1], and are a sliding goal from 100,000 to 200,000 steelhead. He said USFWS has been able to meet the 200,000 goal when broodstock is available. He said the Winthrop program is also 100% adipose (ad)-clipped, and the Twisp program is not; this may initiate a discussion about steelhead marking in the Methow and Okanogan basins, but is important to consider. Murdoch said it is concerning that the progeny of natural-origin broodstock are ad-clipped in the Winthrop program. Tonseth said there is a lot to consider regarding the Twisp steelhead program, and this can be a topic at the next Hatchery Committees meeting on February 15, 2017.

III.Chelan PUD

A. Chelan Falls Broodstock Collection: Canal Trap Pilot Results

Catherine Willard shared a document titled, "Pilot Concept to Trap Summer-Run Chinook Salmon at the Chelan River Habitat Channel Water Conveyance Canal Outlet: Results," which

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[1] 2008-2017 *United States v. Oregon* Management Agreement. May 2008. Available: http://www.westcoast.fisheries.noaa.gov/publications/fishery_management/salmon_steelhead/sr--079.2008-2017.usvor.management.agreement_042908.pdf

Sarah Montgomery distributed to the Hatchery Committees on January 18, 2017 (Attachment D). Willard said the Chelan Falls Canal Trap (CFCT) pilot study was successful in collecting 100 summer Chinook salmon for Chelan Falls broodstock. She said trapping occurred from August 4 to August 10, 2016, and during operation of the CFCT, 51 males and 49 females were collected. She said four fish died while being held at Eastbank Hatchery, resulting in 49 males and 47 females being spawned. She said Chelan PUD evaluated the potential effects of high water temperature on gamete quality because the warm water temperatures of the Chelan River have the potential to affect gamete quality of fish collected at the CFCT. She said gametes from CFCT fish were kept separate from Eastbank Outfall (EBO) and Entiat National Fish Hatchery (ENFH) fish, and eye-up rates were similar for the groups of fish, with CFCT fish having a slightly higher eye-up rate (93% compared to 91%). She said no bull trout were encountered, and Chelan PUD plans to continue the pilot study in 2017. She said in 2017, Chelan PUD intends to start collecting broodstock at the CFCT in July, earlier than in 2016, in order to collect fish throughout the summer Chinook salmon run. She said Chelan PUD intends to use ENFH as the backup broodstock collection location, and does not plan to collect summer Chinook salmon broodstock at EBO due to safety issues. Bill Gale said Chelan PUD and USFWS can discuss using ENFH as the backup broodstock collection location closer to collection time.

Mike Tonseth said the CFCT pilot also included assessing disease profiles for collected female summer Chinook salmon using enzyme-linked immunosorbent assays (ELISA). He asked if any females from the CFCT, EBO, or ENFH had high ELISA values. Willard said there were no females with high ELISA values.

B. Chelan PUD 2017 HCP Action Plan (Catherine Willard)

Catherine Willard shared a spreadsheet titled, "Draft 2017 Rock Island and Rocky Reach HCP Action Plan," which Montgomery distributed to the Hatchery Committees on January 18, 2017 (Attachment E). She said the action plan includes typical items such as the annual Hatchery M&E Report, annual Implementation Plan, broodstock collection, and hatchery releases, as well as pilot studies (Chelan Falls Broodstock Collection and Outplanting Adult MetComp in the Chewuch River), ongoing water quality monitoring at Dryden Acclimation Facility, working on coho salmon NNI mitigation, and permitting activities. She said the draft 2017 Rock Island and Rocky Reach HCP Action Plan is available for review, and will be a decision item at the February 15, 2017, Hatchery Committees meeting.

IV. Joint HCP-HC/PRCC HSC

A. USFWS Bull Trout Consultation Update (Bill Gale)

Bill Gale said Karl Halupka (USFWS) sent him an update on USFWS consultations, which he summarized:

- The memorandum describing Halupka's gap analysis and the strategy to rely on the 2012 Wells Relicensing Bull Trout Biological Opinion (BiOp) for coverage for the Methow spring Chinook salmon program has been approved internally and will be transmitted soon.
- Regarding the Okanogan program consultation, USFWS is working on a letter of concurrence for the Tribal Resources Management Plan (TRMP), which will be reviewed internally soon.
- Regarding the draft BiOp covering hatchery programs in the Wenatchee basin, USFWS is waiting for comments on the revised draft from Chelan PUD and WDFW.

B. NMFS Consultation Update (Justin Yeager)

Regarding the Methow spring Chinook salmon consultation, Justin Yeager said Charlene Hurst distributed draft permits to the applicants for final review, and NMFS expects edits and comments by January 19, 2017. He said regarding the Okanogan steelhead TRMP, the TRMP was available for public comment through the end of December 2016, and NMFS is currently reviewing and addressing comments.

C. M&E Report Scheduling (Greg Mackey/Catherine Willard)

Greg Mackey shared a presentation titled, "Hatchery M&E Reporting: Synching to Required Milestones," which Montgomery distributed to the Hatchery Committees on January 13, 2017 (Attachment F). Mackey said the goal of this discussion is to determine a logical reporting schedule that meets Chelan and Douglas PUD's HCP and Grant PUD's Aquatic Settlement Agreement (ASA) requirements. He summarized the HCP requirements for survival studies, recalculation, updating the M&E Plan, performing a Program Review, and Section 10 permitting. He said the proposed timeline (slide 6) includes survival studies (next in 2023), updating the M&E Plan (next in 2018), and Program Review (next in 2020), as well as other milestones. He said performing the Program Review in 2020 makes sense so it is coordinated with recalculation and M&E plan updates and reports. He said the 5-year M&E Report is not an HCP requirement, but is stipulated in the M&E Plan, and the M&E Plan does not stipulate a 10-year Report/Program Review, but the HCPs do. He said the focus/content of the reports may change as well. He said the PUDs are envisioning the annual M&E reports will contain the data collected that year with summary statistics plus cumulative data, and note any exceptions to field methods and the M&E plan. He said the 5-year Report/Statistical Report would include the results of statistical analyses of each M&E objective with an explanation of the assumptions of the analyses, but with limited interpretation of the analyses. This would allow managers to assess the program and identify any red flags but would make the report shorter and more concise. He said the 10-year Report/Program Review would be a much larger report that would include the type of analyses done in the 5-year cycles with additional analyses as warranted, integrated with regional findings for better context. Chapters in the Program Review would be written in scientific manuscript style to provide a high level of scientific rigor and concise writing in order to enhance interpretation of results and promote the possibility of publishing some of the work. He said the Program Review will be used as part of the adaptive management process and would inform recalculation (slide 3 Mackey said the format and function of each report still needs to be determined and finalized, but agreeing on the timeline for the reports is the first step.

Mike Tonseth asked if the PUDs had considered doing 10-year reports for each species, staggered by different years. Mackey said that was considered, and they also considered organizing the report by basins (e.g., Wenatchee, Methow, Okanogan) to put things into regional context, and then by species. Gale asked if a repeating Hatchery Scientific Review Group (HSRG) review should be included in the proposed timeline. Alene Underwood said the purposes of these reports are to answer questions in the M&E plan within the HCP framework. Tonseth said HSRG reports are more holistic compared to M&E reports. Todd Pearsons agreed and said M&E reports have more specificity about programs and data. Mackey said, after this discussion regarding the timeline, the PUDs can write a description of the components of each report. Underwood suggested writing an SOA so the decision to adopt a new reporting schedule is easily accessible. Tom Kahler summarized that the 10-year Program Review is an HCP requirement, the 5-year Statistical Report is an M&E Plan requirement, and the M&E Plan itself is a requirement of permitting, so any SOA regarding this material should speak only to the reporting timeline and not the pieces in the timeline. Gale asked if the HCP and M&E Plan requirements for Chelan PUD and Douglas PUD are similar to Grant PUD's ASA requirements. Pearsons said it is similar. Mackey said he will coordinate with Chelan and Grant PUDs to develop an SOA describing the components in the proposed Hatchery M&E Reporting Timeline.

D. UCSRB Hatchery Report – Review Period Extension (Tracy Hillman)

Tracy Hillman said the UCSRB's Draft Hatchery Report was distributed to members of the Hatchery Committees for review by Greer Maier. He said Maier agreed to extend the review period and requests comments back to her by January 31, 2017, but the deadline may be flexible. Alene Underwood said Chelan PUD has many comments and will try to respond by January 31, but might need more time. Hillman said after the UCSRB reviews the comments from members of the Hatchery Committees, he will invite Maier to a Hatchery Committees meeting to discuss the comments. *(Note that the UCSRB Draft Hatchery Report was not provided to the Hatchery Committees* *as an official document for review and approval; therefore, it is not listed under Review Items and is not posted to the HCP Hatchery Committees Extranet Site.)*

E. Genetic Analysis for HCP Program Species (McLain Johnson)

McLain Johnson shared a document titled, "Draft Genetic Sampling Timeline," which Sarah Montgomery distributed to the Hatchery Committees on January 18, 2017 (Attachment G). He said he revised the timeline to show analysis needs, the projected year of analysis, and requirements for M&E Plan reporting. He said he and Todd Seamons are still trying to find samples for fall Chinook salmon in the Hanford reach so the stock can be added to the timeline. He said he is still working with Keely Murdoch and CRITFC to acquire more samples for analysis from the Priest Rapids stock. He said WDFW and CRITFC have a growing and positive relationship, which will help in coordinating these genetic analyses. He said developing single nucleotide polymorphism (SNP) panels for analysis incurs an upfront cost and exploratory work, but analyzing a sample using SNPs is relatively inexpensive once a panel has been developed. Many SNPs for these stocks are already established. He said CRITFC, for example, has been doing genetic work related to Lake Cle Elum and can differentiate between Okanagan and Wenatchee sockeye salmon. Tom Kahler added that University of British Columbia researchers have also been working on Okanagan sockeye salmon SNP panels, and similarly, researchers at the Department of Fisheries and Oceans (Canada) have a microsatellite panel for Okanagan sockeye salmon.

Johnson said samples for most of these analyses are collected annually, and the WDFW genetics lab recommends performing analyses on 2 years of samples to increase the robustness of the sample dataset. Mike Tonseth added that the Hatchery Committees still need to discuss whether to vary analysis intervals based on listing status or another factor, and whether to synch analysis years for species. Mackey said genetic analyses should be completed for all populations of the same species in the same year. He said, during the last discussion about this, Todd Pearsons mentioned that a power analysis could determine how large of a genetic change could be detected in a population and how rapid it may occur, which could ultimately inform analysis intervals; populations at risk or with genetic structure that could change a lot or change quickly could be analyzed more frequently (e.g., small populations). Tonseth said Twisp steelhead are an example of a population where genetic change was detected after a few years of genetic analysis, and the population is at risk due to a low effective population size. Pearsons said a power analysis could also be based on the size of programs compared to the size of their receiving natural population; one would expect to see genetic differences occur more quickly in small populations.

Johnson said, historically, samples were analyzed using microsatellite panels, and samples can be reanalyzed with SNP panels. Tonseth said a baseline period for each program needs to be determined, because hatchery programs change over time especially in regards to broodstock. For example, he said the Wenatchee steelhead program started in 1989 using stock from Wells Fish Hatchery, and transitioned to locally adapted broodstock in 1998, so the baseline could be set at 1998. This needs to be discussed and agreed to for each program and can determine whether old samples need to be reanalyzed with SNP panels.

Todd Seamons joined the meeting via phone, and asked about the purpose of genetic monitoring for HCP program species. Catherine Willard said the purpose, as described in the M&E Plan for PUD Hatchery Programs, is to determine if genetic diversity, population structure, and effective population size have changed in natural spawning populations as a result of the hatchery program. Seamons asked what the consequences are to hatchery operations if genetics are found to be changing. Tonseth said it could change the program, for example, a program might have to be segregated rather than integrated. Seamons said analysis intervals can be determined by how much change is acceptable before the genetics "problem" is identified and addressed. He said, after one generation, changes are unlikely to be identified; after two generations, there may be an identifiable trend; and after three generations (likely longer than 10 years), the problem is likely identifiable but at this point, the problem has been compounding for three generations and will be harder to fix. Pearsons said the acceptable risk of genetic change, and therefore the time between analysis intervals, is partially determined by how at-risk the population is. He said a small program might warrant more frequent analysis than a large program because a small program has greater potential for rapid and substantial genetic change—a power analysis can help determine the potential for effects and level of change for each program. Seamons used the Twisp steelhead program as an example of intensive sampling (due to the relative reproductive success study), where a problem has been identified with analysis intervals capturing only one generation (due to the fact that a parentage study has been underway for eight years), a problem which may not have been detected using the diversity statistics other programs use at broader time intervals. The opportunity to address problems after only one generation comes from a different (more intense) level of analysis.

Bill Gale said the USFWS is interested in synching sampling and analysis intervals with the HCP program species timeline. He said the spring Chinook salmon safety-net program at Winthrop NFH could be synched with the Methow spring Chinook salmon analysis. For steelhead, safety-net releases from the Methow Fish Hatchery could also be included in these analyses. USFWS collects summer Chinook salmon in the Entiat River, which could be coordinated with the HCP program analyses. He said the timeline can be modified to include USFWS sampling and analysis, and USFWS can perform analyses at Abernathy Fish Technology Center, or help fund analyses. Seamons said the WDFW genetics lab and Abernathy Fish Technology Center work together frequently, and coordinating those analyses would not be a problem. Gale said he would send a report about genetic analysis of summer Chinook salmon in the Entiat River to Johnson. (*Note: Montgomery distributed the USFWS report, "Summer Chinook Salmon in the Entiat River: Genetic Analysis of*

Hatchery and Natural Origin Adults Spawning in the Wild" to the Hatchery Committees on January 18, 2017.)

Hillman summarized the Hatchery Committees feedback for Johnson regarding the Draft Genetic Sampling Timeline and discussions regarding genetic sampling intervals for HCP program species: 1) perform genetic analyses for all stocks of spring Chinook salmon in the same year (i.e. 2018); 2) add USFWS programs to the timeline; 3) work with the WDFW genetics lab on a power analysis to determine recommended analysis frequency; and 4) determine a baseline period for each analysis.

Seamons said he and the WDFW genetics lab are very busy, but could likely work with Johnson to perform the power analysis in the next 6 months. Mackey asked if there are any new genetic techniques that might replace using SNP panels. Seamons said he does not imagine that anything would replace the use of SNP panels. He said the way SNP genotypes are obtained or the analysis methods could change, but an entirely different marker type being developed is unlikely at this point. Mackey mentioned Hatchery Committees parties are considering reanalyzing older samples with SNP panels that were initially analyzed with microsatellite panels, but if another technique were on the horizon, it would affect that decision. Seamons said detection power is affected by the number of markers used in the analysis, and more and more markers are being developed. For example, a sample could be reanalyzed with a SNP panel with 296 markers (e.g., CRITFC's steelhead panel), but if more markers are added to the panel for a total of 500 markers, the sample could be reanalyzed again with increased statistical power. He said parties should consider whether the benefit of added statistical power is worth the cost. He said WDFW intends to have SNP panels with many markers, and use the same panels as CRITFC, which also adds loci regularly to their panels.

F. Stray Rate Targets (Todd Pearsons)

Todd Pearsons shared a presentation titled, "Stray Rate Targets," which Sarah Montgomery distributed to the Hatchery Committees on January 18, 2017, following the meeting (Attachment H). He said he also distributed a paper by Ford et al. (2015)[2] after the Hatchery Committees last discussed stray rates in October 2016, which Montgomery distributed to the Hatchery Committees on October 20, 2016. He said this discussion focuses on the 5% brood year stray rate target (Question 6.1.1 in the Hatchery M&E Plan), and he has been trying to determine the origin of the target but has not received an explicit answer about how the 5% target was determined even after

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[2] Ford, M.J., A. Murdoch, and M. Hughes, 2015. Using parentage analysis to estimate rates of straying and homing in Chinook salmon (*Oncorhynchus tshawytscha*). Molecular Ecology 24, 1109-1121. Doi: 10.1111/mec.13091

querying a number of scientists that were involved in the fundamental development of recovery plan guidelines. Monitoring Question 6.1.1 of the M&E Plan is: "Is the stray rate of hatchery fish less than 5% for the total brood return?" Pearsons said if natural stray rates are determined to be higher than 5%, it would be unexpected for hatchery-origin fish in the same basin to meet the 5% target; hence, natural stray rates can be used to inform targets.

He summarized many factors that can influence straying such as: imprinting quality; origin (hatchery vs. natural); species, stock or tributary; spawning habitat quality; access, including temperature, flow, and barriers; spawning density; dendricity; and geography. He said only some of these factors are affected by or under the control of hatchery programs. He said Ford et al. estimated natural-origin stray rates for the Chiwawa River, Little Wenatchee River, Nason Creek, the White River, and the Upper Wenatchee River, some of which exceeded 5% and approached 100% in one case. He said Ford et al. demonstrated that stray rates of natural origin fish are higher than previously thought (especially in the Little Wenatchee and Upper Wenatchee rivers), stray rates vary by tributary and generation/origin, and non-hatchery factors influence stray rates (e.g. tributary, habitat). Pearsons said, for example, the upper Wenatchee River does not have high-quality habitat, so it would make sense that stray rates are higher in that location.

Pearsons said imprinting is just one of many factors affecting stray rates. He said the hatchery experience appears to affect fish even when they are imprinted in the natural environment, and some factors are outside the purview of programs. He said he thinks the brood-year stray rate target for spring Chinook salmon is unrealistically low. He said data suggesting salmon imprinted in natural environments have varying stray rates that can be above 5% are not unique—an old study in California showed coho stray rates far exceeding 5% (cf. Quinn 2005[3]).

Pearsons identified one possible target refinement as adding together the possible sources of stray rates (i.e., the stray rate of natural origin fish from hatchery parentage + a stray rate addition as a result of the hatchery experience + a stray rate addition from poor habitat, high density, and other non-imprinting factors). He said fish are not controlled in their selection of a spawning site solely by imprinting, so targets related to the distribution of fish spawning should be realistic and consider the other factors affecting where a fish decides to spawn.

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[3] Quinn, Thomas P. *The Behavior and Ecology of Pacific Salmon and Trout*. American Fisheries Society, Bethesda (Maryland), in association with University of Washington Press, Seattle (Washington), 2005.

Tracy Hillman said he discussed this with Michelle McClure (NMFS) and she provided the following thoughts:

- The Technical Recovery Team (TRT) used some expert opinion in the selection of the 5% and 10% stray rate targets. (Note: the 5% and 10% stray rates apply to the recipient spawning aggregates.) The basic idea was to have the numbers in the flow chart/graph combo be congruent with the previous criterion for genetic integrity. In other words, how much introgression from non-evolutionarily significant unit (ESU) fish would produce impairment to the natural genetic structure of the population? Ultimately, disrupting population structure affects extinction risk, but not quite in the quantifiable way that abundance and productivity can.

She also added the following thoughts:

1. The TRT criteria cannot be formally changed at this point without (probably) a committee forming to review new information.
2. That said, the TRT was very explicit that things should be considered on a case-by-case basis, and the addition of new empirical information would certainly be a factor that should go into that case-by-case consideration. This is part of the reason why guidelines were provided with many disclaimers about making informed judgments based on the situation at hand; the TRT knew that there would be more information, situations would change, and so forth.
3. One word of caution, though, for the Upper Columbia, is that the genetic stock structure of the entire basin is incredibly altered (and basically homogeneous). To the extent that natal fidelity is genetically influenced (and we know that it has some elements of genetic influence and a good deal of environmental), the straying we're seeing empirically might be a result of previous anthropogenic activities (like mixing them all up).
4. It would be important to also include in the review of new empirical information other studies since the TRT guidelines on straying. She recalled one study on the Olympic peninsula, where researchers found that spawners were more closely related to individuals within a 50-yard radius (approximate distance) of their redd than individuals outside that area.

Pearsons said TRT criteria are unlikely to be changed without an entire committee forming to review new information, but empirical information should be a factor in a case-by-case assessment for PUD programs (particularly related to a BY stray target). He said, for the upper Columbia basin, the contemporary genetic stock structure is unnatural, and because natal fidelity is genetically influenced, stray rates could be a result of anthropogenic activities. He said there is flexibility in the case-by-case basis, but that might be decided by the National Oceanic and Atmospheric Administration, especially if the recovery plan needs to be modified or if they need to write a letter describing the different stray rates and supporting data. Casey Baldwin (CCT) pointed out that the spatial aspect of stray rates needs to be considered and identified up-front. He said the initial criteria in the M&E Plan is straying between populations, and Pearsons' example using the Wenatchee basin is a within-population stray, and it is important to consider if strays are from outside the ESU. He said it should be identified whether the stray rate is for within-population strays, between-population strays, or out-of-ESU strays. Hillman asked if the TRT developed criteria for brood year return. Baldwin said the TRT did not have a set criteria for brood-year stray rates (Question 6.1.1). He said what matters more than brood year return is the spawner composition—the sum of strays to a population, not just the sum of strays from one program in the receiving population. Pearsons said he wants to focus this discussion on brood year stray rates. Hillman said brood year stray rate targets and Question 6.1.1 have implications for Questions 6.1.2 and 6.1.3. Pearsons said, if there are many issues in addition to imprinting, a 5% target will probably not be met in some cases no matter how much the program is shifted and tweaked. Baldwin suggested that weighting natural-origin stray rates based on abundance of natural origin fish could decrease stray rates in each spawning aggregate.

Tonseth requested that Pearsons write a white paper about factors affecting the brood year stray rates of hatchery fish, and considerations for revising stray rate targets. Pearsons agreed and asked the representatives present to please contact him if they find any information on the sources of the brood year stray rate targets set in the M&E Plan.

G. Spring Chinook Salmon Outplanting in the Chewuch River (Catherine Willard/All)

Catherine Willard said a subgroup of Hatchery Committees members met on January 9, 2017, and made progress on a plan for outplanting adult spring Chinook salmon (MetComp) in the Chewuch River. She said several data gaps were identified, and participants are working on follow-up tasks. Willard said this will be discussed in more detail at the February 15, 2017, Hatchery Committees meeting.

H. Expanded Sampling at the OLAFT (Mike Tonseth)

Mike Tonseth said he plans to discuss expanded sampling at the OLAFT at Priest Rapids Dam with the Hatchery Committees at the February 15, 2017, meeting, and will follow up with an email describing the sampling before the next meeting.

V. HCP Administration

A. Representative Changes and Distribution Lists (Tracy Hillman)

Tracy Hillman welcomed Brett Farman (NMFS representative) and Casey Baldwin (CCT alternate) to the Hatchery Committees, and said Charlene Hurst has also been designated as the NMFS alternate.

Hillman said these changes in representation are described in letters distributed by Sarah Montgomery on December 23, 2016 (for Baldwin), and January 6, 2017 (for Farman and Hurst).

Hillman reminded the Hatchery Committees that HCP Parties designate representatives and alternates as they see fit, with no approval required from the Coordinating or Hatchery Committees. Representatives and alternates are automatically provided access to email distribution lists and the HCP Extranet Site. Hillman reminded the Hatchery Committees that Coordinating Committees review and approval is, however, required to provide non-HCP representatives/alternates access to HCP Extranet Sites and email distribution lists.

B. Letters to HCP Non-Signatories (Tracy Hillman)

Tracy Hillman said the HCP Coordinating Committees Chairperson (currently John Ferguson) sends a letter each year on behalf of the Parties to the Wells, Rocky Reach, and Rock Island HCPs to the HCP Non-signatory parties (American Rivers and the Confederated Tribes of the Umatilla Indian Reservation) offering to meet, discuss progress, and answer questions. Hillman said Ferguson sent the letters on January 4, 2017, and if a positive response is received, Hillman and Ferguson will set up a workshop that includes representatives from the Coordinating, Hatchery, and Tributary committees.

C. Back-to-back Meetings with the PRCC HSC (Sarah Montgomery)

Sarah Montgomery summarized that the Hatchery Committees discussed back-to-back meetings with the PRCC HSC as a joint item during the PRCC HSC November 17, 2016, meeting. Hatchery Committees representatives present agreed that they will hold back-to-back meetings with the PRCC HSC at Grant PUD's Wenatchee, Washington, office, with the HCP Hatchery Committees meeting from 9 a.m. to as late as 12:30 p.m., unless prevented by lengthy agenda items or logistical constraints. Montgomery said that agreement is summarized in these meeting minutes for clarity.

D. Next Meetings

The next Hatchery Committees meetings are February 15, 2017 (Grant PUD), March 15, 2017 (Grant PUD), and April 19, 2017 (Grant PUD).

VI. List of Attachments

Attachment A	List of Attendees
Attachment B	Estimating steelhead egg-to-fry survival in the Twisp River: 2017 pilot study
Attachment C	Twisp steelhead hatchery broodstock issues
Attachment D	Pilot Concept to Trap Summer-Run Chinook Salmon at the Chelan River Habitat Channel Water Conveyance Canal Outlet: Results

Attachment E	Draft 2017 Rock Island and Rocky Reach HCP Action Plan
Attachment F	Hatchery M&E Reporting: Synching to Required Milestones
Attachment G	Draft Genetic Sampling Timeline
Attachment H	Stray Rate Targets

Attachment A
List of Attendees

Name	Organization
Tracy Hillman	BioAnalysts, Inc.
Sarah Montgomery	Anchor QEA, LLC
Catherine Willard*	Chelan PUD
Alene Underwood*†	Chelan PUD
Tom Kahler*	Douglas PUD
Greg Mackey*	Douglas PUD
Todd Pearsons†‡	Grant PUD
Peter Graf†‡	Grant PUD
Deanne Pavlik-Kunkel†‡	Grant PUD
Bill Gale*	U.S. Fish and Wildlife Service
Matt Cooper*†	U.S. Fish and Wildlife Service
Michael Humling†	U.S. Fish and Wildlife Service
Justin Yeager*†	National Marine Fisheries Service
Brett Farman*†	National Marine Fisheries Service
Mike Tonseth*	Washington Department of Fish and Wildlife
McLain Johnson	Washington Department of Fish and Wildlife
Todd Seamons†[0]	Washington Department of Fish and Wildlife
Charlie Snow†	Washington Department of Fish and Wildlife
Keely Murdoch*	Yakama Nation
Casey Baldwin*†	Colville Confederated Tribes

Notes:
* Denotes Hatchery Committees member or alternate (note that Justin Yeager is the outgoing NMFS representative, and Brett Farman is the NMFS representative as of February 1, 2017)
† Joined by phone
‡ Joined for the joint HCP-HC/PRCC HSC discussion
[0] Joined for the Genetic Analysis for HCP Program Species discussion

Estimating steelhead egg-to-fry survival in the Twisp River: 2017 pilot study

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Summary

We propose to monitor in-situ steelhead egg-to-fry survival at 12 locations in the Twisp River using gametes from hatchery steelhead and using methods similar to what have been used for spring Chinook salmon in the Twisp and other rivers. The overall goal is to provide estimates of egg-to-fry survival within the Twisp River throughout the range of steelhead spawning, complementing studies being done on other steelhead life stages. In addition, we will examine how survival varies across habitat conditions (location, fine sediment, scour, substrate size) at different locations. The methods will include the construction of three artificial redds at each location, constructing redds of uniform size and dimension, collection of gametes from hatchery fish, placing 100 fertilized eggs in modified Whitlock-Vibert boxes with native spawning gravel (from site), placing egg boxes in constructed redds, burying them, and recovering the boxes and fry after predicted hatching and emergence. The modified Whitlock-Vibert boxes prevent fry from escaping and all alevins of fry will be destroyed on completion of the study. **To conduct the study, we are requesting gametes from three female and three male Twisp River hatchery steelhead from the Methow Hatchery.**

Background

Survival from spawning to parr-stage is thought to limit many salmon (*Oncorhynchus sp*p.) and steelhead (*O. mykiss*) populations particularly those in the interior Columbia River basin (Johnson et al. 2012; Roni et al. 2016). Unfortunately, most of the modeling efforts that point to egg-to-fry survival as limiting factor have used data from laboratory studies or data from a handful of natural redds (e.g., Karieva et al.

2000; Honea et al. 2009; Roni et al. 2016). Egg-to-fry survival in particular is thought to be a critical life stage and only recently have large-studies been conducted to examine the variation in survival in the natural environment for Chinook and coho (e.g. Johnson et al. 2012; De Boer et al. unpublished). In addition, egg-to-fry survival is particularly sensitive to changes in habitat conditions such as fine sediment, scour and temperature (Chapman et a. 1988; Devries 1997). Beginning in 2009, we studied egg-to-fry survival for Chinook salmon in the Yakima (2009 to 2013), Wenatchee (2010 to 2017) and Twisp (2014 to 2015) rivers. We developed efficient and effective techniques for estimating egg-to-fry survival at multiple locations throughout a watershed that can be applied to other species. While we have considerable data on Chinook salmon and some data on coho salmon, almost no data exist on egg-to-fry survival in the natural environment for steelhead. Thus, using methods similar to those we developed for Chinook salmon, we propose to conduct a pilot study to estimate egg-to-fry survival for Steelhead in the Twisp River.

Goals and Objectives

The overall goal of this study is to provide reasonable estimates of egg-to-fry survival for Twisp River steelhead and complement ongoing fall-parr abundance and smolt-production estimates, spawning ground surveys, and companion studies of relative reproductive success, to identify factors limiting the reproductive success of Twisp River steelhead. Successful implementation of this study, in combination with those other ongoing investigations in the Twisp River, will leave only the fry-to-parr stage of the steelhead life-cycle without a survival estimate.

More specifically our objectives are to:

1) Provide reliable estimates of Twisp River steelhead egg-to-fry survival using modified methods used for Chinook and coho2) Estimate Twisp River steelhead egg-to-fry survival under a variety of habitat conditions by sampling twelve sites throughout the known spawning distribution of Twisp River steelhead

3) Examine relationship between key habitat variables (fines, substrate size, and temperature) and steelhead survival

4) Estimate egg-to-fry survival at existing Columbia Habitat Monitoring Program (CHaMP) sites to examine effects of meso and micro habitat conditions on survival

Methods

Steelhead egg-to-fry survival would be measured at twelve sites throughout the range of spawning steelhead in the Twisp River drainage. Specific locations of sites will be determined based on existing spawning, access, and known locations of CHaMP sites (Figure 1). We will also examine whether sampling can occur at any of the 12 locations used previously for spring Chinook salmon egg-to-fry study; many of these locations are also used by steelhead, and we have existing agreements with land owners for access.

A total of three redds would be constructed at each site, using the gametes from three unique male-female pairs**.** Tracking survival of individual crosses is important as previous studies on Chinook have shown a strong parentage effect (Johnson et al. 2012; Roni et al. 2016). The detailed methods would follow those of Johnson et al. (2012), which include constructing redds of uniform size and dimension, collection of gametes from hatchery fish, placing 100 fertilized eggs in modified Whitlock-Vibert boxes with native spawning gravel (from site), placing egg boxes in constructed redds and burying them. Whitlock-Vibert boxes have a long history of use in incubation and fine sediment intrusion studies (Wesche et al. 1989; Johnson et al. 2012; Roni et al. 2016). Modification of Whitlock-Vibert boxes includes placing fine mesh screen to prevent alevins and fry from escaping, removal of the top tray, addition of native gravels (from sites) and addition of a PIT tag in the box to assist in locating redds for recovery.

Egg boxes will then be recovered at the stage where 50% of the fry would be expected to swim up from gravel (typically 700 to 900 temperature units depending upon the species). Temperature loggers will be deployed at each of 12 study sites to monitor the accumulation of thermal units and determine exact date of recovery. **Because we will place 100 eggs in each egg box, approximately 1500 eggs would be needed from each of three females and approximately 4 ml of milt would be needed from each of three males.** Artificial redd locations will be identified by triangulation from the bank and through the use of a hand held PIT tag detector. The redds will then be excavated, the egg box delicately removed to minimize loss of fine sediment and transported to the bank in a small tub of water to enumerate survivors and dead eggs or fry and the total number of days between stocking of eggs and redd excavation recorded (see Johnson et al. 2012 for detailed description of methods). Surviving fry will be transported live to the lab where length to the nearest millimeter and wet-weight to the nearest milligram will be measured on each individual. Developmental indices (kD) will be calculated for each of the surviving fry based on Bams (1970).

Microhabitat data assessed at each site will include substrate size (D16, D50, D84, % fines) based on Wolman pebble counts (Wolman 1954), scour based on chains at each redd (Nawa and Frisell 1993; Johnson et al. 2012), and fine sediment infiltration. Fine sediment infiltration (percent fines) into artificial redds will be estimated from the egg boxes following excavation of artificial redds (Johnson et al. 2012). In addition, where possible, sites will be located within reaches currently monitored as part of CHaMP, which will provide additional information about meso habitat conditions within study sites/reaches.

Data analysis

To demonstrate the range of steelhead egg-to-fry survival in the Twisp, initial analysis will include basic *summary* statistics (mean, standard error of mean) by sites and cross (male-female pair). To specifically examine the influence of site and mating on survival and developmental stage, we will use an Analysis of variance (ANOVA) with both site and cross (male-female pairs or parentage) as fixed factors in the model. Tukey multiple comparisons will be used to determine differences between pairs of reaches and crosses. An ANOVA will also be used to compare physical variables (percent fines, D_{50}, D_{84},

D_{16}, days in gravel, scour) among reaches. We will use regression to examine relationships between physical variables and egg-to-fry survival. Because we will have survival data from twelve sites spread across the basin, we can also use spatial statistical and analysis tools developed by Ver Hoef et al. (2014) and Peterson et al. (2014) to interpolate and map steelhead egg-to-fry survival throughout the study area.

Expected Results and Potential Challenges

Based on results of previous studies we've conducted on Chinook in the Twisp, Yakima and Wenatchee as well as with coho in the Yakima, we expect to find differences in both egg-to-fry survival, fry developmental indices, and condition among locations in the Twisp as well as among crosses (male-female pairs). Depending upon the differences in fine sediment, scour, and spawning substrate among sites there may be correlations between survival and fine sediment, scour, and other physical variables.

We have used this method at nearly 100 redds per year for more than 5 years particularly for Chinook salmon, but this will be the first time for steelhead. Thus the first year of this study is a pilot to confirm the feasibility of the methods for steelhead and make any necessary modifications to protocols used for Chinook and coho. Most of challenges faced with Chinook and coho were related to unusual weather conditions and recovery egg boxes during spring flows. Thus one potential challenge could be high flows during either redd construction or recovery as steelhead spawn in the spring rather than fall. However, most steelhead appear to spawn near the channel margins and the Twisp is smaller than some other rivers we have worked in. We have had some minor vandalism (most likely curious fisherman) at a few sites on the Yakima and Wenatchee, but these were largely restricted to summer or early fall when there was heavy recreation use; we don't expect this to be a problem on the Twisp given the land ownership and time of year.

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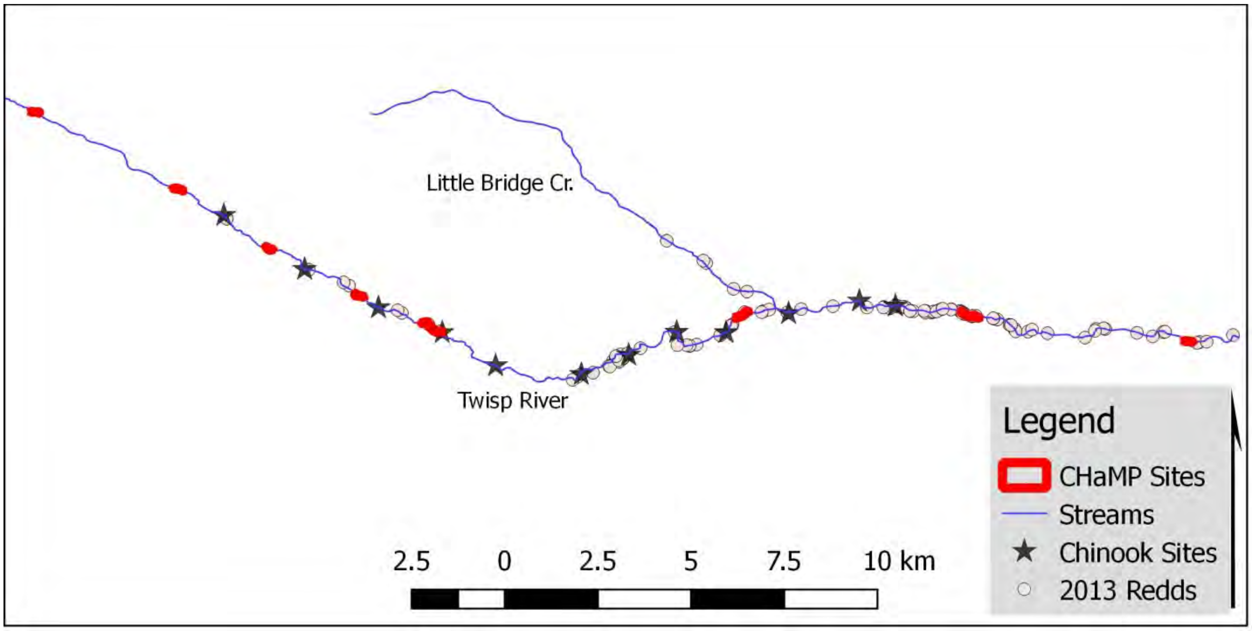


Figure 1. Map of Twisp River showing 2013 Steelhead redd, current CHaMP sites, and location of Chinook egg-to-fry study sites (2013/2014). Note that several years of spawner data are available. 2013 is presented simply for demonstration purposes and multiple years of spawning data will be used to determine final locations.

Problem statement: The current target number of Twisp River wild broodstock is low (26 fish), and variation in family survival results in few families represented as returning adults. Life history diversity also appears to be lower for the hatchery population leading to hatchery adults having fewer age classes and less overlap among cohorts. These issues combined with a pHOS target of 0.5 results in a large fraction of natural spawners originating from only a few families. The continued operation of the Twisp program using current protocols will likely result in a severe reduction of Ne (i.e., Ryman-Laikre effect), posing unacceptable long-term genetic risks.

WDFW has developed a suite of actions for consideration which range from the immediate concerns in 2017 to more long term programmatic issues associated with meeting future Section 10 Permit conditions while minimizing genetic risks and continuing to support recovery (see Tables 1 and 2 for current and proposed program structure). In addition, we have provided new and more precise estimates of run escapement into the Methow (before fishery impacts; Table 3) and spawning escapement estimates for all major tributaries (Table 4). Current redd survey data suggest mainstem spawning has been much lower than historical due to shifts in hatchery release locations. Based on PIT tag data, the majority of natural fish are spawning in tributaries. Hence, a majority of fish spawning in the mainstem are likely of hatchery origin.

In general, actions considered that could be taken to reduce the impacts of current hatchery management on Ne are:

1. Increasing the number of families produced in the hatchery and released in the Twisp River, which can be achieved by:
   a. Using Twisp NOR broodstock, but increasing the number of NOR broodstock taken at the Twisp weir
   b. Changing the source of broodstock for producing fish to be released in the Twisp River by:
      i. Combining Twisp and Winthrop NOR broodstock to create a larger composite broodstock
      ii. Releasing a mix of Twisp and Winthrop produced smolts without mixing spawners of each program
      iii. Switching to Winthrop NOR broodstock
      iv. Switching to Wells safety net broodstock
2. Reducing releases of adult hatchery fish upstream of the Twisp weir (i.e, reducing pHOS)
3. Increasing the number of families of adult hatchery fish released upstream of the Twisp weir, which can be achieved
   a. Indirectly by increasing the diversity of age at maturity of adult hatchery fish released upstream (better cohort diversity
   b. Directly by measuring relatedness among hatchery fish returning to the weir and releasing fish based on their estimated relatedness to balance familial representation

The Joint Fisheries Parties (JFP) met recently to discuss how these actions may or may not meet management objectives for the Methow sub-basin and the potential implications/benefits thereof. There is still strong interest in maintaining releases of WxW smolts into the Twisp River.

Given the genetic risks of associated with low Ne under the current program, there are both juvenile and adult actions the JFP is recommending to be implemented beginning this spring.

Immediate actions for Twisp hatchery adults returning in 2017:

Reduce Twisp hatchery escapement (pHOS) to 0.3 plus, prior to release, hold and tag hatchery fish, perform in-season near real-time genetic analysis for relationship status in order to distribute released fish among as many families and cohorts as possible.

Immediate actions for Twisp smolt releases in 2017:

Alternative 1: Release Twisp stock and an additional 13,000 WNFH smolts (this number was identified as what was available at WNFH with a unique coded wire tag that could be PIT tagged prior to release) following a volitional release at Buttermilk Bridge. *This is currently the preferred alternative.*

Alternative 2: Mix Twisp juveniles with WNFH progeny and release 48,000 mixed progeny (production target) from Buttermilk Bridge. Releases into the Twisp River and those from WNFH would both include some proportion of Twisp and WNFH-origin progeny. This alternative may not be feasible based on how the USFWS operates the two year smolt program (the Twisp is only a yearling program).

Immediate actions for broodstock collection in 2017:

- Collect the requisite 26 NO broodstock from the Twisp weir (consistent with the 2016 Broodstock Collection Protocols) and transfer to WNFH to support meeting the 110 NO broodstock requirement for the USFWS conservation program.

- Collect additional hatchery origin returns from the Twisp weir and WNFH (through hatchery returns and/or through the USFWSs hook and line broodstock collection) to produce 48K safety net fish which would be subsequently released into the lower Methow (2018 release).

Future actions for broodstock collection and smolt production and release in 2018 and beyond:

- Shift the DPUD Twisp release goal to a lower Methow safety net program. Fish would be released at the lower Burma Road bridge. Juveniles would be adequately PIT tagged to evaluate to determine distribution within the Methow sub-basin (i.e., do fish stay within the lower Methow where they can be targeted in a conservation fishery with minimal impacts to NO fish or are we likely to see these fish distribute themselves significantly upstream and in particular the tributaries). Information from this evaluation will help inform future decisions for the upper Methow safety net program, should pHOS/PNI objectives under the new permits fail to be reached under the current program structure and permit requirements).

- Release 50,000 WNFH smolts (post volitional release) upstream of the Twisp Weir (Buttermilk Bridge and other sites). Excess hatchery fish collected at the weir will be used for broodstock at MSH for safety net program.

- Reduce pHOS in the Twisp to <0.3 and Methow (< 0.5). The distribution of safety net fish could be monitoring using PIT tags and adjustments to release numbers and locations adaptively managed through time.

- In subsequent years, a mix of Twisp and WNFH adults will be allowed to spawn naturally. Excess hatchery fish would be culled or used for safety net program.

Under the new program structure, the size of the aggregate conservation program (USFWS and DPUD) would change from 248,000 to 200,000 (WNFH would house the full conservation program) with adult requirements reducing from 136 to 110. The total number of NO adults removed at the Twisp weir would go from 26 to 22 (to ensure the Twisp is not over represented, adult collection would be consistent with the proportion of NO fish spawning in the Twisp (about 20%) relative to the rest of the basin.

Table 1. 2017 brood year Steelhead Program Structure at Wells Hatchery and the Methow River sub-basin.

Program	Hatchery	Owner	Release Location	Release Target	Broodstock Collection Locations
Twisp Conservation	Methow Hatchery (incubation); Wells Hatchery (rearing)	Douglas PUD	Twisp Acclimation Pond	48,000	Twisp WxW
Methow Safety-Net	Wells Hatchery	Douglas PUD	Methow Hatchery	100,000	HxH: Twisp Weir (up to 25%) + WNFH Hatchery (75%) or WNFH 1st, MFH 2nd to make up balance
Mainstem Columbia Safety-Net	Wells Hatchery	Douglas PUD	Wells Hatchery	160,000	HxH: Wells FH/Dam returns (1st option); Methow FH/WNFH (2nd option)

WNFH Conservation Program	WNFH	USFWS	WNFH	Up to 200,000	Maximize use of NOR, up to 55 pair captured by hook and line in the Methow River above Twisp, volunteers to WNFH, and tangle netting in Spring Creek.

Table 2. 2018 brood year and beyond Steelhead Program Structure at Wells Hatchery and the Methow River sub-basin.

Program	**Hatchery**	**Owner**	**Release Location**	**Release Target**	**Broodstock Collection Locations**
Twisp Conservation	WNFH	USFWS	Buttermilk Bridge	50,000	Methow Composite WxW from WFNH conservation program.
Upper Methow Safety-Net	Wells Hatchery	Douglas PUD	Methow Hatchery	100,000	HxH: Twisp Weir (up to 25%) + WNFH Hatchery (75%) or WNFH 1st, MFH 2nd to make up balance
Lower Methow Safety-Net	Wells Hatchery	Douglas PUD	Methow Hatchery ?	48,000	HxH: Twisp Weir (up to 25%) + WNFH Hatchery (75%) or WNFH 1st, MFH 2nd to make up balance
Mainstem Columbia Safety-Net	Wells Hatchery	Douglas PUD	Wells Hatchery	160,000	HxH: Wells FH/Dam returns (1st option); Methow FH/WNFH (2nd option)
WNFH Conservation Program	WNFH	USFWS	WNFH	Up to 150,000	Maximize use of NOR, up to 55 pair captured by hook and line in the Methow River, Twisp Weir, volunteers to WNFH, and tangle netting in Spring Creek.

Table 3. Methow steelhead run escapement estimates based on PIT tag model

Year	Hatchery	Natural	pHOS
2011	2687	1142	0.70
2012	1812	980	0.65
2013	2057	528	0.80
2014	1893	1047	0.64
2015	2121	1081	0.66
Mean	2114	956	0.69

Table 4. Mean tributary spawning escapement estimates based on PIT tag model (2011-2015)

Stream	Hatchery	Natural	pHOS
Gold	58	101	0.35
Libby	42	40	0.45
Beaver	22	58	0.28
Twisp	317	186	0.62
Chewuch	204	240	0.46
Upper Methow	181	106	0.64
Total	824	731	0.53

Pilot Concept to Trap Summer-Run Chinook Salmon at the Chelan River Habitat Channel Water Conveyance Canal Outlet-Results

Summary

- In an effort to identify a new summer Chinook broodstock collection site, Chelan PUD implemented a pilot in 2016 to trap adult summer Chinook salmon at the outlet structure of the water conveyance canal for the Chelan Tailrace Pump Station.
- Trapping at the Chelan Falls Canal Trap (CFCT) began August 4th, 2016 and concluded on August 10th, 2016. The trap was open for broodstock collection for four days.
- During operation of the CFCT, 51 males and 49 females were collected for broodstock. The broodstock experienced four mortalities while being held at Eastbank Hatchery resulting in 49 males and 47 females being spawned.
- Gamete Evaluation: The warm water temperatures of the Chelan River have the potential to affect the gamete quality of fish collected at the CFCT. In order to evaluate gamete quality, broodstock and subsequent gametes collected at this site were held separate at Eastbank Hatchery from broodstock collected from the Eastbank Outfall (EBO) and Entiat National Fish Hatchery (ENFH). The eye-up rate between gametes from broodstock collected at the CFCT and the EBO/ENFH were compared (Table 1).
- Zero bull trout were encountered at the trap.

Table 1. Eye-up rates for the Chelan Falls Canal Trap (CFCT), Eastbank Outfall (EBO) and Entiat National Fish Hatchery (ENFH).

Type	Eye-up rate
CFCT	93.33%
EBO/ENFH	91.05%

2017 Rocky Reach and Rock Island
HCP Action Plan - Draft

COORDINATING COMMITTEE	Jan 2017			Feb			Mar			Apr			May			Jun			Jul			Aug			Sep			Oct			Nov			Dec		
Activity	1	15	31	1	15	29	1	15	31	1	15	30	1	15	31	1	15	30	1	15	31	1	15	31	1	15	30	1	15	31	1	15	30	1	15	31
Deliver 2016 RR Bypass Evaluation Report				D				F																												
Deliver 2017 RR Bypass Operations Plan				D					F																											
Deliver 2016 RI Bypass Evaluation Report				D					F																											
Deliver 2017 RI Bypass Operations Plan				D				F																												
Pikeminnow long-line control programs				S																													C			
Pikeminnow angling control programs													S																C						
Avian Predation programs										S														C												
Piscivorous Bird Monitoring										S																										C
Deliver 2017 RI/RR Fish Passage Plan					D			F																												
Deliver 2017 RR/RI Spill Plan							D			F																										
Deliver 2017 RR/RI Spill Report																										D			F							
RR 9% Summer Spill																S							C													
RI 10% Spring Spill											S												C													
RI 20% Summer Spill																S							C													
RR Juvenile Fish Bypass Operations										S														C												
Coho Survival Standards SOA	D									C																										
RI Juvenile Bypass Trap Operations										S														C												
2016 HCP Annual Report							D			F																										

HATCHERY COMMITTEE	Jan 2017			Feb			Mar			Apr			May			Jun			Jul			Aug			Sep			Oct			Nov			Dec		
Activity	1	15	31	1	15	29	1	15	31	1	15	30	1	15	31	1	15	30	1	15	31	1	15	31	1	15	30	1	15	31	1	15	30	1	15	31
2016 Hatchery M & E Report																	D								F											
2018 Hatchery M & E work plans																						D						F								
Dryden Water Quality Monitoring (Year 6)							S						C																							
Coho NNI Mitigation										S																										F
Chelan Falls Broodstock Collection Canal Trap Pilot																				S							C									
Chelan Hatchery Rehabilitation Feasibility	D																																			
Pilot Outplant adult MetComp spr Chinook to Chewuch																							S				F									
Steelhead Residualism Plan - *Permit No. 18583*	D																								F											
Hatchery Program Broodstock Collection													S																						C	
Hatchery Releases											S		C																							
Receive Methow spring Chinook Permit								C																												
Receive Wenatchee Steelhead Permit								C																												

TRIBUTARY COMMITTEE	Jan 2017			Feb			Mar			Apr			May			Jun			Jul			Aug			Sep			Oct			Nov			Dec		
Activity	1	15	31	1	15	29	1	15	31	1	15	30	1	15	31	1	15	30	1	15	31	1	15	31	1	15	30	1	15	31	1	15	30	1	15	31
RR and RI Plan Species Account Annual Deposit			C																																	
General Salmon Fund Approval	→ Ongoing																																			
General Salmon Fund Implementation	→ Ongoing																																			
Small Project Review and Approval	→ Ongoing																																			
Small Project Implementation	→ Ongoing																																			

D = Draft Document
F = Final Document

S = Start Project
C = Complete Project

Hatchery M&E Reporting

Synching to Required Milestones

Todd Pearsons
Greg Mackey
Peter Graf
Catherine Willard

January 18, 2017

HCP Requirements

Element	Section	Frequency	Previous	Next
Survival Studies	8.4.4	Every 10 years	2010	2020
Recalculation	8.4.5	Every 10 years	2013	2023
M&E Plan Update	8.5	Every 5 years	2013	2018
Program Review	8.8	Every 10 years	2012	2020
Section 10 Permit	10.2.5	Every 10 years	2004	2017

Program Review

- Review hatchery evaluation program
- Review population/hatchery interaction studies
- Review if hatchery program is operating according to goals in M&E Plan
- Hatchery production
- Adult-to-smolt (in-hatchery survival standards)
- Smolt-to-adult (not actually a standard, but covered by HRR)
- Section 10 Permits

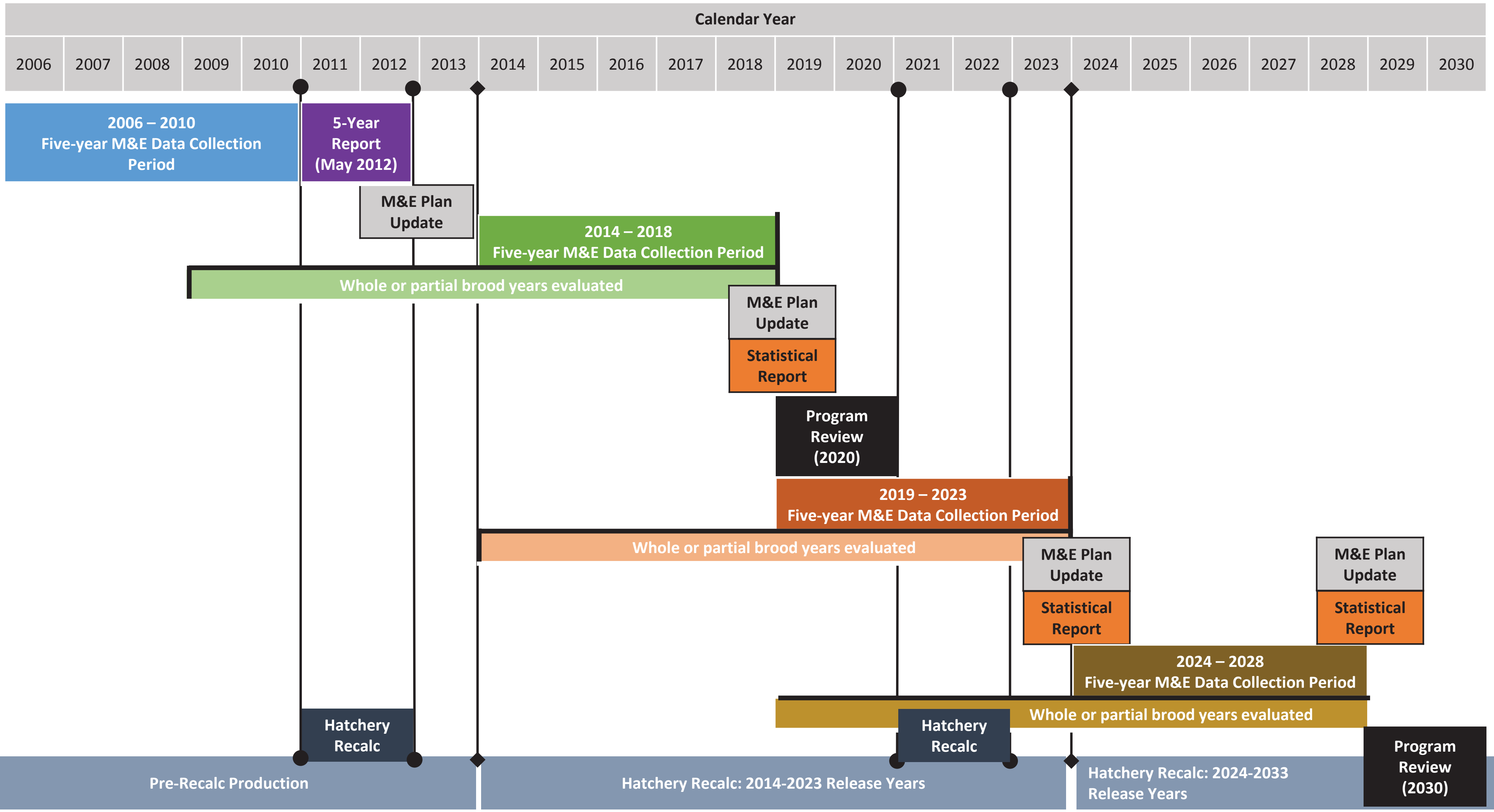
Hatchery M&E Reports

Report type	Frequency	Content	Function
Data	Annual	Cumulative description of data (raw and derived) and field methods	Informs annual M&E implementation plans
Statistical	5 year	Presentation of statistical analyses and description of statistical methods	Informs 5 year M&E plan
Program Review	10 year	Integrates and interprets information from data and statistical reports and also includes integration from other programs and studies. Written in scientific manuscript format. Fulfill "Program Review" requirements	Informs recalculation and adaptive management

Report Schedule (anchors from recalculation)

Year	Activity	Data years
2023	Hatchery recalculation	2011-2019
2022	First brood collection for hatchery recalculation (2024 release)	--
2021	Hatchery recalculation process and agreement	--
2020	Program Review	Adds 2011-2019
2018 2019	Statistical report and 5 year M&E plan review, contracting	Adds 2011-2018
2013	Statistical report, 5 year M&E plan review	Thru 2010

PUD Hatchery Monitoring and Evaluation Reporting Timeline



Species	Stock	Life Stage	Location	Last Analyses	Samples Needed	Analyses Year	Reporting
Fall Chinook	Hanford	Adult	brood, spawning ground	2010?	2019, 2020	2020	2021
Spring Chinook	Wenatchee	Adult	brood, Tumwater	2004	(in hand) 2016, 2017	2017	2018
	Entiat	Adult	brood, spawning grounds	2006	2017, 2018	2018	2019
	Methow	Adult	brood, spawning grounds	2006	2017, 2018	2018	2019
	Okanogan	Adult	none for now, spawning grounds	none	2017, 2018	2018	2019
Steelhead	Wenatchee	Adult	brood, Tumwater	2010	2017, 2018	2018	2019
	Entiat	Adult/Smolt	brood, screw trap	2010	2017, 2018	2018	2019
	Methow	Adult	brood, weir	2008	2017, 2018	2018	2019
	Okanogan	Adult/Smolt	brood, weir	none	2017, 2018	2018	2019
Sockeye	Wenatchee	Adult	spawning grounds	2007	2018, 2019	2019	2020
	Okanogan	Adult	brood, spawning grounds	none	2018, 2019	2019	2020
Summer Chinook	Wenatchee	Adult	brood, spawning grounds	2010	2019, 2020	2020	2021
	Methow	Adult	brood, spawning grounds	2010	2019, 2020	2020	2021
	Okanogan	Adult	brood, spawning grounds, weir	2010	2019, 2020	2020	2021

Stray Rate Targets

Presented to HSC/HC, 1/18/2017

Stray rates (Hillman et al. 2013)

- **Q6.1.1:** Is the stray rate of hatchery fish less than 5% for the total brood return?
- **Q6.2.1:** Do hatchery strays make up less than 5% of the spawning escapement within other non-target independent populations?
- **Q6.3.1:** Do hatchery strays make up less than 10% of the spawning aggregate within non-target spawning areas within the target population?

- *Does anyone know the origin of the 5% BY stray?*

Expectations and standards (Hillman et al. 2013)

- "When populations are not independent, straying among them does not pose a risk of genetic homogenization. In addition, stray rates of hatchery-origin fish cannot be expected to be lower than for natural-origin fish. When estimates of stray rates for natural-origin fish are available and if they exceed the 5% or 10% thresholds identified in this plan, analysis and interpretation of stray rates must take into account the concept that hatchery programs may be held to unattainable standards based on the natural stray rate."

Factors that influence straying

- Imprinting quality (Dittman et al. 2015)
- Origin (e.g., hatchery or natural, Ford et al. 2015)
- Species, stock or tributary (Shapovalov and Taft 1954, Keefer and Caudill 2012, Ford et al. 2015)
- Spawning habitat quality (Cram et al. 2013, Ford et al. 2015)
- Access (water temperature, flow, barriers) (Bugert 1998, Dittman et al. 2010, Cram et al. 2013)
- Spawning Density (e.g., competition, pheromones; Keefer and Caudill 2012, Quinn 2005)
- Dendricity (e.g., choices, opportunities)
- Geography (e.g., distance, configuration)

Data from Tables 2 and 4, Ford et al. (2015) (*small differences in results from tables 2 and 4)

Origin	Stray rate (%, 2 and 4)
Chiwawa	4%, 3%
Little Wenatchee	18%, 17%
Nason	9%, 9%
White	1%, 5%
Upper Wenatchee	100%

Relevant points from Ford et al. 2015

- Stray rates of natural origin fish are higher than previously thought (up to 100%)
- Stray rates varied by tributary (LW>N>W>C) and generation/origin (H1>H2>NW)
- Non-hatchery factors can influence stray rates (e.g., tributary, habitat)

Considerations

1. Imprinting is one of many factors that influence straying
2. The hatchery experience appears to do something to increase straying, even when fish are imprinted in the natural environment
3. Some factors that influence straying are outside the purview of hatchery programs
4. Stray rates of spring Chinook that were produced in the natural environment (i.e., correct imprinting) ranged from 1-100%
5. BY stray rate target is unrealistically low (5%) and other stray targets may not always be achievable if program size is sufficiently high
6. The stray rate target should be revised to incorporate new information

Possible BY stray target refinement

- Target = (stray rate of natural origin fish from hatchery parentage) + (stray rate addition as a result of hatchery experience) + (stray rate addition from poor habitat, high density, and other non-imprinting factors)

FINAL

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ANCHOR QEA

Memorandum

To: Wells, Rocky Reach, and Rock Island HCPs Hatchery Committees

Date: March 13, 2017

From: Tracy Hillman, HCP Hatchery Committees Chairman

cc: Sarah Montgomery, Anchor QEA, LLC

Re: Final Minutes of the February 15, 2017, HCP Hatchery Committees Meeting

The Wells, Rocky Reach, and Rock Island Hydroelectric Projects Habitat Conservation Plans (HCPs) Hatchery Committees meeting was held at the Grant PUD office in Wenatchee, Washington, on Wednesday, February 15, 2017, from 9:00 a.m. to 12:30 p.m. Attendees are listed in Attachment A to these meeting minutes.

Action Item Summary

- McLain Johnson (Washington State Department of Fish and Wildlife [WDFW]) will revise the timeline for conducting genetic analysis for HCP program species by incorporating suggestions provided during the Hatchery Committees January 18, 2017, meeting (Item I-A). *(Note: This item is ongoing.)*
- McLain Johnson and WDFW geneticists will perform a power analysis to inform genetic analysis intervals and intensity for HCP program species (Item I-A). *(Note: this item is ongoing.)*
- Sarah Montgomery and Tracy Hillman will renumber the Hatchery Monitoring and Evaluation (M&E) Plan appendices and append them to the Hatchery M&E Plan (Item I-A). *(Note: this item is ongoing.)*
- Sarah Montgomery will add a summary table to the draft summary of the 5-Year Hatchery M&E Review process (Item I-A). *(Note: this item is complete.)*
- Greg Mackey will distribute a link to Scott Blankenship's (Cramer Fish Sciences) blog (Item III-B). *(Note: Mackey sent a paper and tool by Blankenship on the Ryman-Laikre effect to Montgomery on March 3, 2017, which she distributed to the Hatchery Committees that same day.)*
- Brett Farman will check on the status of Methow spring Chinook salmon permits and the timeline for Methow steelhead consultation (Item IV-B).
- Catherine Willard will look into other potential release locations in the Chewuch River, particularly upstream, for the spring Chinook salmon outplanting study (Item IV-D).
- The Hatchery Committees will review the draft study plan, "Outplanting Surplus Methow Composite Spring Chinook Salmon Adults to Increase Natural Production in the Chewuch River," and provide comments to Catherine Willard by March 8, 2017. Sarah Montgomery

distributed the draft outplanting plan to the Hatchery Committees on February 14, 2017 (Item IV-D). *(Note: This item is complete.)*

- Greg Mackey will coordinate with Chelan and Grant PUDs to revise the proposed Hatchery M&E Reporting Timeline, which Sarah Montgomery distributed to the Hatchery Committees on February 13, 2017 (Item IV-E). *(Note: Mackey sent a revised M&E Reporting Timeline to Montgomery on March 2, 2017, which Montgomery distributed to the Hatchery Committees for review that same day.)*
- Tracy Hillman will discuss with WDFW and Yakama Nation (YN) the level of effort involved in adding statistical analyses to the annual M&E reports for PUD programs (Item IV-E).
- Andrew Murdoch (WDFW) will write an overview of proposed expanded sampling at the off-ladder fish trap (OLAFT) at Priest Rapids Dam (Item IV-F).

Decision Summary

- The Rock Island and Rocky Reach Hatchery Committees representatives present approved the hatchery portion of Chelan PUD's 2017 HCP Action Plan as follows: Chelan PUD, U.S. Fish and Wildlife Service (USFWS), National Marine Fisheries Service (NMFS), WDFW, Colville Confederated Tribes (CCT), and YN approved on February 15, 2017 (Item II-A). *(Note: this is also a decision item at the HCP Coordinating Committees meeting on February 22, 2017.)*

Agreements

- The Hatchery Committees agreed to reschedule the March 15, 2017, meeting to March 13, 2017, starting at 1 p.m. (Item V-A).

Review Items

- Sarah Montgomery sent an email to the Hatchery Committees on February 23, 2017, notifying them that Douglas PUD's draft 2017 Wells HCP Action Plan is available for review, with approval requested at the March 13, 2017, Hatchery Committees meeting.
- Sarah Montgomery sent an email to the Hatchery Committees on March 3, 2017, notifying them that the draft 2017 Broodstock Collection Protocols are available for review and discussion at the March 13, 2017, Hatchery Committees meeting. Mike Tonseth requests comments by March 16, 2017.
- Sarah Montgomery sent an email to the Hatchery Committees on March 3, 2017, notifying them that Chelan PUD's draft 2017 Steelhead Release Plan is available for review and discussion at the March 13, 2017, Hatchery Committees meeting, with approval requested by March 16, 2017. *(Note: a revised version of the draft plan was distributed on March 6, 2017.)*

- Sarah Montgomery sent an email to the Hatchery Committees on March 3, 2017, notifying them that Douglas PUD's draft Wells HCP SOA, "Monitoring and Evaluation Reporting Schedule for the Douglas PUD, Grant PUD and Chelan PUD Hatchery Programs" is available for review and discussion at the March 13, 2017, Hatchery Committees meeting, with approval requested by March 17, 2017. *(Note: the SOA and the M&E Reporting Timeline are separate documents; the draft timeline was distributed by Montgomery on March 2, 2017.)*
- Sarah Montgomery sent an email to the Hatchery Committees on March 8, 2017, notifying them that Chelan PUD's draft Rocky Reach and Rock Island HCP SOA, "Monitoring and Evaluation Reporting Schedule for the Douglas PUD, Grant PUD, and Chelan PUD Hatchery Programs" is available for review and discussion at the March 13, 2017, Hatchery Committees meeting, with approval requested by March 21, 2017. *(Note: the SOA and the M&E Reporting Timeline are separate documents; the draft timeline was distributed by Montgomery on March 2, 2017. Also note the Rocky Reach and Rock Island HCP SOA is a separate SOA from the Wells HCP SOA, though the content is similar.)*

Finalized Documents

- No documents have been finalized recently.

I. Welcome

A. Review Agenda, Review Last Meeting Action Items, and Approve the January 18, 2017, Meeting Minutes (Tracy Hillman)

Tracy Hillman welcomed the Hatchery Committees and asked for any additions or changes to the agenda. The following revisions were requested:

- Sarah Montgomery added the draft Hatchery M&E Reporting Schedule and draft statement of agreement (SOA).
- Greg Mackey added an update on the Twisp River steelhead egg-to-fry survival study.
- Mackey also added a discussion on Twisp River steelhead broodstock.
- Casey Baldwin removed the Similkameen summer Chinook salmon stray rates discussion.

The Hatchery Committees reviewed the revised draft January 18, 2017, meeting minutes. Sarah Montgomery said there are several outstanding comments to be discussed, which the Hatchery Committees reviewed and addressed. Hatchery Committees representatives present approved the draft January 18, 2017, meeting minutes, as revised.

Action items from the Hatchery Committees meeting on January 18, 2017, and follow-up discussions were addressed *(note: italicized text below corresponds to agenda items from the meeting on January 18, 2017)*:

- *Sarah Montgomery and Tracy Hillman will renumber the Hatchery Monitoring and Evaluation (M&E) Plan appendices and append them to the Hatchery M&E Plan (Item I-A).*
  This item is ongoing.
- *Sarah Montgomery will add a summary table to the draft summary of the 5-Year Hatchery M&E Review process (Item I-A).*
  This item is ongoing.
- *Keely Murdoch will research who is leading the Columbia River Inter-Tribal Fish Commission's (CRITFC's) parentage-based tagging effort in order to coordinate with Mclain Johnson (Washington Department of Fish and Wildlife [WDFW]) about genetic sampling (Item IV-E).*
  Murdoch said this item is complete.
- *Justin Yeager and Brett Farman will discuss internally the Douglas PUD Twisp gamete request and provide National Marine Fisheries Services' (NMFS') vote to the Hatchery Committees (Item II-A).*
  Tracy Hillman said Farman provided NMFS approval on January 27, 2017.
- *Douglas PUD will review WDFW's white paper, "Twisp Steelhead Hatchery Broodstock Issues," which Sarah Montgomery distributed to the Hatchery Committees on January 18, 2017, and provide comments to Mike Tonseth (Item II-B).*
  Greg Mackey said he provided comments to Tonseth.
- *Greg Mackey will coordinate with Chelan and Grant PUDs to develop a SOA describing the components in the proposed Hatchery M&E Reporting Timeline, which Sarah Montgomery distributed to the Hatchery Committees on January 13, 2017 (Item IV-C).*
  The revised draft Hatchery M&E Reporting Timeline and SOA were distributed to the Hatchery Committees on February 13, 2017, and both will be discussed today.
- *Hatchery Committees members will review the Upper Columbia Salmon Recovery Board (UCSRB) Draft Hatchery Report and provide edits and comments to Greer Maier (UCSRB) by January 31, 2017, and invite Maier to discuss comments in person at an upcoming Hatchery Committees meeting (Item IV-D).*
  Tracy Hillman said various members of the Hatchery Committees have provided comments to Maier and this item is complete.
- *McLain Johnson will revise the timeline for conducting genetic analysis for HCP program species incorporating suggestions provided during the Hatchery Committees January 18, 2017, meeting (Item IV-E).*
  This item is ongoing.

- *McLain Johnson and WDFW geneticists will perform a power analysis to inform genetic analysis intervals and intensity for HCP program species (Item IV-E).*
  This item is ongoing.
- *Todd Pearsons (Grant PUD) will write a white paper about factors affecting the brood year stray rates of hatchery fish and considerations for revising stray rate targets (Item IV-F).*
  Pearsons sent his paper, "Stray Rate Targets for Hatchery Programs," to Sarah Montgomery on February 6, 2017, which she distributed to the Hatchery Committees. This will be discussed today.

II. Chelan PUD

A. Decision: Chelan PUD 2017 HCP Action Plan (Catherine Willard)

Catherine Willard shared a spreadsheet titled, "Draft 2017 Rock Island and Rocky Reach HCP Action Plan," which Sarah Montgomery distributed to the Hatchery Committees on January 18, 2017 (Attachment E of January 18, 2017, meeting minutes). Willard asked if anyone had questions about the plan. She said it includes typical items such as the annual Hatchery M&E Report, annual Implementation Plan, broodstock collection, and hatchery releases, as well as pilot studies (Chelan Falls Broodstock Collection and Outplanting Adult MetComp in the Chewuch River), ongoing water quality monitoring at Dryden Acclimation Facility, working on coho salmon No Net Impact (NNI) mitigation, and permitting activities. Casey Baldwin asked if anyone raised concerns about the plan at the January 18, 2017, Hatchery Committees meeting. Tracy Hillman said there were none, and this is the same version as the one presented in January. He reminded everyone that the Hatchery Committees vote on the hatchery portion of their respective committee's draft HCP Action Plans, and the Coordinating Committees vote on approving the whole plan. The Rock Island and Rocky Reach Hatchery Committees representatives present approved the hatchery portion of Chelan PUD's 2017 HCP Action Plan as follows: Chelan PUD, USFWS, NMFS, WDFW, CCT, and YN approved on February 15, 2017.

Greg Mackey said Douglas PUD will distribute their draft 2017 HCP Action Plan for review soon.

III. Douglas PUD

A. Egg-to-Fry Survival Study in the Twisp River (Greg Mackey)

Greg Mackey said, after discussing the Twisp River Steelhead egg-to-fry survival study initially planned for 2017 with Phil Roni (Cramer Fish Sciences), Douglas PUD has decided to do an egg-to-fry survival study with spring Chinook salmon instead of steelhead. He said Douglas PUD will request approval for spring Chinook salmon gametes later in spring 2017. He said spring Chinook salmon are more of a concern for conservation and Douglas PUD still intends to work with Chelan PUD to acquire the surplus steelhead gametes they need from the Twisp River for their study. Hillman said the document that supported a steelhead egg-to-fry survival study (which Sarah Montgomery distributed to the Hatchery Committees on January 6, 2017, and was reviewed last month) noted that egg-to-fry survival for spring Chinook salmon has been extensively studied, and he asked why Douglas PUD is choosing to switch to spring Chinook salmon. Mackey said Douglas PUD will develop a more in-depth study design to get better estimates of spring Chinook salmon egg-to-fry survival than previously attained. Mike Tonseth asked if Douglas PUD would consider expanding the egg-to-fry survival study into the Methow and Chewuch rivers. Mackey said Douglas PUD is interested in expanding the study to those rivers, but they have not reached that level of detail in discussions yet.

B. Twisp Steelhead Program Broodstock Issues (Greg Mackey)

Greg Mackey said Douglas PUD reviewed WDFW's memorandum, "Twisp Steelhead Broodstock Issues" (which Sarah Montgomery distributed to the Hatchery Committees on January 18, 2017), and provided comments to WDFW. Mackey said the memorandum states that continued operation of the Twisp program would likely result in severe reduction of effective population size (i.e., Ryman-Laikre effect), and he asked that WDFW and Todd Seamons (WDFW geneticist) write up the methods and results of the analysis. Mike Tonseth said WDFW is still addressing Douglas PUD's comments on the memorandum, and will bring a more detailed document and plan back to the Hatchery Committees. Mackey said programmatic shifts are not straightforward, so the Hatchery Committees should keep in mind that any changes to the PUD or USFWS programs would result in changes to agreements about broodstock collection and adult management. Tonseth said no decisions regarding programmatic changes have been made yet, so the 2016 Broodstock Collection Protocols are still being followed. He said the draft 2017 Broodstock Collection Protocols (not yet distributed) may change in early 2017, depending on agreements within the Hatchery Committees.

Mackey said the Ryman-Laikre effect is detectable in Twisp River steelhead because parentage analyses are being performed every year, so data are available for assessing effective population size (N_e) with a sensitivity that normally would not be possible. He said other programs are likely experiencing the same effect, but it is not detectable or being investigated as intensively, and this could result in a severe reduction in effective population size because the issues continue for a longer period without detection. Tonseth said relative reproductive success studies are designed to detect changes such as effective population size, and the results and discussion of this analysis might necessitate taking a closer look at other programs. He said, for now, issues with the Twisp steelhead program are a parallel conversation with developing the draft 2017 Broodstock Collection Protocols, but if the Hatchery Committees agree to Twisp steelhead program changes, the draft 2017

Broodstock Collection Protocols will change as well. Mackey added that Scott Blankenship wrote a blog post about how hatcheries have the potential to reduce effective population size, and said he will distribute a link to the blog.

IV. Joint HCP-HC/PRCC HSC

A. USFWS Bull Trout Consultation Update (Matt Cooper)

Matt Cooper said Karl Halupka (USFWS) sent him an update on USFWS consultations, which he summarized as follows:

- The USFWS letter of concurrence regarding the Tribal Resource Management Plan developed by the CCT was signed on January 31, 2017.
- Regarding the draft Biological Opinion (BiOp) covering hatchery programs in the Wenatchee basin, Halupka plans to distribute a schedule soon for finalizing the BiOp and requests input on the draft from parties (Chelan PUD and WDFW) who have not provided comments yet.

Greg Mackey asked if the memorandum describing Halupka's gap analysis and the strategy to rely on the 2012 Wells Relicensing Bull Trout BiOp for coverage for the Methow spring Chinook salmon program was sent to NMFS. Bill Gale confirmed the memorandum was distributed to NMFS.

B. NMFS Consultation Update (Brett Farman)

Regarding the Methow spring Chinook salmon consultation, Brett Farman said the permits are in queue for signature at NMFS. After that, the permits will be distributed to the applicants for their signature and will then be finalized and distributed by email. Mike Tonseth said the applicants were expecting the permits in January 2017 and asked for a more detailed update on the timeline for permits being signed. Farman said, if NMFS does not sign the permits by February 17, 2017, he will send an email to the applicants with an updated timeline.

Regarding the Okanogan steelhead Tribal Resources Management Plan (TRMP), Farman said NMFS received public comments and will be reviewing and addressing the comments. He said Charlene Hurst can answer questions about that consultation.

Greg Mackey asked if Farman had an update from Hurst or Craig Busack (NMFS) on the Methow steelhead consultation. Mackey said Douglas PUD's last discussion with NMFS on the Methow steelhead consultation was regarding gene flow. He said, because the Methow spring Chinook salmon consultation is almost complete, Douglas PUD is wondering about the timeline for the Methow steelhead consultation. Farman said he would check on the timeline.

C. Draft 2017 Broodstock Collection Protocols (Mike Tonseth)

Mike Tonseth said the draft 2017 Broodstock Collection Protocols will be distributed for review soon. WDFW is waiting on spring Chinook salmon forecasts and predictions on ocean conditions. He said the Hatchery Committees will have approximately 2 weeks to review the protocols so Tonseth can revise them prior to further discussion at the March 13, 2017, Hatchery Committees meeting. He suggested the Hatchery Committees review the appendix about marking, because passive integrated transponder (PIT)-tagging levels tend to vary between years. Todd Pearsons said the Hatchery Committees and Priest Rapids Coordinating Committee Hatchery Sub-Committee (PRCC HSC) recently discussed steelhead marking and tagging and asked if anything related to that discussion has been incorporated into the draft protocols. Tonseth said only agreed-to changes are incorporated into the protocols. Pearsons asked if changes proposed now (e.g., differential steelhead marking) would be incorporated into the 2017 protocols or if they would have to wait until 2018. Tonseth said anything proposed can be discussed and incorporated, because the protocols are a living document and can be added to or changed. Casey Baldwin mentioned that if the Okanogan steelhead TRMP is approved, CCT might seek changes to the protocols this year. Tonseth added that the spring Chinook salmon forecasts are uncertain and the thermal blob might also affect the size of the return in 2017. He said models are currently predicting low returns, which might also change the protocols. Baldwin said run forecasts for spring Chinook salmon from the Columbia River Technical Advisory Committee (TAC) are not too bad for 2017. Tonseth said WDFW considers the TAC forecasts for other species, but does not rely on them for spring Chinook salmon.

Tonseth reminded the Hatchery Committees that in 2016, they discussed trapping constraints at Wells Dam related to broodstock collection, and the Coordinating Committees agreed trap operators at Wells Dam have the flexibility to trap spring Chinook salmon outside the protocols used to date (16 hours per day, 3 days per week) in order to achieve broodstock collection targets as prescribed in the annual Broodstock Collection Protocols. He said the new spring Chinook salmon permits will not limit the trapping days available for spring Chinook salmon at Wells Dam. He said part of the discussion at the Coordinating Committees meetings (including an SOA that was never approved) regarded potentially evaluating the size of the conservation program in the Methow basin. He said appropriate program levels for safety-net and conservation programs were previously determined for the Wenatchee basin, but not for the Methow basin, and the conservation program may not currently be the appropriate size. He said WDFW proposes an increase in trapping at Wells Dam as part of the Broodstock Collection Protocols in 2017 in order to meet the current size of the program, but he asked the Hatchery Committees to commit to determining whether the conservation program in the Methow basin is the right size. Bill Gale said the distribution of the program between conservation and safety-net is better suited to discussion by the Joint Fisheries Parties (JFP) than the Hatchery Committees, because the JFP also discuss federal programs like the Winthrop National Fish

Hatchery (NFH). He suggested the JFP make a commitment to discussing this in 2017. Tonseth said he does expect the JFP to discuss this, but the outcome of the program size discussions affect PUD programs, so it will also need to be discussed by the Hatchery Committees. Gale agreed and said it should be clarified that the JFP will perform the program size analysis and the overall program obligation will not change, but it might be proportioned into conservation and safety-net differently. Greg Mackey said although the Hatchery Committees do not have jurisdiction over federal programs, the Hatchery Committees do need to make the determination of the PUD programs size and type.. Tonseth summarized that WDFW is okay with increased trapping efforts at Wells Dam in 2017, and the level of effort for trapping in the future will be based on the outcome of the JFP and Hatchery Committees discussions about the size of the Methow spring Chinook salmon program.

Mackey said an additional concern with permit conditions under the Wells Bull Trout BiOp and increased trapping effort is that the timing for spring Chinook salmon trapping at Wells Dam is also the time of year most bull trout pass Wells Dam, so increased trapping could result in increased bull trout encounters. Gale said new spring Chinook salmon permits for the Methow program do not have detailed stipulations about trapping constraints because permit conditions default to the 2012 Wells Relicensing Bull Trout BiOp. Mackey said the 2012 Bull Trout BiOp might not have detailed stipulations about trapping periods. Gale said trapping constraints likely depend on how bull trout take is calculated. Mackey said take is calculated for different activities at Wells Dam, so it is not very straightforward. Tonseth summarized that there is still a lot of uncertainty about how the 2017 spring Chinook salmon run will form for hatchery and natural-origin fish, and the draft 2017 Broodstock Collection Protocols include a change in proposed trap operations at Wells Dam due to a shortage in collection in 2016.

Tonseth said, for the 2017 steelhead return, WDFW expects a collapse of the 2-salt return, because there was a collapse of the 1-salt return in 2016. He said, as the run develops, WDFW will be able to determine how many steelhead may be collected for broodstock and this number may need to be adjusted based on the age structure of the return. Catherine Willard asked Tonseth if the Chelan Falls broodstock collection site is included in the draft protocols, and Tonseth replied yes.

Gale said, in 2016 and previous years, USFWS has raised concerns regarding Pacific lamprey passage at Tumwater Dam. He said USFWS approved the 2016 Broodstock Collection Protocols contingent on further discussions and studies of Pacific lamprey. Willard said Chelan PUD plans to provide an update on Pacific lamprey and Tumwater Dam at the Rocky Reach Fish Forum (RRFF) March 2017 meeting. Gale asked that an update also be provided to the Hatchery Committees. Tracy Hillman asked if questions about Pacific lamprey pertain to the Hatchery Committees and said the RRFF typically addresses Pacific lamprey discussions. Gale said, from the USFWS' perspective, they are being asked to approve activities in the protocols that potentially affect Pacific lamprey passage. He said it is unclear whether the dam itself or the activities at the dam are affecting Pacific lamprey passage. Hillman said it is still not clear to him how Pacific lamprey relate to Hatchery Committees discussions, because they are not an HCP plan species. Gale said bull trout are not an HCP plan species, but they pertain to Hatchery Committees discussions. Tonseth said bull trout are unique in that they are a listed species. Gale said bull trout and Pacific lamprey are similar in that they are not plan species, and he said there is an issue with Pacific lamprey passage at Tumwater Dam and he wants to continue discussing it and working on it.

D. Spring Chinook Salmon Outplanting in the Chewuch River (Catherine Willard/All)

Catherine Willard said a subgroup of Hatchery Committees members met on January 9, 2017, and made progress on a plan for outplanting surplus adult spring Chinook salmon (MetComp) in the Chewuch River. She said several data gaps were identified and participants are working on follow-up tasks. She shared the draft plan titled, "Out-planting Surplus Methow Composite Spring Chinook Salmon Adults to Increase Natural Production in the Chewuch River – Draft," which Sarah Montgomery distributed to the Hatchery Committees on February 14, 2017 (Attachment B). She said the goal of the draft plan is to determine if outplanted surplus Chinook salmon in the Chewuch River stay in the Chewuch River and, if they do, determine their spawner success. She said Cameron Sharpe (Oregon Department of Fish and Wildlife [ODFW]) provided some advice based on ODFW outplanting in the Willamette River, namely to place fish as close to the peak spawning time as possible and put fish as high in the watershed as possible. Willard said the draft plan includes PIT tagging fish and releasing them at two locations: 1) above the upper Chewuch River PIT array, where there is easy access through the campground and good spawning habitat; and 2) at Memorial Bridge, between the PIT arrays in the Chewuch River, so travel outside of the PIT-array zone can be determined. The study will also document any outplanted fish returning to the Methow Fish Hatchery and PIT-tag detections at the Chewuch River arrays. Willard said they do not intend to place fish on occupied spawning grounds and would release them upstream or downstream in that case. She said the plan will be a decision item at the March Hatchery Committees meeting.

Greg Mackey said skewed sex ratios tend to reduce effective population size and asked why the female to male ratio is 80:20. Todd Pearsons said he recommended the 80 female to 20 male ratio as a way to maximize the number of eggs put into spawning gravel, knowing that males may mate with multiple females. He said the proposed ratio was a compromise and noted that the ratio can be adjusted depending on the sex ratio of the run-at-large. Mike Tonseth said sampling at Wells Dam will inform the expected sex ratio of the run, and if it is 75 females to 25 males or greater, the ratio can be managed. Pearsons added that literature on salmon reproduction suggests males are less successful than females in producing surviving progeny, so for a first-year investigation the risk in an 80:20 sex ratio is relatively low.

Willard asked Tonseth what the permitting approval process would be for this study. Tonseth said permits limit the number of adults and juveniles that can be released and permits determine the pHOS and proportionate natural influence (PNI) levels for programs. He said current permits acknowledge that pHOS and PNI targets in the Methow basin are difficult to meet. He said, in 2017, anticipating an overall low abundance of spring Chinook salmon in the Methow basin means that WDFW will likely be more concerned with meeting escapement objectives than PNI and pHOS objectives. Keely Murdoch said 2017 might turn out to be a good year to try this outplanting study because overall abundance is predicted to be low.

Bill Gale said the priority of actions for surplus hatchery fish returning to the Methow basin should be discussed. He said he sees the priorities as: 1) escapement; 2) broodstock for the Methow program; and 3) broodstock for the Winthrop program. Tonseth said he sees the priorities as: 1) broodstock for the conservation program; 2) WNFH safety-net production; and 3) outplanting in the Chewuch River. Pearsons challenged those priorities and said the fish targeted for use in this study are conservation program fish; therefore, this study, which contributes to natural production, should be prioritized over the safety-net program. Tonseth said the Hatchery Committees will need to consider the permits and structure of the programs before deciding how to assign surplus fish in 2017. He said counts at Wells Dam will inform the number of wild fish returning to the Methow basin. From that, they can calculate escapement, pHOS, and PNI. Mackey said there can also be a balance of priorities, with some fish used for this outplanting study and others used for broodstock for WNFH. Pearsons said the safety-net program can still be met without using surplus fish as would be used in this study. Gale said not including these fish in the safety-net program would affect the 3-population PNI value. Casey Baldwin asked where the Okanogan spring Chinook salmon program is on the priority list for surplus fish and if those fish come from Winthrop NFH. Gale said the Okanogan program uses safety-net fish that return to Winthrop NFH, so the Okanogan program would not be affected.

Baldwin said it would be helpful for Figure 1 in the proposed outplanting study to show relative spawner abundance and habitat quality in reaches of the Chewuch River and it might make sense to move the upstream release site even farther upstream because there might be even more unpopulated habitat above the most upstream release site. Willard said she will look into other potential release locations in the Chewuch River, particularly upstream, for the spring Chinook salmon outplanting study. Pearsons said ease of release is a major consideration for this study; truck access is very important at release locations so fish can go straight from the truck into the river using a tube. Baldwin said the CCT have a Whooshh system to aid with truck releases, which might be useful for this study. Willard summarized that the subgroup will revise the study and provide it to the Hatchery Committees for review prior to the March Hatchery Committees meeting.

E. M&E Report Scheduling (Greg Mackey/Catherine Willard)

Greg Mackey shared two documents, the draft "Wells HCP Hatchery Committees SOA: Monitoring and Evaluation Reporting Schedule for the Douglas PUD, Grant PUD, and Chelan PUD Hatchery Programs" (Attachment C), and the draft "Monitoring and Evaluation Reporting Schedule for the Douglas PUD, Grant PUD and Chelan PUD Hatchery Programs" (Attachment D; Sarah Montgomery distributed both documents to the Hatchery Committees on February 13, 2017). Mackey said the SOA provides background and purpose for the schedule, and the schedule itself is a separate document that describes the reporting timeline and content and function of each report. Mackey said M&E report types are summarized in Table 1. The content for the annual data report will be a cumulative presentation of data and concise description of field methods, plus any deviations in methods (though the methods themselves are in the M&E Plan). ESA permit reporting requirements will also be covered in this report. The 5-year statistical report will present statistical analyses for each M&E plan objective, descriptions of statistical methods, and explanation of violations of assumptions of statistical procedures. The 10-year Program Review will be a bigger, in-depth report written in scientific manuscript format, which integrates and interprets information, including integration of findings from other populations, programs, and studies. It will fulfill the HCP's "Program Review" requirements. Mackey said Table 2 describes the major elements of HCP processes and their time intervals. He said, among the PUDs, survival studies have the most variation in time intervals. He said Table 3 is a proposed schedule through 2024. Mackey said the purpose of the SOA is to accept this document and state that altering the timeline would require Hatchery Committees approval, and a similar SOA could be used for Grant PUD and the PRCC HSC [note: each PUD plans to present their own SOA that is specific to their agreement(s)].

Casey Baldwin noted that the statistical report is scheduled to be completed 2 years before the 10-year Program Review and asked if data from the 2 years between the reports would be analyzed in the 10-year Program Review. Tracy Hillman said, in order to complete a Program Review, the statistical analyses would have to be completed again, including those 2 years of data. Baldwin asked why the statistical report and Program Review are offset, because it seems redundant to do statistical analyses again 2 years after the statistical report. Mackey said one option would be to skip every other 5-year report and instead include the statistical analyses in the Program Review. When the schedule was developed all the reporting requirements were trying to be met explicitly, hence the redundant reporting of the 5-year and Program Review. Hillman suggested that most of the statistical analyses could actually be done in the annual report, but the productivity and abundance comparisons to reference or control populations take more time and should probably only be included in the statistical report or Program Review. Peter Graf said recalculation begins next in 2023 and the document authors tried to fit the timeline around doing a Program Review in 2020 just before recalculation. Graf suggested the statistical report and Program Review could be collapsed into one report, because they are currently only 18 months apart in the timeline. Mike Tonseth agreed and said duplication of effort is unnecessary. Hillman said he will coordinate with WDFW and YN, as M&E operators, to determine if most of the statistical analyses can be completed in each annual report. He said it might be beneficial to present the statistical analyses each year so the Hatchery Committees can make informed decisions, and every 5 years include statistical analyses on reference populations, population dynamics, and productivity. Hillman said the timeline could be set up so the 5-year statistical report falls on years when the 10-year Program Review is done. Todd Pearsons said the purpose of the 5-year report is to inform the M&E Plan review and update. Tonseth replied having statistical analyses in the annual report provides sufficient information to review and update the M&E Plan, so the timeline and purpose of the 5-year report could be shifted to align with Program Review. Todd Pearsons suggested that the PUDs discuss the timeline further and distribute a revised version for review. Greg Mackey said he will coordinate with Chelan and Grant PUDs to revise the proposed Hatchery M&E Reporting Timeline.

F. Expanded Sampling at the Off-ladder Fish Trap (Mike Tonseth)

Mike Tonseth said the OLAFT at Priest Rapids Dam is currently operating from about July 1 to early or mid-November, primarily for steelhead viable salmon population (VSP) monitoring. He said this monitoring (8 hours a day, 3 days a week) plus supplemental PIT tagging provides adult return estimates of hatchery and wild steelhead with high precision. Tonseth said he thinks it would also be a good approach for monitoring spring Chinook salmon. He said monitoring for spring Chinook salmon under the same operation (8 hours a day, 3 days a week) beginning in mid-April would provide sufficient sample size and precision to assess populations of spring Chinook salmon. He said unbiased estimates for prespawn mortality are lacking for spring Chinook salmon and this sampling could inform those estimates, as well as providing data for managing pHOS and PNI objectives. He said operating the OLAFT from mid-April to mid-November would encompass many species' runs, though sockeye would not be included in sampling because their abundances are so high. He said the JFP met and discussed this, and thinks there is utility in pursuing this sampling scheme. He said, if it works, sampling at Wells and Tumwater dams for spring Chinook salmon could be decreased and the OLAFT approach could answer more detailed questions about entire distinct population segments or non-evolutionarily significant units. He said the state does not want to invest time and money into developing a plan and proposal for expanded OLAFT sampling unless the Hatchery Committees parties support pursuing it.

Greg Mackey said the population estimate for steelhead uses PIT-tag detection data and it would be helpful to fully understand the model and ensure it is a statistically rigorous approach to estimating populations before shifting M&E programs. He said expanded sampling at OLAFT is probably a better way to acquire data for estimating populations, practical limitations notwithstanding. Tonseth said the expanded sampling may not change how broodstock is collected, but it would decrease ancillary handing and delay.

Tracy Hillman asked if the population estimates come from the mark-recapture model developed by Kevin See (Quantitative Consultants, Inc.). Tonseth replied yes; the model works well for steelhead and is being considered for other stocks and runs. Hillman said the model is described in Appendix D to the Chelan and Grant PUDs Annual Hatchery M&E Report. Pearsons said it would be helpful to understand how the model will be used, how run composite sampling would be performed, and what would change relative to existing M&E efforts. He asked, for example, would it increase or decrease the handling events of fish? And, what is proposed to change at every location compared to what is proposed to change at the OLAFT? Tonseth said he will work with Andrew Murdoch (WDFW) to write an overview of proposed sampling and program changes to address these discussion items.

G. Stray Rate Targets (Todd Pearsons)

Todd Pearsons said the Hatchery Committees and PRCC HSC discussed stray rates in January 2017 and he was asked to expand his presentation in January into a paper, "Stray Rate Target for Hatchery Programs," which Sarah Montgomery distributed to the Hatchery Committees on February 2, 2017 (Attachment E). Pearsons summarized recent scientific literature that for natural-origin fish, stray rates vary between 0 and nearly 100%, and there are a variety of factors influencing stray rates. He said this implies that it is difficult to set a standardized stray rate target, and Keefer and Caudill (2014)[1] state the following:

> There are certainly no universally 'appropriate' straying rates that can be used as management targets…Fisheries managers must balance the potential demographic and genetic risks of straying on both donor and recipient populations with the benefits of proposed management actions. This will require consideration of how strays are identified and enumerated, the size and spatial distribution of donor and recipient populations, and agreement

[1] Keefer, M. L., and C. C. Caudill. 2014. Homing and straying by anadromous salmonids: a review of mechanisms and rates. *Rev Fish Biol Fisheries* (2014) 24:333–368. DOI 10.1007/s11160-013-9334-6.

> about what stray rates are desirable or ''natural''. Costs, benefits, and target rates are likely to differ widely among study systems."

Pearsons said his paper focuses on the first type of stray rate target from Hillman et al. 2013[2], brood-year stray rates, and the paper summarizes and includes quotes from existing literature so everyone can interpret the material for themselves. He asked for questions and said he would like to discuss the stray rate target itself, whether it should be eliminated, or if there is a scientifically supported target to which the Hatchery Committees and PRCC HSC can agree. He said the origin of the 5% brood-year stray rate target is also interesting, because it was unclear where it originated from and experts in straying mainly focus on targets related to the origin of the stray in regard to the recipient population, instead of brood-year stray rates. Hatchery Committees representatives' questions and comments are summarized in the following paragraphs.

Purpose of the brood-year stray rate target

Bill Gale said question (Q)1 (regarding brood-year stray rates) of the M&E Plan is a measure of hatchery performance, whereas Q2 and Q3 are related to natural-origin populations and permit conditions. Mike Tonseth said Q1 is more of an indicator objective or management index than a target and exceeding Q1 means a higher likelihood of exceeding the Q2 and Q3 targets. Pearsons said the recipient population targets (Q2 and Q3) are more important targets because not meeting them requires program changes. He said he is uneasy about having management implications tied to a target where the target is not achievable and scientifically supported. Casey Baldwin said eliminating Q1 would decrease the ability to understand or take management actions for programs that do have a stray problem and the problem with relying on Q2 is that it is program-specific [note: does not account for the strays from other sources than the program that is evaluated]. Pearsons also questioned whether hatchery fish should be expected to have stray rate targets close to those of natural-origin fish?

Baldwin said it would be helpful to know what proportion of programs are not meeting the 5% brood-year stray rate target. Greg Mackey said fish transported to acclimation sites never meet the target and fish released directly from a fish hatchery usually do meet the target, but it varies a lot.

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[2] Hillman, T., T. Kahler, G. Mackey, J. Murauskas, A. Murdoch, K. Murdoch, T. Pearsons, and M. Tonseth, 2013. *Monitoring and evaluation plan for PUD hatchery programs*. Chelan PUD, Wenatchee, Washington.

Keely Murdoch said the Chewuch and Twisp rivers have pronounced stray rates because fish have a strong connection to the Methow Fish Hatchery.

Gale said, from a program performance view, the stray rate should be as low as possible and 5% is just a benchmark. Not meeting that target does not mean the program is not meeting its permit conditions. Pearsons said management actions should be based on scientifically derived targets and, for things that are beyond the control of the hatchery, targets should not be set. Murdoch countered that if there was no target for brood-year stray rates, needed changes to programs might not occur. Pearsons said brood-year stray rates should be reported whether there is a target or not, and targets are not necessary to make program changes.

Hatchery versus wild stray rates

Tonseth said results from the Ford et al. 2015[3] paper suggest that straying is largely habitat related. He said wild fish do not tend to stray, but hatchery-origin fish do. He said descendants from natural-origin fish spawning in one location return to that location, whereas progeny of hatchery-origin fish seek out higher quality habitat. He said imprinting, and the location of fish hatcheries are therefore important pieces to understanding hatchery-origin fish and straying.

Mackey said the rate of straying is not as important as the result of straying. He said, in the Methow basin, the population is homogenized (there is no genetic differentiation among the fish in the Twisp, Methow and Chewuch rivers), so it does not matter where hatchery fish go from a population genetic standpoint, but it does matter from an escapement goal and pHOS standpoint. He said the adult spring Chinook outplanting plan in the Chewuch River will also help inform stray rates in the Methow basin.

Potential changes to the target

Pearsons said that the approved M&E plan says that the committees will incorporate new information about natural stray rates when they become available so that hatchery programs are not held to unrealistic standards. He said that new information is now available and should be used to inform the broodyear stray target. He asked what the role of science was in the committees if we were not willing to use recent compelling science on a topic that was specifically identified in the

[3] Ford, M. J., A. Murdoch, and M. Hughes, 2015. Using parentage analysis to estimate rates of straying and homing in Chinook salmon (*Oncorhynchus tshawytscha*). *Molecular Ecology* 24:1109–1121.

monitoring plan? He asked what level of science would be necessary to change the broodyear stray target?

Baldwin said information from the Wenatchee basin (high stray rates) suggests that a one-size-fits-all approach to stray rate targets may not be appropriate. He suggested adding subsections to Q1; 1a) would address within-basin brood-year stray rates and 1b) would address out-of-basin brood-year stray rates.

Tracy Hillman asked if the stray rates identified in Ford et al. (e.g., 1.3 to 17.5%) would be appropriate for spring Chinook salmon within the Wenatchee River basin. That is, Ford et al. indicates that the natural-origin stray rate for Chiwawa spring Chinook salmon is 4.1%. Should that be the target for this program? Pearsons said peer-reviewed scientific literature suggests there is not a single appropriate brood-year stray rate target to set. Baldwin summarized that the Hatchery Committees appear to be uncomfortable with eliminating Q1 altogether, but would rather come up with a revised stray rate target based on information in Ford et al. or other sources. Hillman said this discussion will continue at the March 13, 2017, Hatchery Committees meeting.

V. HCP Administration

A. Next Meetings

Mike Tonseth said he and Jeff Korth are unavailable from March 14 to 16, 2017, and asked the Hatchery Committees if they would like to reschedule the in-person March meeting to a time when WDFW is available to discuss the draft 2017 Broodstock Collection Protocols or if they would prefer to schedule a conference call in addition to the scheduled meeting to discuss the protocols and other items requiring WDFW input in March. Hillman summarized that the protocols and the Twisp Steelhead program are both items requiring WDFW input. Hatchery Committees representatives present discussed alternate dates and times, and agreed to meet on Monday, March 13, 2017, starting at 1 p.m. They plan to meet at the Grant PUD conference room.

The next Hatchery Committees meetings are on Monday, March 13, 2017, at 1 p.m. (Grant PUD), April 19, 2017, (Grant PUD), and May 17, 2017 (Grant PUD).

VI. List of Attachments

Attachment A	List of Attendees
Attachment B	Out-planting Surplus Methow Composite Spring Chinook Salmon Adults to Increase Natural Production in the Chewuch River – Draft
Attachment C	Wells HCP Hatchery Committees SOA: Monitoring and Evaluation Reporting Schedule for the Douglas PUD, Grant PUD, and Chelan PUD Hatchery Programs – Draft

Attachment D	Monitoring and Evaluation Reporting Schedule for the Douglas PUD, Grant PUD and Chelan PUD Hatchery Programs – Draft
Attachment E	Stray Rate Target for Hatchery Programs

Attachment A
List of Attendees

Name	Organization
Tracy Hillman	BioAnalysts, Inc.
Sarah Montgomery	Anchor QEA, LLC
Catherine Willard*	Chelan PUD
Greg Mackey*	Douglas PUD
Todd Pearsons‡	Grant PUD
Peter Graf‡	Grant PUD
Deanne Pavlik-Kunkel†‡	Grant PUD
Bill Gale*	U.S. Fish and Wildlife Service
Matt Cooper*	U.S. Fish and Wildlife Service
Brett Farman*†	National Marine Fisheries Service
Mike Tonseth*	Washington Department of Fish and Wildlife
Brian Lyons†	Washington Department of Fish and Wildlife
Jayson Wahls†	Washington Department of Fish and Wildlife
Keely Murdoch*	Yakama Nation
Casey Baldwin*	Colville Confederated Tribes

Notes:
* Denotes Hatchery Committees member or alternate
† Joined by phone
‡ Joined for the joint HCP-HC/PRCC HSC discussion

Out-planting Surplus Methow Composite Spring Chinook Salmon Adults to Increase Natural Production In the Chewuch River - DRAFT

Background

During the recent review of the “Evaluation of Hatchery Programs Funded by Douglas County PUD 5-year Report 2006-2010”, Objective 6, Monitoring Question Q6.1.1: “Is the stray rate of hatchery fish less than 5% for the total brood year return?” was identified as not meeting the target for the Chewuch River final acclimated fish. The Hatchery Committees (HCs) determined that methods to improve homing would have uncertain success, be difficult to implement, and challenging to statistically evaluate. In an effort to achieve the goal of increased hatchery-origin spawner abundance in identified reaches that a higher rate of homing would convey, the HCs agreed to pilot adult out-planting of surplused Methow Composite spring Chinook into the Chewuch River.

The goal of this pilot evaluation is to determine if surplused Methow Composite spring Chinook adults collected and held at the Methow Hatchery, and subsequently out-planted into the Chewuch River, spawn in the Chewuch River. This pilot evaluation will be conducted in an effort to increase spawner abundance, spawner distribution, and natural production in the Chewuch River. It is a low-risk management tool that has been used in many locations such as the Wenatchee and Willamette watersheds.

2017 Out-planting Surplused Methow Composite Spring Chinook Salmon Adults Objectives

- Document the number of female hatchery-origin spring Chinook salmon adults that are trapped and held at the Methow Hatchery and out-planted in the Chewuch River that exhibit spawning behavior and ultimately spawn in the Chewuch River.
- Assess the percentage of hatchery origin spring Chinook salmon adults that are trapped and held at the Methow Hatchery and out-planted in the Chewuch River leave the Chewuch River.

Methods

Hatchery-origin spring Chinook salmon adults returning to the Methow Hatchery, in excess of broodstock needs for the Methow Hatchery, will be candidates for transporting into targeted spawning reaches of the Chewuch River.
We will collect, hold and out-plant a maximum of 200 surplused adults at a sex ratio of 80% females and 20% males (excluding jacks and adjustable depending upon the sex ratio of the run at large). The specific number of fish to be held and out-planted will be based upon permit requirements, availability of fish, and pHOS constraints in the sub-basin.

Holding and Out-planting

Surplus hatchery-origin adults returning to the Methow Hatchery will be held and out-planted one week before estimated peak spawning (i.e., during the latter part of August/early September). All fish that are out-planted will be PIT-tagged and marked with a visible mark. Up to 100 adults will be released into one of two sites. One of the sites will be above the upper Chewuch PIT tag instream PIT tag antenna array (CRU) and the other below CRU and above the Winthrop (CRW) PIT tag antenna array (Figure 1). Release locations will be determined based on vehicle access, suitable spawning habitat, distance from the hatchery, distance from PIT tag arrays, and areas that are not being utilized by spawners already in the system.

Evaluation

The association of the transported adults with redds will be documented during spawner surveys (e.g., identification of transported adults on redds). Potential spawning success of females will be documented by estimating the proportion of eggs that are retained within female carcasses sampled during carcass recovery surveys. Carcass location will be documented using a GPS device.

The CRW PIT tag antenna array will be used to determine the percentage of PIT-tagged hatchery origin spring Chinook salmon adults that are out-planted in the Chewuch River that leave the Chewuch River. Additionally, any adults that are out-planted and last detected outside of the Chewuch River will be considered to have left the Chewuch River. Fish returning to the Methow Hatchery will also be documented.

The results of the 2017 out-planting effort will be used to adjust the methods in 2018.

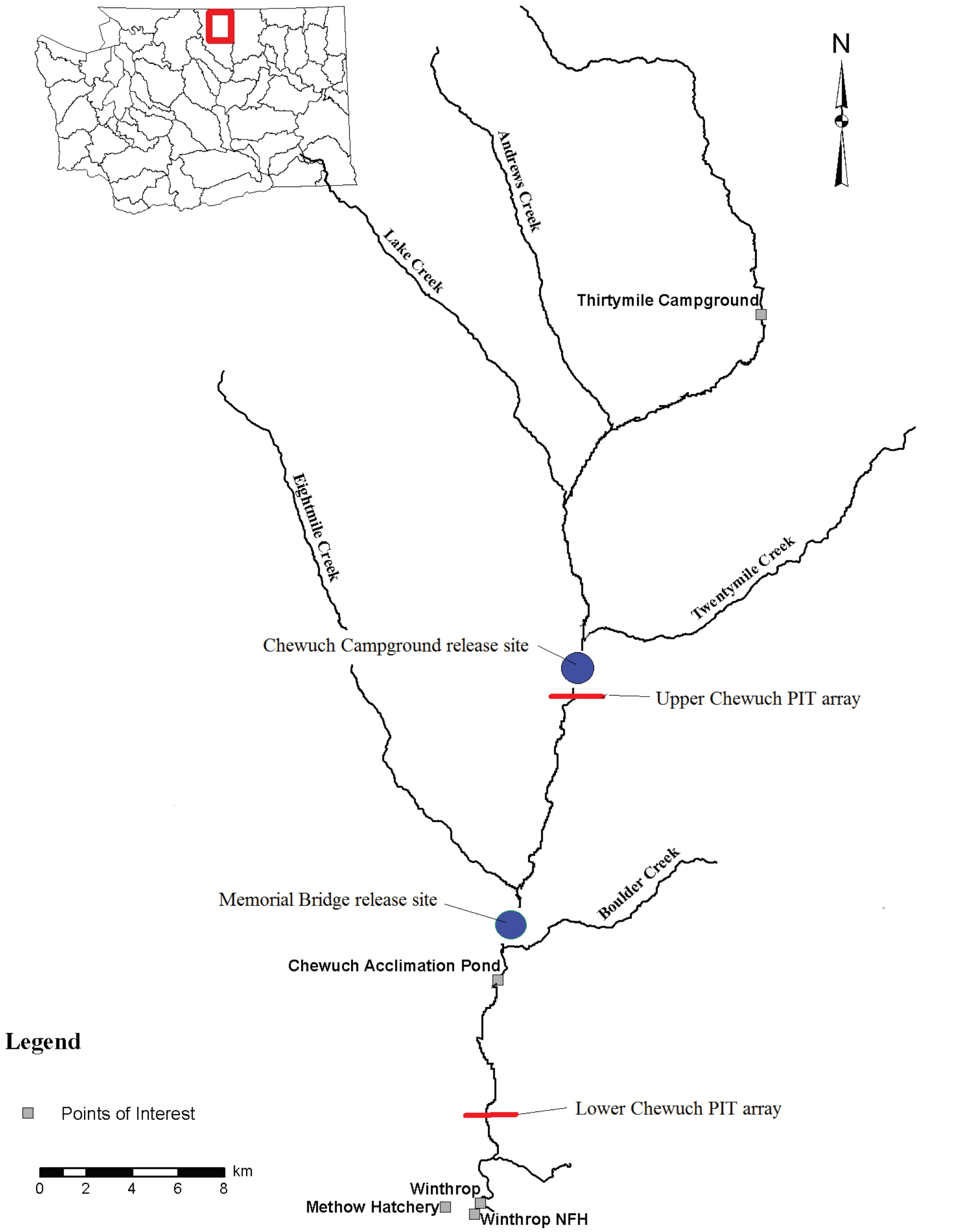

Figure 1. Release site locations for out-planting surplus Methow spring Chinook, 1) Chewuch Campground release site and, 2) Memorial Bridge release site.

Wells HCP Hatchery Committees
Statement of Agreement

Monitoring and Evaluation Reporting Schedule for the Douglas PUD, Grant PUD and Chelan PUD Hatchery Programs, dated March 15, 2017

Statement

The Wells HCP Hatchery Committees approves the Monitoring and Evaluation Reporting Schedule for the Douglas PUD, Grant PUD and Chelan PUD Hatchery Programs, dated March 15, 2017. Any future alterations of the schedule will require HCP Hatchery Committee approval.

Background

The Douglas and Chelan HCPs and Grant Settlement Agreement and 2008 NMFS Biological Opinion for Grant PUD (hereafter referred to collectively as the Agreements) specify certain reporting dates or intervals for hatchery monitoring and evaluation (M&E). The Endangered Species Act incidental take permits and the PUD hatchery M&E Plan also have reporting requirements. These reporting time requirements were designed to provide timely information to operators and managers, fulfill permitting requirements, inform other activities such as updating M&E plans, recalculation of hatchery production, evaluation of meeting objectives, status of meeting permit requirements, and adaptive management actions. To date, the reporting timing that has been implemented has not necessarily met the intent of the Agreements, and has not been orchestrated to work with the various actions that the Hatchery Committees and NMFS require. This document, Monitoring and Evaluation Reporting Schedule for the Douglas PUD, Grant PUD and Chelan PUD Hatchery Programs, dated March 15, 2017, is the new reporting schedule that is consistent with the Agreements, meets reporting requirements under the M&E Plan, meets ESA Section 10 permit requirements, and optimizes the sequence of reporting and the actions that rely on M&E information.

Monitoring and Evaluation Reporting Schedule for the Douglas PUD, Grant PUD and Chelan PUD Hatchery Programs

March 15, 2017

Introduction

The Douglas and Chelan PUDs' HCPs, Grant PUD's Settlement Agreement, and the 2008 NMFS Biological Opinion (Biop) for Grant PUD (hereafter referred to collectively as the Agreements) specify certain reporting dates or intervals for hatchery monitoring and evaluation (M&E). The Endangered Species Act (ESA) incidental take permits and the Monitoring and Evaluation Plan for PUD Hatchery Programs (Hillman et al. 2013) also have reporting requirements. These reporting date requirements were designed to provide timely information to operators and managers and fulfill permitting requirements. Additionally, the reports are used to inform other activities such as updating M&E plans, recalculation of hatchery production, evaluation of meeting M&E objectives, status of meeting permit requirements, and adaptive management actions. To date, the past reporting timing has not necessarily met the intent of the Agreements, and has not been orchestrated to align with the various actions that the Hatchery Committees and NMFS require. Subsequently, we have designed a reporting schedule that is consistent with the Agreements, meets reporting requirements under the M&E Plan, meets ESA Section 10 permit requirements, and optimizes the sequence of reporting and the actions that rely on M&E information.

Section 1: Monitoring and Evaluation Reports

Three levels of M&E reporting will be implemented (Table 1). These reports are consistent with past reporting and the M&E Plan, but have been restructured to streamline transfer of information and meet the Agreements requirements.

Table 1. M&E Report Types

Report type	Frequency	Content	Function
Data	Annual	Cumulative description of data (raw and derived) and field methods	Informs annual M&E implementation plans
Statistical	5 year	Presentation of statistical analyses and description of statistical methods	Informs 5 year M&E plan and provides in depth data analysis
Program Review	10 year	Integrates and interprets information from data and statistical reports and also includes integration from other programs and studies. Written in scientific manuscript format. Fulfills HCP "Program Review" requirements	Informs recalculation and adaptive management. Determines if programs are meeting objectives.

The Data report will be produced annually and will provide data collected in the most recent field year. The report will provide tables of cumulative data, including the most recently collected, and provide summary statistics where appropriate (e.g., mean, standard deviation, etc.). The report will provide a concise description of the field methods that could be used in a scientific publication and describe deviations from previous sampling, standard field practices or sampling plans. This report will provide up to date information for managers and operators, fulfill incidental take reporting requirements, and inform annual adjustments to the implementation of the M&E plan.

The Statistical report will be produced every five years. The report will provide a concise description of the analytical methods used (e.g., similar to a scientific journal article) and the results of the statistical analyses for each objective as described in the M&E plan. The report will also provide the assumptions of the statistical analyses and note any deviations in expected performance of a given analysis (e.g., issues related to normality, dependency, non-constant variance; etc.). The report is not intended to provide interpretation of the results, but will provide the outcomes of the statistical tests. This will provide managers and operators a periodic update of the performance of the hatchery programs.

The Program Review will be produced every ten years and will meet the Program Review as described in the HCPs (Section 8.8 of the Wells HCP, Section 8.7 of the Rocky Reach/Rock Island HCPs). The report will provide the results of any natural population/hatchery interaction studies (as needed), and determine if the hatchery programs are operating consistent with the goals as outlined in the relevant M&E Plan. The review will determine if hatchery program goals and objectives, as defined in the Hatchery Plan (HCPs Section 8), Section 10 permits, as further defined in the HCPs, have been met or sufficient progress is being made toward their achievement; and determine if hatchery production objectives are being achieved.

Section 2: Required Reports and Actions

The HCPs list required reports or actions. The M&E reporting is either directly described or closely tied to these milestones (Table 2).

Table 2. Required Elements in the Agreements

Element	Document	Section	Frequency	Previous	Next
Survival Studies	HCP	8.4.4	Every 10 years	2010	2020
Recalculation	HCP SSSA/BiOp	8.4.5	Every 10 years Every 10 years	2013	2023
M&E Plan Update	HCP SSSA	8.5 13.1.4	Every 5 years Every 5 years	2013	2018
Program Review	HCP	8.8	Every 10 years	2012	2020
Section 10 Permit	HCP	10.2.5	Every 10 years	2004	2017

Section 3: Schedule

The M&E reporting schedule is designed to be consistent with the Agreements. However, it also has been designed to provide a logical sequence of information based on significant milestones in the HCPs as well as consistency with Grant PUDs settlement agreement and NMFS BiOp. Reporting was designed to provide the Program Review prior to recalculation in order to have the most up to date data vetted and organized prior to recalculation. The Statistical Report will be produced every five years, including years when the program Review is due. The Data Report will be produced annually (see Table 3 and Figure 1). The PUDs also require advanced knowledge of M&E and reporting requirements to facilitate timely contracting.

Table 3: Schedule of M&E Reporting and Significant Actions under the Agreements

Year	Activity	Data Years
2024	5-year M&E plan review	--
2023	Hatchery Recalculation finalized	2011-2019
2023	Data Report	Adds 2022
2022	First brood collection for hatchery recalculation (2024 release)	--
2022	Data Report	Adds 2021
2021	Hatchery recalculation process and agreement	--
2021	Data Report	Adds 2020
2020	Program Review	Adds 2011-2019
2020	Data Report	Adds 2019
2019	Data Report	Adds 2018
2019	Statistical Report	Through 2018
2019	5-year M&E plan review	--
2018	Data Report	Adds 2017
2017	Data Report	Adds 2016
2016	Data Report	Adds 2015
2015	Data Report	Adds 2014
2014	Data Report	Adds 2013
2013	5 year M&E plan review	--
2013	Statistical Report (i.e. 5-Year Report)	Through 2010

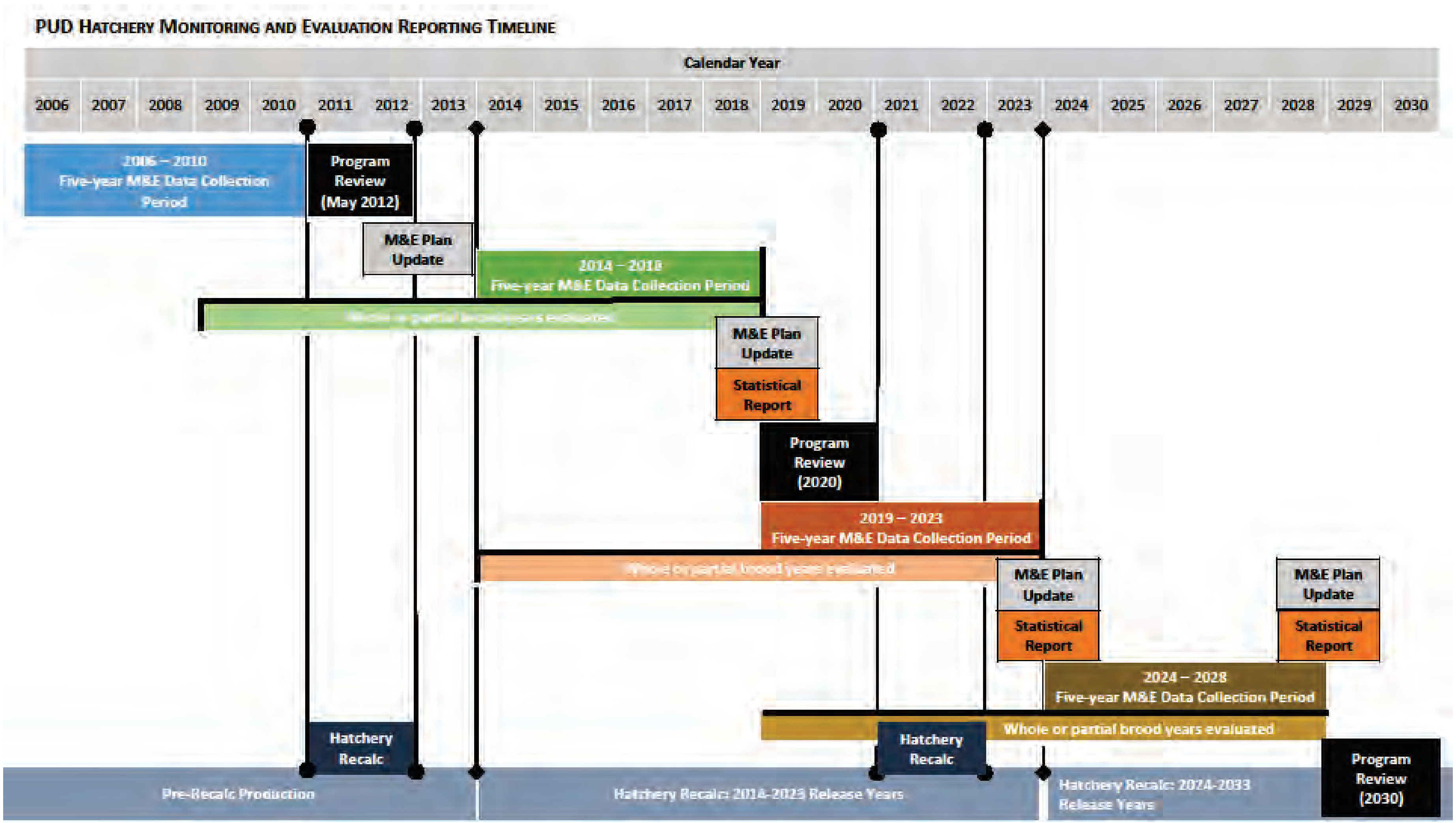

Figure 1. Timeline of requirements and reporting under the Agreements.

Stray Rate Target for Hatchery Programs

Todd Pearsons, Grant PUD

Stray rates of hatchery fish are used to evaluate the risk hatchery programs may pose to non-target populations and to estimate the potential benefits to a target population. As such, targets or guidelines have been developed to set standards for maximum stray rates. For example, the following stray rate targets have been identified in the Middle Columbia Public Utility Districts hatchery Monitoring and Evaluation plan (Hillman et al. 2013):

1) stray rate of hatchery fish less than 5% for the total brood return,

2) hatchery strays make up less than 5% of the spawning escapement within other non-target independent populations, and

3) hatchery strays make up less than 10% of the spawning aggregate within non-target spawning areas within the target population.

This paper focusses on the first target above, which is the percent of adult returns that fail to return to the tributary of release (e.g., tributary such as Nason Creek or Chewuch River). Although there are implications of the first target on targets 2 and 3, those implications will not be the focus of this paper. In Keefer and Caudill's (2014) nomenclature of straying, this paper will focus on donor straying and not recipient population straying.

Origin of the 5% Brood year Target

Murdoch and Peven (2005) defined the original brood year stray target for Chelan PUD hatchery programs as 5% but provided no background for this number. As such, it is difficult to know how this number was generated. In contrast, the targets for recipient populations was "suggested based on a literature review and recommendations by the ICTRT. It can be re-evaluated as more information on naturally-produced Upper Columbia salmonids becomes available. This will be evaluated on a species and program specific basis and decisions made by the HCP HC." (Murdoch and Peven, 2005, page 11).

Stray rate targets for hatchery fish were developed prior to much empirical information on straying of natural origin fish. The belief was that straying of natural origin fish was less than 5%. Even as recent as 2005, Quinn (2005; page 104) reported "Homing to the natal site is the characteristic behavior pattern in all salmonids; about 95-99% of the fish that survive to adulthood do so." This statement supports the idea of a 5% stray target. However, in the same publication stray rates of natural origin fish were presented that exceeded 5% and reached 26.8%.

An informal survey of experts on straying suggests that the original brood year stray target was based upon expert opinion because there was limited information about stray rates of natural origin fish.

Stray rates of natural origin fish

Rates of straying of natural origin fish have ranged between 0% and 100%. Shapovalov and Taft (1954) performed one of the earliest studies of stray rates of natural origin fish involving more than one species. They studied stray rates of coho salmon and steelhead in two coastal California creeks that were less than 8 km apart. They didn't evaluate other creeks for strays beyond the two nearby creeks so their stray rates should be considered minimums. The minimum stray rate of coho salmon was 14.9% for coho originating from Waddell Creek and 26.8% from coho originating from Scott Creek. The minimum stray rate for steelhead was 1.9% for steelhead originating from Waddell Creek and 2.9% from steelhead originating from Scott Creek.

More recently, Ford et al. (2015) estimated stray rates of natural origin spring Chinook salmon in the upper Wenatchee watershed using genetic techniques. Based upon tables 2 and 4 of Ford et al. (2015); stray rates were 4% or 3% for fish originating from the Chiwawa River, 18% or 17% for fish originating from the Little Wenatchee River, 9% for fish originating from Nason Creek, 1% or 5% for fish originating from the White River, and 100% for fish originating from the upper Wenatchee River. It is not clear why the numbers differ slightly between the tables.

Their continues to be a paucity of studies that have evaluated stray rates of natural origin fish, but the few studies that are available indicate that stray rates can be quite high and variable between locations.

Factors that influence stray rates

A variety of factors have the potential to influence stray rates of hatchery origin fish. Keefer and Caudill (2014, page 333) identified a number of factors that influence straying: "Research in several disciplines indicates that adult straying is affected by endocrine physiology and neurological processes in juveniles, incomplete or interrupted imprinting during rearing and emigration, and by complex interactions among adult maturation processes, reproductive behaviors, olfactory memory, environmental conditions during migration, and senescence physiology. Reported salmonid stray rates indicate that the behavior varies among species, among life-history types, and among populations within species." Furthermore they state on page 339, "In the wild, changing environmental conditions and stress promote frequent hormonal fluctuations, which in turn generate olfactory receptor neurons and imprinting opportunities. In contrast, juveniles reared in relatively stable hatchery environments show fewer and lower amplitude hormone surges. These differences likely explain the reduced imprinting and a greater propensity for straying in hatchery versus wild salmonids."

Ford et al. (2015) found variation in spring Chinook salmon stray rates that were related to origin (hatchery vs. natural) and location (e.g., tributary such as Nason Creek). Fish released from the Chiwawa acclimation facility had higher stray rates than natural origin fish that originated from the Chiwawa River. Progeny of hatchery origin fish that spawned in nature had higher rates of straying than progeny of natural origin fish that spawned in nature. They suggested that the difference in stray rates between origins could be a genetic effect. They further speculated that variation in location such as the upper Wenatchee River may be partially explained by the quality of spawning habitat; poor spawning habitat was related to high stray rates.

Dittman et al. (2010) evaluated homing of spring Chinook salmon that were released from three different acclimation sites in the upper Yakima River watershed. They found that, “While homing was clearly evident, the majority (55.1%) of the hatchery fish were recovered more than 25 km from their release sites, often in spawning areas used by wild conspecifics.” They further concluded that, “These results suggest that genetics, environmental and social factors, or requirements for specific spawning habitat may ultimately override the instinct to home to the site of rearing or release.” Cram et al. (2012) also showed evidence of multiple factors influencing homing of hatchery origin spring Chinook salmon in the Yakima River; “Environmental conditions near each acclimation facility were markedly different and contributed to varying fidelity among spawning groups to their release areas.” “Acclimation facilities characterized by marginal habitat could be expected to have higher stray rates than those in more productive areas”. “Salmon released from the two sites that were located in areas of marginal spawning habitat quality (Clark Flat and Jack Creek) showed low fidelity to their acclimation areas, but their distribution was affected by homing. Females that strayed from these acclimation sites may be the most likely to colonize other reaches in the watershed, as they are unable to spawn near their release site.” Dittman et al. (2010) estimated a stray rate of 97% for fish released from the Jack Creek acclimation site and spawned in 2005. It was highly unlikely that the high stray rate was the result of poor imprinting and more likely to have been due to access and spawning habitat (Cram et al. 2012); “social or imprinting factors are unlikely to be the primary drivers of straying behavior, given the frequency with which the Cle Elum River was used for spawning by hatchery-origin females. Females that spawned in the Cle Elum River were almost exclusively wild- or Jack Creek-origin salmon.”

Westley et al. (2013) concluded that there are differences among different taxonomic groupings of fish: “Our results revealed large and generally consistent differences in the propensity to stray among species, life history types within species, and populations. Paired releases indicated that (i) Chinook salmon (*Oncorhynchus tshawytscha*) strayed more (mean population range 0.11%–34.6%) than coho salmon (*Oncorhynchus kisutch*) (0.08%–0.94%); (ii) ocean-type Chinook (5.2%–18.6%) strayed more than stream-type Chinook (0.11%–10%); and Chinook salmon (0.90%–54.9%) strayed more than steelhead (0.30%–2.3%). We conclude these patterns are largely the result of species-specific behavioral and endocrine factors during the juvenile life stages, but analyses also suggest that environmental factors can influence straying during the adult upstream migration.” The magnitude of straying presented by Westley et al. (2013) was influenced by the spatial scale that was considered a stray; “each recovery we defined individuals as strays if they were recaptured outside the river basin of their release, a spatial scale that generally conforms to the local population level and scale for conservation.” This spatial scale is generally larger than what is targeted in the upper Columbia Basin and so the relatively low magnitudes of straying are likely the result of the spatial scale evaluated.

Westley et al. (2015) found that multiple factors influenced straying including migration distance and density dependence: “We used two decades of tagging and recapture data from 19 hatchery populations of *Oncorhynchus tshawytscha* (Chinook salmon) in the Columbia River, USA, to quantify the effects of regional and local climate conditions, density dependence, watershed features such as area and position on the landscape, and direct anthropogenic influence on dispersal rates by adult salmon during the breeding season. We found that the probability of dispersal, termed ‘‘straying’’ in salmon, is plastic in response to multiple factors and that populations showed varied responses that were largely idiosyncratic. A regional climate index (Pacific Decadal Oscillation), water temperatures in the mainstem Columbia River that was commonly experience by populations during migration, water temperatures in local subbasins unique to each population during the breeding season, migration distance, and density dependence had the strongest effects on dispersal." They further stated: "Ultimately, our results provide evidence that analyses that examine the response of dispersal to single factors may be misleading."

There are likely a variety of other factors that influence straying that have not been discovered yet, but published work indicates a variety of factors influence stray rates including those outside the control of hatchery imprinting.

Implications of stray data on stray rate target

The stray rate of adult fish that were born in nature is likely to be the best that could be expected for hatchery programs (i.e., optimal imprinting for the given environmental conditions) and it may not be possible to duplicate similar rates of straying in hatchery programs. Hatchery fish may have higher stray rates than natural origin fish because of: 1) imperfect water sources for rearing and acclimation, 2) moving fish resulting in less than optimal imprinting circumstances (e.g., to acclimation sites, Dittman et al. 2015), 3) low stress resulting in low hormone triggers to promote imprinting in juveniles (Keefer and Caudill 2014), 4) altering a natural life-history pattern (e.g., subyearling to yearling; Westley et al. 2013), 5) the timing and method of release (Keefer and Caudill 2014), as well as 6) the possible genetic phenomenon that offspring of hatchery origin fish stray more than offspring of natural origin fish (Ford et al. 2015). The genetic effect may be stronger in the first generation than the second generation so the hatchery effects reported by Ford et al. (2015) for naturally spawned progeny may be even larger in first generation hatchery fish. It is possible to control some of the factors that contribute to higher stray rates of hatchery fish, but others are likely to be an inherent cost of achieving other hatchery related benefits (i.e., a tradeoff).

The PUD M&E plan says that the stray targets will be revised as new information becomes available:

> "When populations are not independent, straying among them does not pose a risk of genetic homogenization. In addition, stray rates of hatchery-origin fish cannot be expected to be lower than for natural-origin fish. When estimates of stray rates for natural-origin fish are available and if they exceed the 5% or 10% thresholds identified in this plan, analysis and interpretation of stray rates must take into account the concept that hatchery programs may be held to unattainable standards based on the natural stray rate." (Hillman et al. 2013).

There is new published information about the stray rate of naturally spawning fish that indicates that the 5% brood year stray target should be revised because stray rates of offspring of naturally spawning fish can exceed 5% and that stray rate is influenced by a number of factors outside the control of hatchery programs.

In their review of straying, Keefer and Caudill 2014 (page 359) concluded: "There are certainly no universally 'appropriate' straying rates that can be used as management targets." Furthermore, they wrote, "Fisheries managers must balance the potential demographic and genetic risks of straying on both donor and recipient populations with the benefits of proposed management actions. This will require consideration of how strays are identified and enumerated, the size and spatial distribution of donor and recipient populations, and agreement about what stray rates are desirable or ‘‘natural’’. Costs, benefits, and target rates are likely to differ widely among study systems.”

Furthermore, changing the normal life-history of fish in hatcheries can result in trade-offs describe by Westley et al. (2013; page 744) “the release of ocean-type Chinook salmon as yearlings rather than subyearlings was associated with increased straying. Presumably, this reflects a disruption of the normal seasonal patterns of growth, endocrine events, imprinting, and migration for the yearling releases. Though the mechanisms underpinning this finding are unclear, the patterns suggest that attempts to rear ocean-type Chinook salmon an extra year in fresh water to increase the size of smolts may come at a cost of extra straying.” In short, the benefit of higher survival must be assessed relative to benefits of homing: both cannot be maximized in all hatchery programs.

Consistent with the finding from Keefer and Caudill (2014) that there is not a universally appropriate stray rate target, it is recommended that the brood year stray rate target in Hillman et al. (2013) be eliminated or revised using the best available information. If sufficient information is available, then location and stock specific brood year stray targets could be approximated using the following equation: Target = (stray rate of natural origin fish from hatchery parentage) + (stray rate addition as a result of hatchery experience) + (stray rate addition from poor habitat, high density, and other non-imprinting factors). In most cases, sufficient information will not be available to populate such an equation and case-by-case management choices will have to be made to balance the benefits and costs of artificial propagation (Keefer and Caudill 2014).

It is important to note that imprinting is one of many factors that influence straying. As such, hatchery programs do not have full control over the stray rate of hatchery fish. For example, if habitat conditions or access are poor or become worse, then it is possible that stray rates may be high or could increase (e.g., Jack Creek and Clark Flats acclimation sites in the Yakima Basin; Cram et al. 2012). Furthermore, the density of spawners or juveniles, amount of pesticide exposure, or other habitat conditions can influence stray rates (Keefer and Caudill 2014, Brett and Hinch 2015).

Use of acclimation sites are a trade-off that generally result in increased number of fish back to a target location but at the cost of increased stray rates (relative to on-station release such as Methow Hatchery). As such, a balanced approach might include determining the desired number of fish to return to a target location, adjusting program size by factoring in the stray rate, and then determining whether the system can absorb the number of strays. If the number of strays is too high, then one option is to reduce the number of fish released into a target area until acceptable numbers of strays are achieved. Alternatively, if straying is caused by poor habitat conditions, then efforts to improve spawning habitat could be pursued.

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FINAL

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ANCHOR QEA

Memorandum

To: Wells, Rocky Reach, and Rock Island HCPs Hatchery Committees

Date: April 20, 2017

From: Tracy Hillman, HCP Hatchery Committees Chairman

cc: Sarah Montgomery, Anchor QEA, LLC

Re: Final Minutes of the March 13, 2017, HCP Hatchery Committees Meeting

The Wells, Rocky Reach, and Rock Island Hydroelectric Projects Habitat Conservation Plans (HCPs) Hatchery Committees meeting was held at the Grant PUD office in Wenatchee, Washington, on Monday, March 13, 2017, from 1:00 p.m. to 4:30 p.m. Attendees are listed in Attachment A to these meeting minutes.

Action Item Summary

- McLain Johnson (Washington State Department of Fish and Wildlife [WDFW]) will revise the timeline for conducting genetic analysis for HCP program species incorporating suggestions provided during the Hatchery Committees January 18, 2017, meeting (Item I-A). *(Johnson sent the revised timeline to the Hatchery Committees on April 6, 2017.)*
- McLain Johnson and WDFW geneticists will perform a power analysis to inform genetic analysis intervals and intensity for HCP program species (Item I-A). *(Johnson sent a memo regarding genetic analysis intervals to the Hatchery Committees on April 6, 2017.)*
- Andrew Murdoch (WDFW) will write an overview of proposed expanded sampling at the off-ladder fish trap (OLAFT) at Priest Rapids Dam (Item I-A). *(Note: this item is ongoing.)*
- Hatchery Committees representatives will review the Hatchery Monitoring and Evaluation (M&E) Plan Objectives before the Hatchery Committees April 19, 2017, meeting (Item IV-A).
- Casey Baldwin will discuss internally the steelhead marking strategy in the draft 2017 Broodstock Collection Protocols and provide feedback to Mike Tonseth (Item IV-D).
- Keely Murdoch will discuss internally the Yakama Nation (YN)'s egg requests for their summer Chinook salmon program (Item IV-D).
- Hatchery Committees representatives will discuss internally WDFW's proposal for collection and rearing for the Twisp Steelhead program in 2017 and provide a vote by March 30, 2017 (note: this includes adult collection at the Twisp Weir, transfer to Winthrop National Fish Hatchery (NFH), spawning as part of aggregate composite population. and incubation to eyed-egg or fry stage at Winthrop NFH, then transfer to Methow Fish Hatchery (FH); Item IV-E). *(See "Agreements".)*

- Catherine Willard will revise the draft study plan, "Outplanting Surplus Methow Composite Spring Chinook Salmon Adults to Increase Natural Production in the Chewuch River," and distribute it to the Hatchery Committees for approval at the April 19, 2017, meeting (Item IV-F). *(Note: Willard sent a revised draft plan to Sarah Montgomery on March 24, 2017, which she distributed to the Hatchery Committees that same day.)*
- Tracy Hillman will preliminarily revise the brood-year (BY) stray rate target language in the Hatchery M&E Plan for further discussion at the Hatchery Committees April 19, 2017, meeting (Item IV-G).
- Tracy Hillman will assess the relationship over the last 10 years between exceeding BY stray rate targets and exceeding recipient stray rate targets (Item IV-G).

Decision Summary

- The Wells Hatchery Committee representatives present approved Douglas PUD's Wells HCP 2017 Action Plan as follows: Douglas PUD, U.S. Fish and Wildlife Service (USFWS), WDFW, National Marine Fisheries Service (NMFS), YN, and Colville Confederated Tribes (CCT) approved on March 13, 2017 (Item II-A). *(Note: the Wells HCP Coordinating Committee will also discuss the Action Plan on March 28, 2017.)*
- The Wells Hatchery Committee representatives present approved Douglas PUD's Statement of Agreement (SOA), M&E Reporting Schedule for the Douglas PUD, Grant PUD, and Chelan PUD Hatchery Programs, as follows: Douglas PUD, USFWS, WDFW, NMFS, YN, and CCT approved on March 13, 2017 (Item II-B).
- The Rock Island and Rocky Reach Hatchery Committees representatives present approved Chelan PUD's SOA, M&E Reporting Schedule for the Douglas PUD, Grant PUD, and Chelan PUD Hatchery Programs, as follows: Chelan PUD, USFWS, WDFW, NMFS, YN, and CCT approved on March 13, 2017 (Item III-A).
- The Rock Island and Rocky Reach Hatchery Committees representatives approved Chelan PUD's draft 2017 Steelhead Release Plan as follows: Chelan PUD approved on March 13, 2017, and USFWS, WDFW, NMFS, YN, and CCT approved via email on March 16, 2017 (Item III-B).
- The Hatchery Committees representatives approved WDFW's draft (v3) 2017 Broodstock Collection Protocols as follows: WDFW, Chelan PUD, Douglas PUD, NMFS, USFWS, YN, and CCT approved via email on April 7, 2017 (Item IV-D). *(Note: the Wells HCP Coordinating Committee also approved the protocols via email on April 11, 2017.)*

Agreements

- The Wells Hatchery Committee agreed that the approximately 48,000 BY 2016 Twisp River steelhead smolts will be truck-released from Buttermilk Bridge instead of acclimated at the Twisp Acclimation Pond (Item IV-E).
- The Rock Island Hatchery Committee agreed that Chelan PUD and USFWS can perform maturation sampling for 300 Chiwawa spring Chinook salmon (Item IV-H).
- The Wells Hatchery Committee agreed that Douglas PUD may perform maturation sampling for 300 Methow spring Chinook salmon (Item IV-H).
- The Wells Hatchery Committee approved the following items related to the Twisp Steelhead Program: 1) For the 2017 BY, the HC agrees to use composited broodstock (in coordination with the USFWS program at WNFH) to support the Douglas PUD S1 conservation program currently in the Twisp River, and 2) Broodstock sufficient to meet Douglas PUD's Twisp S1 conservation program will be collected via hook-and-line in the mainstem Methow River concurrent with broodstock collection for the USFWS and utilize the Twisp Weir as a backup location if mainstem collections fall short. Adults will be transferred to, held, spawned, and incubated to the eyed egg stage at Winthrop NFH. Eyed eggs proportionally representative from each spawn take necessary to meet DPUD's 48K S1 conservation production will be transferred to Wells hatchery for final incubation and rearing before release. These items were approved via email as follows: WDFW and YN approved on March 30, USFWS and CCT approved on March 31, NMFS approved on April 4, and Douglas PUD approved on April 5, 2017, and concurred with 3) For the 2017 juvenile releases, 13,000 Winthrop NFH S2 conservation fish will be direct planted at Buttermilk Bridge (Item IV-E).

Review Items

- Sarah Montgomery sent an email to the Hatchery Committees on March 24, 2017, notifying them that a revised version of the Draft Outplanting Surplus Methow Spring Chinook Salmon Plan is available for review, with comments due to Catherine Willard by April 12, 2017 (Item IV-F).

Finalized Documents

- Sarah Montgomery sent an email to the Hatchery Committees on March 13, 2017, notifying them that the Final Douglas PUD SOA, M&E Reporting Schedule for the Douglas PUD, Grant PUD, and Chelan PUD Hatchery Programs, is now available for download from the Hatchery Committees Extranet site.

- Sarah Montgomery sent an email to the Hatchery Committees on March 13, 2017, notifying them that the Final Chelan PUD SOA, M&E Reporting Schedule for the Douglas PUD, Grant PUD, and Chelan PUD Hatchery Programs, is now available for download from the Hatchery Committees Extranet site.
- Sarah Montgomery sent an email to the Hatchery Committees on March 13, 2017, notifying them that the Final M&E Reporting Schedule for the Douglas PUD, Grant PUD, and Chelan PUD Hatchery Programs is now available for download from the Hatchery Committees Extranet site.
- Sarah Montgomery sent an email to the Hatchery Committees on March 24, 2017, notifying them that the 2016 Wells HCP Annual Report was finalized following a 30-day review period, which ended on March 10, 2017. Comments received on the draft report were incorporated into the final report.
- Sarah Montgomery sent an email to the Hatchery Committees on April 6, 2017, notifying them that the 2016 Rock Island and Rocky Reach HCP Annual Reports were finalized following a 30-day review period, which ended on March 20, 2017. Comments received on the draft report were incorporated into the final report.
- Sarah Montgomery sent an email to the Hatchery Committees on April 14, 2017, notifying them that the Final 2017 Broodstock Collection Protocols were finalized and submitted to NMFS, and are now available for download from the Hatchery Committees Extranet site.

I. Welcome

A. Review Agenda, Review Last Meeting Action Items, and Approve the February 15, 2017, Meeting Minutes (Tracy Hillman)

Tracy Hillman welcomed the Hatchery Committees and asked for any additions or changes to the agenda. The following revisions were requested:

- Greg Mackey added a discussion regarding Methow Hatchery Pond 13 Predation

Sarah Montgomery said the revised draft February 15, 2017, meeting minutes are available for review until March 15, 2017 (seven days after they were distributed), but the Hatchery Committees can still discuss the minutes today and elect to approve them early. The Hatchery Committees reviewed the revised draft February 15, 2017, meeting minutes. Montgomery said there are several outstanding comments to be discussed, which the Hatchery Committees reviewed and addressed. Hatchery Committees representatives present approved the draft February 15, 2017, meeting minutes, as revised.

Action items from the Hatchery Committees meeting on February 15, 2017, and follow-up discussions were addressed *(note: italicized text below corresponds to agenda items from the meeting on February 15, 2017)*:

- *Sarah Montgomery and Tracy Hillman will renumber the Hatchery Monitoring and Evaluation (M&E) Plan appendices and append them to the Hatchery M&E Plan (Item I-A).*
  This item is complete.
- *Sarah Montgomery will add a summary table to the draft summary of the 5-Year Hatchery M&E Review process (Item I-A).*
  This item is complete.
- *McLain Johnson (Washington State Department of Fish and Wildlife [WDFW]) will revise the timeline for conducting genetic analysis for HCP program species by incorporating suggestions provided during the Hatchery Committees January 18, 2017, meeting (Item I-A).*
  This item is ongoing. Mike Tonseth said he expects a revised timeline will be distributed to the Hatchery Committees soon.
- *McLain Johnson and WDFW geneticists will perform a power analysis to inform genetic analysis intervals and intensity for HCP program species (Item I-A).*
  This item is ongoing.
- *Greg Mackey will distribute a link to Scott Blankenship's (Cramer Fish Sciences) blog (Item III-B).*
  Mackey sent a paper and tool by Blankenship on the Ryman-Laikre effect to Montgomery on March 3, 2017, which she distributed to the Hatchery Committees that same day. Mackey said the blog was not working when he searched for the link.
- *Brett Farman will check on the status of Methow spring Chinook salmon permits and the timeline for Methow steelhead consultation (Item IV-B).*
  Farman provided an update on the status of Methow spring Chinook salmon permits, which is included under item IV-C in these meeting minutes.
- *Catherine Willard will look into other potential release locations in the Chewuch River, particularly upstream, for the spring Chinook salmon outplanting study (Item IV-D).*
  Willard said this will be discussed today.

- *The Hatchery Committees will review the draft study plan, "Outplanting Surplus Methow Composite Spring Chinook Salmon Adults to Increase Natural Production in the Chewuch River," and provide comments to Catherine Willard by March 8, 2017. Sarah Montgomery distributed the draft outplanting plan to the Hatchery Committees on February 14, 2017 (Item IV-D).*
  Willard said comments were received and incorporated into the revised draft for discussion today.

- *Greg Mackey will coordinate with Chelan and Grant PUDs to revise the proposed Hatchery M&E Reporting Timeline, which Sarah Montgomery distributed to the Hatchery Committees on February 13, 2017 (Item IV-E).*
  This item is complete and will be discussed today; a revised version was distributed on March 2, 2017.
- *Tracy Hillman will discuss with WDFW and Yakama Nation (YN) the level of effort involved in adding statistical analyses to the annual M&E reports for PUD programs (Item IV-E).*
  Hillman said he discussed this with Andrew Murdoch (WDFW) and Brian Ishida (YN); however, the PUDs decided not to include statistical analyses in the annual M&E Reports.
- *Andrew Murdoch will write an overview of proposed expanded sampling at the off-ladder fish trap (OLAFT) at Priest Rapids Dam (Item IV-F).*
  Mike Tonseth said this is ongoing.

II. Douglas PUD

A. Decision: Draft 2017 Wells HCP Action Plan (Greg Mackey)

Greg Mackey shared a document titled "Draft 2017 Wells HCP Action Plan" (Attachment B), which Sarah Montgomery distributed to the Hatchery Committees on February 23, 2017. Mackey said the plan is similar to previous years. He said the Wells Hatchery Modernization will be completed in August, so he can arrange a tour or meeting at the facility at that time. The Wells Hatchery Committee representatives present approved the hatchery portion of Douglas PUD's Wells HCP 2017 Action Plan as follows: Douglas PUD, USFWS, WDFW, NMFS, YN, and CCT approved on March 13, 2017.

B. Decision: Wells HCP SOA M&E Report Scheduling (Greg Mackey)

Greg Mackey said the Wells Hatchery Committee is voting on an SOA specific to the Wells HCP, even though the topic of the SOA is a joint HCP-HC and Priest Rapids Coordinating Committee Hatchery Sub-Committee (PRCC HSC) discussion (under item IV-A). The Wells Hatchery Committee representatives present approved Douglas PUD's SOA M&E Reporting Schedule for the Douglas PUD, Grant PUD, and Chelan PUD Hatchery Programs, as follows: Douglas PUD, USFWS, WDFW, NMFS, YN, and CCT approved on March 13, 2017. Sarah Montgomery distributed a final version of the SOA, which is included in these minutes as Attachment C.

C. Methow Pond 13 Predation (Greg Mackey)

Greg Mackey said there have been high levels of predation at Pond 13 at the Methow FH this winter. He said Pond 13 is a rectangular outdoor pond, where approximately 80,000 spring Chinook salmon were placed during the summer and held throughout the winter. He said despite using wires, netting, and daytime hazing to deter predators, many of the salmon were consumed by birds, especially by mergansers, cormorants, and herons. He said one potential cause for the higher than usual predation is that it was a cold winter and more bodies of water than usual froze over. He said Pond 13 was one of the only open water areas nearby, so it attracted birds.

Hatchery managers seined and weighed fish in the pond to determine how many salmon survived. They estimated about 35,306 salmon remain. He said current plans to further deter predators include installing a 12-foot chain-link fence with a higher density of bird wires (but not so dense as to trap or kill birds).

Bill Gale asked how this level of predation affects overall release goals. Mackey said the Twisp Program has extra spring Chinook salmon smolts (approximately 11,000 extra smolts). He said the Methow spring Chinook salmon program has approximately 191,200 smolts remaining, which is about 15% lower than the release goal. Jayson Wahls (WDFW) said this was an abnormal year for temperature and predation. He said the primary predators were mergansers, cormorants, and herons, and he noticed more birds than usual accessing Pond 13. He said Pond 13 is susceptible to predation because its netting must be removed in the winter (otherwise it freezes into the pond during snow loads).Douglas PUD and Methow FH staff are planning to install more bird wires to decrease future predation.

III.Chelan PUD

A. Decision: Rocky Reach/Rock Island HCP SOA M&E Report Scheduling (Catherine Willard)

Catherine Willard said the Rocky Reach and Rock Island Hatchery Committees are voting on an SOA specific to the Rocky Reach and Rock Island HCPs, even though the topic of the SOA is a joint HCP-HC and PRCC HSC discussion (under item IV-A). Mike Tonseth suggested one change to language in the SOA related to Endangered Species Act (ESA) permits, which Willard edited in the document. The Rocky Reach and Rock Island Hatchery Committees representatives present approved Chelan PUD's SOA M&E Reporting Schedule for the Douglas PUD, Grant PUD, and Chelan PUD Hatchery Programs, as follows: Chelan PUD, USFWS, WDFW, NMFS, YN, and CCT approved on March 13, 2017. Sarah Montgomery distributed a final version of the SOA, which is included in these minutes as Attachment D.

B. Decision: Draft 2017 Steelhead Release Plan and Preliminary 2016 Results (Catherine Willard)

Catherine Willard shared a presentation titled, "Release Year 2016 Preliminary Results" (Attachment F). Willard described the program and variables at Chiwawa Acclimation Facility, then summarized the preliminary results for survival to McNary Dam for screened (which includes movers vs. non-movers) vs. non-screened, brood origin (HxH vs. WxW) and release locations (Chiwawa River, Nason Creek, and upper Wenatchee River). Fork length, smolt index, and residualism were also evaluated. Questions and comments are summarized in the following sections.

Bill Gale asked if the survival for Blackbird Island Pond is evaluated based on only fish that leave the pond, or the survival of all the fish that are were stocked in the pond. Willard replied that Chelan PUD uses passive integrated transponder (PIT) tags to track the survival of fish stocked in Blackbird Island Pond and fish that stay in the pond are not removed from the analysis.

Tracy Hillman asked where flow (cubic feet per second [cfs]) is measured for the Chiwawa River releases. Willard said flow is measured at the gauge in Plain, Washington.

Regarding the expanded numbers for potential residuals by BY, Hillman asked if any of the steelhead migrated downstream after holding for one year. Willard said there is evidence that at least one PIT-tagged fish did this and Chelan PUD is working with John Skalski (Columbia Basin Research) to determine if residualism can be estimated from historic data and if additional PIT tags and/or PIT antenna arrays are needed in the Wenatchee sub-basin to provide a more robust estimate of residualism for future releases.

Regarding the BY 2015 screened movers and screened non-movers, Casey Baldwin asked if there is a significant difference in release timing between the two groups. Willard said yes ($P<0.01$); there were significantly more non-movers detected after July 1 than movers. She said the multiple cohort analysis will provide a better assessment of PIT-tagged fish that stay longer than 1 year before migrating, which will supplement information gained from studying movement before and after July 1.

Willard shared a document titled "Draft 2017 Steelhead Release Plan" (Attachment G), which Montgomery distributed to the Hatchery Committees on March 6, 2017. Willard summarized the differences between the draft 2017 plan and the 2016 plan. Willard said Chelan PUD will only perform screened (a.k.a. volitional) releases in 2017 and will implement more intensive length-weight sampling on fish held indoors to increase the dataset for non-moving fish. She said Chelan PUD plans to PIT-tag a group of non-moving fish (held in the raceway) to assess the movements of non-moving fish. She said one potential change for 2017 that is not included in this document is an evening release and Chelan PUD and WDFW are working together to determine its feasibility.

Willard said Chelan PUD requests a vote on the draft release plan either today, or before March 16, 2017 (10 days after the plan was distributed). Hillman asked the Rocky Reach and Rock Island Hatchery Committees if they approve the plan or if they would like more time. The Chelan PUD representatives present approved the 2017 Steelhead release plan during the meeting on March 13, 2017, and other parties said they would provide a vote by March 16, 2017. (Note: The 2017 Steelhead Release Plan was approved by USFWS, WDFW, NMFS, YN, and CCT via email on March 16, 2017.)

IV. Joint HCP-HC/PRCC HSC

A. Decision: M&E Report Scheduling (Greg Mackey/Catherine Willard)

Greg Mackey shared a document titled, "Monitoring and Evaluation Reporting Schedule for the Douglas PUD, Grant PUD, and Chelan PUD Hatchery Programs," which Sarah Montgomery distributed to the Hatchery Committees on March 2, 2017 (Attachment E). Mackey said Douglas PUD and Chelan PUD also have SOAs related to this document (Items II-B and III-A). The SOAs provide background and purpose for the schedule, and the schedule itself is a separate document that describes the reporting timeline and content and function of each report. Mackey said this document details the required M&E reports and actions, the content of the M&E reports, and the reporting schedule through 2052. He said Table 3 summarizes the schedule and data to be used in each report. He said 2017 to 2019 is a transition period, after which the schedule falls into regular reporting cycles. Todd Pearsons asked if the Statistical Report would be produced every 5 years except in years where the Program Review is also produced (i.e., every 10 years, with statistical information included in the Program Review document instead of a separate Statistical Report). Keely Murdoch said yes, statistical analyses will be performed every 5 years and will be included in the Statistical Report or Program Review, which alternate every 5 years. Mackey said the last report including statistical analyses was completed in 2012, so analyses were initially planned for 2017 in the schedule (5 years later), but have been moved to 2019 (7 years later) to coincide with the Program Review. He said if there are any statistical questions about certain datasets in the interim, specific analyses can be performed.

Mackey said there is currently an M&E Plan update scheduled for 2017 or 2018, then one again in 2021. Mike Tonseth recalled the level of effort involved in updating the M&E Plan and appendices, and suggested the Hatchery Committees review the M&E Plan and write amendments to the existing plan as necessary in 2017 or 2018, with the expectation that the 2021 update incorporates these amendments into the M&E Plan itself. Regarding contracting, Bill Gale asked if there is an ideal time of year to complete the M&E Plan update. Mackey said Douglas PUD begins their M&E contract year on January 1, so September would be a good target to finish the update in order to draft related items, such as budgets and scopes of work for contracting. Willard agreed for Chelan PUD. Pearsons said Grant PUD would prefer to finalize updates in August. Murdoch said she does not anticipate updating the M&E Plan will take much effort and it could even be completed by August 2017. Tonseth said the Hatchery Committees should focus the next update (in 2017 or 2018) on items that need to be fast-tracked for implementation. Mackey suggested the Hatchery Committees representatives review the Hatchery M&E Plan prior to the April 19, 2017, meeting and bring forth any objectives for discussion. Representatives present agreed to update the M&E Plan in 2018. The Wells, Rocky Reach, and Rock Island Hatchery Committees voted on the SOAs approving the schedule as described under Items II-B and III-A.

B. USFWS Bull Trout Consultation Update (Matt Cooper)

Matt Cooper said Karl Halupka (USFWS) sent him an update on USFWS consultations, which he summarized as follows:

- The USFWS is moving forward with finalizing the biological opinion (BiOp) for the batch of Wenatchee hatchery programs. USFWS requests comments by Friday, March 31, 2017, and will respond to comments, review the BiOp internally, then finalize it, with a target date of mid-May.

- Natasha Meyers-Cherry (NMFS) has been coordinating with Halupka about the next hatchery program consultation in the upper Columbia River basin. There are two candidates; Methow steelhead and a batch for Columbia River mainstem unlisted programs. Which of these will go first is currently unclear, but NMFS will coordinate with committee members on the decision. Either candidate will likely result in information requests from the USFWS to committee members about specific aspects of these programs as they are currently implemented.

Mike Tonseth asked if Halupka would like feedback on prioritization for the next hatchery program consultation and said he believes Methow steelhead are the priority. Cooper said NMFS will coordinate that prioritization. Bill Gale said some of the steelhead programs in the Methow basin already have bull trout coverage—similarly to the Methow spring Chinook salmon programs, the steelhead program at Winthrop NFH has bull trout coverage (the USFWS is currently reviewing the adequancy of coverage for the PUD programs). Greg Mackey said the Wells BiOp should provide bull trout coverage for the new steelhead consultation. Gale said that would be a good question for Halupka, and said he is not sure whether the steelhead program has fishery effects; the spring Chinook salmon program does not, so the aspects of coverage may be different. Gale said a gap analysis will probably occur.

C. NMFS Consultation Update (Brett Farman)

Regarding the Methow spring Chinook salmon consultation, Brett Farman said the last signatures are being obtained and the permits should be distributed this week by Charlene Hurst.

Regarding the Methow steelhead consultation, Farman said Hurst may have time in May and June to work further on finalizing this consultation. He said the proposed action needs to be finalized, which will include genetics and fisheries information. He said for some of the programs, Section 7 consultations will be complete, but National Environmental Policy Act (NEPA) will not be complete, and permits will not be issued. He said NMFS is trying to finish the Section 7 consultations, then follow up with NEPA and permit processes. Gale asked if that means it would be approximately 12 months until permits are issued for the Methow steelhead consultation. Farman said it depends on other timelines and there is not a defined sequence or timeline at this time. Mackey said if Hurst needs anything else for the next steps for this consultation to please let the PUDs know. Farman said he is not aware of any specific needs, but that communication can happen with Hurst.

D. Draft 2017 Broodstock Collection Protocols (Mike Tonseth)

Mike Tonseth shared a document titled, "Draft 2017 Broodstock Collection Protocols v1" (Attachment H), which Sarah Montgomery distributed to the Hatchery Committees on March 3, 2017. Tonseth said he requested feedback on the protocols and changes from 2016 and comments will be discussed today.

Tonseth said one item that should be discussed is external marking for Okanogan steelhead program wild-by-wild fish. He said there is currently a "TBD" label for this program in Appendix B. Tonseth said in 2016, Kirk Truscott had incorporated language in the protocols for external marking to include an alternate fin clip to distinguish from other program fish, which was never resolved during the year. He said now would be a good time to discuss and resolve this. Todd Pearsons said there is concern about doing a ventral clip on descendants of wild-by-wild Omak steelhead and marking should be consistent with the conservation value of the fish. Casey Baldwin agreed and said he would discuss this with Truscott. Tonseth said Truscott had brought up potentially differentiating between Omak wild-by-wild and Twisp wild-by-wild steelhead. Baldwin asked if the differential marking is related to a Methow management objective. Tonseth said the Methow steelhead program may be bound by proportionate natural influence and proportion of hatchery-origin spawners objectives and fish may need to be intercepted earlier in the system, so distinguishing between Methow and Omak steelhead may be desired. Baldwin asked why Omak fish should be marked instead of Twisp fish, since it is a Methow management objective. Greg Mackey said the Twisp Weir is being used to target Twisp wild-by-wild fish, so they are no longer collecting wild broodstock at Wells Dam. He said it would not be desirable to take steelhead bound for the Okanogan River and put them into a Wells FH program, since the CCT are trying to get an Okanogan basin steelhead stock going. He said he and Truscott had discussed how it is difficult to differentially mark all the different groups of steelhead coming through Wells Dam. Baldwin said he and Truscott will discuss this and provide clarification on the steelhead marking strategy for Omak steelhead.

Tonseth said another question in the protocols regards summer Chinook salmon eggs for the YN program. He said each year, the protocols state an egg allocation for the YN program, and he asked Keely Murdoch to discuss whether the request in the protocols is still consistent with YN's expectations. Murdoch said she will discuss this internally.

Tonseth said one change from the 2016 protocols is the Methow spring Chinook salmon trapping schedule. He said the Wells HCP Coordinating Committee has oversight for the trapping schedule because it is related to fish passage and hydropower operations. The 2017 protocols include additional trapping days (5 total days per week, not to exceed 3 days in a row) to increase the probability of meeting the broodstock collection targets for the program and a decrease in the total trapping hours per day to 12 hours. He said this schedule provides more availability and flexibility in broodstock collection without a significant increase in trapping hours.

Tonseth said the ongoing discussion about the Twisp steelhead conservation program also factors into the draft 2017 Broodstock Collection Protocols. He said the 2017 protocols include a near-term plan for the direction of the Methow steelhead program: compositing the existing programs with a Winthrop NFH component and a PUD component and mixed releases of S1 and S2 smolts in the Twisp River and other locations. He said the Joint Fisheries Parties (JFP) identified a necessity to develop a steelhead management plan (similar to that proposed for spring Chinook salmon), so there is better direction on steelhead recovery in the Methow basin. He said the current proposal is to composite the Twisp and Winthrop NFH programs. The one-year smolt program (48,000 fish) would be a combined USFWS-and Twisp broodstock, then sufficient eggs would be transferred to Methow or Wells FH for rearing, and fish would be released into the Twisp River (at Buttermilk Bridge), from Winthrop NFH on station, or released elsewhere in the basin as part of a study. He said studies could be set up on a rotational basis, such as 5 years of supplementation in the Chewuch River, then 5 years of supplementation at another location. Tonseth summarized that compositing the programs is the near-term plan while a comprehensive management plan is being developed.

Bill Gale said compositing the program would help with steelhead gene flow in the Methow basin, because each year would have multiple BYs returning. He said the steelhead currently released from Methow FH should be PIT-tagged [they already are] so their return locations can be evaluated. This would inform the longer-term plan and whether shifting to releases lower in the basin would help with management objectives. Mackey said Douglas PUD's No Net Impact commitment is 8,000 fish and they were releasing 48,000 to maintain constant release numbers for the reproductive success study, for which 2016 was the last adult cohort. He said the 48,000 number can change and Douglas PUD should contribute in whatever way makes the most sense for safety-net or conservation fishery numbers. Tonseth said the JFP thinks the conservation numbers (i.e., 48,000) should be maintained until the longer-term management plan is developed. Tonseth and Gale both emphasized the value in releasing S1 and S2 smolts in 2017 for comparison and age class diversity reasons. Mackey said he, Tom Kahler, and Todd Seamons (WDFW) discussed the Twisp steelhead program, and Seamons stated that steelhead are naturally a multi-age emigrant, but hatcheries force steelhead into one age class, which limits the age structure of the returning adults. This further emphasizes the benefit in having two age groups for 2017 releases. Tonseth summarized that the biggest change in the 2017 protocols is compositing the steelhead conservation programs in the Methow basin.

Gale said during the February 15, 2017, Hatchery Committees meeting, he requested an update from Chelan PUD on the feasibility study for Pacific lamprey at Tumwater Dam. Willard said Chelan PUD received the draft feasibility study on March 2, 2017, and it is currently undergoing internal review, after which it will be distributed to the Rocky Reach Fish Forum (RRFF) where anyone can receive updates. Gale said Pacific lamprey at Tumwater Dam are an issue for both the RRFF and the Hatchery Committees. Willard said Chelan PUD requests that Gale receive updates from Steve Lewis, the USFWS representative on the RRFF, or the HCP Coordinating Committees if it relates to passage, because it is not an issue for the Hatchery Committees to discuss. She said Chelan PUD understands that there are conflicting concerns regarding Pacific lamprey at Tumwater Dam, but Hatchery Committees representatives are responsible for implementing the hatchery programs, and that does not include Pacific lamprey at Tumwater Dam. Gale said the draft 2016 Rocky Reach HCP Annual Report states that Pacific lamprey are an issue for discussion in the HCP Coordinating Committees and HCP Hatchery Committees meetings. Willard said Chelan PUD does not intend to discuss Pacific lamprey during Hatchery Committees meetings; though they understand the concern for Pacific lamprey and implementing hatchery programs requires using Tumwater Dam. Tracy Hillman asked Gale about the level of detail of discussions about Pacific lamprey he is requesting, and whether he is asking for a broad overview of Chelan PUD’s current actions, or whether he is asking the Hatchery Committees to be involved in decision-making regarding Pacific lamprey. Gale said he is requesting a brief update on current actions and study results and that the USFWS vote on the draft 2017 Broodstock Collection Protocols depends on meeting the Upper Columbia Non-Target Taxa of Concern objectives for Pacific lamprey. Willard said Chelan PUD can provide a brief update, but not a presentation as previously requested. Tonseth suggested that the Hatchery Committees request an update from the RRFF on the status of Pacific lamprey-related activities occurring at Tumwater Dam that could affect actions that the Hatchery Committees are involved in. He said that would provide information about plans and actions and would not compromise the proposed broodstock collection protocols. He said while the RRFF is the appropriate venue for discussing Pacific lamprey, the Hatchery Committees should be aware of any actions that might affect meeting the goals and objectives of hatchery programs involving Tumwater Dam. Hillman said he is the chair of the RRFF and he can provide Pacific lamprey as they relate to Tumwater Dam updates to the Hatchery Committees.

Pearsons said another topic of discussion under broodstock collection protocols is the size of conservation programs. He said he noticed the large number of fish that would be managed at Tumwater Dam and if natural fish are being used in a way where their returning offspring are killed, it should be discussed in 2017. Pearsons clarified that he is specifically talking about Nason Creek spring Chinook salmon. He said Grant PUD's Nason Creek spring Chinook salmon came from tangle-net fishery broodstock collection, and he said he wants to discuss whether programs are the right mix of conservation and safety-net fish. Tonseth said this would not involve changing production levels, just the ratio of conservation to safety-net fish.

Tonseth said Pearsons' concern about the size of the conservation and safety-net programs also relates to potential M&E Plan updates. He said the Twisp steelhead program is experiencing a Ryman-Laikre effect and has a low effective population size. He said the genetic effects were detected because analyses were in place and sampling was relatively intensive. This begs the question of whether similar effects are occurring elsewhere in conservation programs, but are not being detected. He said smaller programs and populations are more at risk of negative genetic effects, so as the Hatchery Committees discuss new management plans with conservation elements, they should consider program sizes and potential genetic effects, which may also result in changes to the M&E Plan and objectives. He said the timeline and scope for M&E for conservation programs may need to be more intensive. Gale asked if the Wenatchee management plan has a timeline for being updated. Tonseth said that plan can be updated any time and developing Methow basin spring Chinook salmon and steelhead management plans will provide guidance for updating the Wenatchee management plan, too. He said effective population size is one extra consideration for management plans that may not have been originally considered.

Pearsons mentioned that the protocols can be discussed further on Thursday, March 16, 2017, during the joint portion of the PRCC HSC meeting, if Chelan and Douglas PUDs are available. Tonseth said he requests any further comments on the draft 2017 Broodstock Collection Protocols by March 16, 2017, and if edits are straightforward he will send a revised version to vote on via email. (Note: if further discussions are warranted, he and Montgomery will coordinate to set up a conference call.)

E. Brood Year 2017 Twisp Steelhead (Mike Tonseth)

Mike Tonseth said the draft 2017 Broodstock Collection Protocols previously discussed today include information for the BY 2018 Twisp River steelhead. He said because the Twisp program has spring collection targeted, adults are not yet in hand for the BY 2017. He said there are two components of the BY 2017 Twisp steelhead that need to be discussed.

The first component is the schedule and location for release of the BY 2016 Twisp steelhead. He said there are approximately 48,000 S1 smolts on hand for release. He said rather than acclimating and releasing them from the Twisp Acclimation Pond, WDFW would like to truck plant those fish at Buttermilk Bridge. He said plans for moving fish need to be decided quickly. Keely Murdoch asked if the smolts are PIT-tagged, and Tonseth replied yes. He said the total number that would be truck-planted at Buttermilk Bridge would be approximately 48,000 smolts, plus Winthrop NFH will also release an additional 13,000 smolts that have coded wire tags. The Wells Hatchery Committees representatives present agreed that the approximately 48,000 BY 2016 Twisp River steelhead smolts should be truck-released from Buttermilk Bridge, instead of acclimated at the Twisp Acclimation Pond as follows: Douglas PUD, WDFW, YN, CCT, USFWS, and NMFS agreed on March 13, 2017.

Tonseth said the second component is BY 2017 steelhead collection. He said WDFW wants to collect BY 2017 fish at the Twisp Weir in the spring, then transfer them to Winthrop NFH, where they would be spawned as part of the aggregate composite population there. Wells FH or Methow FH would then receive eggs or fry, and WDFW and Douglas PUD would rear the fish as S1s. He said the BY 2017 could be the start of what is proposed for BY 2018 and beyond. Some questions and concerns in deciding how to handle BY 2017 fish include fish health, temperature, live-spawning, sampling schemes, tagging, and hatchery space. Bill Gale said Chris Pasley (USFWS) and Jayson Wahls (WDFW) should discuss temperature concerns. Greg Mackey said one consideration for fish health is if Twisp wild brood are brought to Winthrop NFH and are live-spawned, then kelts will be on station, simplifying the kelt program, but possibly creating fish health transfer concerns for the juveniles. Murdoch said the Winthrop NFH brood is already live-spawned, so that would not be a difference from current methods. She said the difference in fish health protocols between the two programs is in their lethal sampling of fish. She said the Winthrop NFH program is big enough that a sufficient fish health sample is achieved without lethally sampling progeny from all wild females that are live-spawned (males and hatchery-origin fish are lethally sampled). She said WDFW's Twisp steelhead program lethally samples fry from 100% of live-spawned fish, so a question for WDFW's fish health program is whether subsampling of adults instead of sampling progeny of live-spawned females is sufficient. Tonseth said there might be enough background and sampling at a high enough rate that subsampling could be sufficient, but the fish health experts will need to talk about it. He said WDFW's preference is to transfer eyed eggs, not fry. Wahls said more feedback is needed, but he does not think WDFW will allow transferring non-tested fish. Mackey said keeping the fish until they are juveniles creates a lot more effort to transfer. Mackey said in 2017, Douglas PUD would incubate eyed eggs at Methow FH (Wells FH is not ready to receive eggs in spring 2017), and if eyed egg transfer is allowable, they can use the room at the hatchery dedicated to the Twisp program. Gale asked if early rearing for the composite steelhead program could be separated from other programs during early rearing. Mackey said the Twisp room is an isolated incubation room but the start room is not bio-isolated, and the fish would eventually be placed into circular tanks at Well FH.

Tonseth asked if representatives present are comfortable with compositing the Twisp and Winthrop programs for BY 2017. This would include fish collection at the Twisp Weir, held, spawned, incubated to eyed egg stage or held to fry stage at Winthrop NFH, then transferred to Methow or Wells FH. He asked if decisions should wait on fish health conversations, hatchery space, and the possibility of raising fish to an S1 stage at Methow FH. Wahls said the Twisp Weir will begin operating at the end of March, so a decision is needed by the end of the month at the latest. WDFW voted yes on this agreement during the meeting on March 13, 2017, and other representatives requested more time. Tonseth requested a vote by March 30, 2017.

Michael Humling (USFWS) said the Winthrop S2 program broodstock collection has typically avoided collection below the Twisp River, but since compositing the programs is an ongoing discussion and trending towards a positive vote, he asked if USFWS should extend their collection area below the Twisp River. Tonseth said if that were to happen, fish collected in the area between Carlton Acclimation Pond and the Twisp River should be subtracted from the total number targeted from the Twisp Weir. He said it would not be desirable to exceed the proportion of Twisp-origin fish in the collection. Humling said at the moment, he thinks steelhead are stacked up in the lower Methow River, but with warmer temperatures, fish will start moving very soon. Mackey suggested collecting as Humling proposed, up to the number identified as the Twisp broodstock collection target. Humling said he will have USFWS avoid collecting in the area where fish are currently stacked up and will expand broodstock collection below the Twisp River.

F. Spring Chinook Salmon Outplanting in the Chewuch River (Catherine Willard/All)

Catherine Willard shared a document titled, "Revised Draft Outplanting Surplus Methow Composite Spring Chinook Salmon Adults" (Attachment I) and a related spreadsheet, "Adult Outplanting Calculator" (Attachment J), which Sarah Montgomery distributed to the Hatchery Committees on March 13, 2017. Willard said she received comments on the previous version of this draft and inserted any substantial changes in track-changes. She summarized the changes to the document and questions and comments followed.

Casey Baldwin asked how long fish are retained in the system. Willard said there are likely differences between males and females and translocation of females may be more successful because males are more transient. She said male maturation is difficult to ascertain compared to females.

Greg Mackey introduced the spreadsheet and said it can be used to ensure the study stays within permit conditions (the gene flow sliding scale). He said some of the inputs to this equation could be estimated in-season at the 50% passage point at Wells Dam. He said there should be sufficient fish on hand as they are captured at Methow FH during brood collection and gene flow management, and the size of release at that point would be a management decision. Matt Cooper asked if there is a minimum number at which point the study would not be undertaken. Mackey replied that the study intends to augment returns to the Chewuch program, up to the point that is defined by the ESA permit conditions.

Bill Gale asked if there is enough space at Methow FH to accommodate this study. Mackey said yes and because there are prescription restrictions forfish that may be released, they will be held separately. Tonseth said these fish can be treated with Formalin but not antibiotics or other substances. Tonseth suggested adding a caveat that if fish are being held for the study and there is a significant bacterial outbreak, the fish will not be released.

Regarding release sites, Keely Murdoch said YN requested that the workgroup consider out-planting higher up in the basin. Willard said she discussed this with Charlie Snow (WDFW), who said there is not abundant spawning habitat above the areas identified in this draft; it is more "pocket spawning" Willard said she will add text about if there is available spawning habitat that is not occupied by spawners, crews can be flexible about planting upstream of the currently designated locations.

Gale asked what the reporting strategy for this would be. Willard said she will add language about reporting and she will revise the draft plan and distribute it for approval in April 2017.

Murdoch said contingency language should be added for higher release sites and a preference should be stated for upper sites. Todd Pearsons pointed out that this will be a multi-year study, so the release location can be changed.

G. Brood Year Stray Rate Targets (Todd Pearsons)

Tracy Hillman introduced the BY stray rates topic by emphasizing the potential implications of failing to meet a target, even if the target does not link to extinction risk. He said some objectives are more important than others and the BY stray rate target is linked to the other two stray rates, even if it is not linked directly to extinction risk. He said BY stray rates may be better suited as informing other targets, which appears more in line with how the Hatchery Committees consider BY stray rates—it is useful information to describe what is happening within programs, and can also inform Q2 and Q3. Mike Tonseth said if there is an issue with recipient population strays, looking at the BY stray rate for example could determine if a specific BY, culture, handling difference, or broodstock origin is correlated with the issue. He said in this way, BY stray rates could be considered a management objective. Bill Gale said one issue with this approach might be programs with really high BY stray rate targets, but are still within the target for recipient populations because these programs stray a little bit to many locations. Another potential issue would be spikes of recipient stray rate problems because of low natural-origin returns. He said examining the differences or causative factors is most important. Tonseth said it is difficult to set a BY stray rate target for all programs, because facilities and limitations affect programs in different ways. Tonseth said it is important to maintain the perspective of examining BY stray rates without tying the rates to a target. Gale said he is not opposed to changing the language of stray rate targets, but he sees a potential issue if the target is removed and a program has a very high BY stray rate but is still meeting Q2 and Q3 targets. He said folks might argue at that point that change is not warranted, because the targets are met.

Hillman said that most hatchery fish stray to only a few locations. He suggested performing an analysis to determine if the situation Gale describes often occurs. That is, did programs with high BY stray rates also exceed within and among recipient population stray rate targets.

Gale said the language about BY stray rates is important and should state that the BY stray rates should be used as an indicator of program performance. Keely Murdoch said she will need to discuss this internally before making a decision about eliminating the target altogether or changing the language behind it and said she supports performing the analysis. Greg Mackey said another option is rewriting Q1 so that it is contingent on Q2 and Q3. Tonseth said because the Hatchery Committees are already committed to reviewing the M&E Plan before the next meeting, they can also begin to flag objectives for review. He said it will be important to provide plenty of background as to why the target is changing. Todd Pearsons said the M&E Plan clearly states that new information should be used to update the plan, so as long as the new information is detailed in the review process, it is okay to change or eliminate the target. Hillman agreed and said there appears to be justification for removing or modifying the BY stray rate target. Casey Baldwin said from the perspective of the receiving population, strays should be assessed as the total stray rate rather than a program by program rate, and how the objective is worded should take this into consideration. Hillman said he will preliminarily revise the BY stray rate target language in the Hatchery M&E Plan for further discussion at the Hatchery Committees April 17, 2017, meeting and will analyze the relationship over the last 10 complete BYs between exceeding BY stray rate targets and exceeding recipient stray rate targets.

H. Maturation Sampling for Methow and Chiwawa Spring Chinook Salmon 2017 Releases (Willard/Mackey)

Catherine Willard said Chelan PUD proposes to perform maturation sampling in partnership with USFWS and WDFW on 300 spring Chinook salmon for the third year in a row. The Rock Island Hatchery Committee agreed that Chelan PUD,USFWS, and WDFW can perform maturation sampling on 300 Chiwawa spring Chinook salmon as follows: YN, WDFW, USFWS, NMFS, Chelan PUD, and CCT agreed March 13, 2017.

Greg Mackey said Douglas PUD proposes to sample 300 spring Chinook salmon for maturation sampling as part of their new permit conditions. The Wells Hatchery Committee agreed that Douglas PUD can perform maturation sampling on 300 Methow spring Chinook salmon as follows: Douglas PUD, YN, WDFW, USFWS, NMFS, and CCT agreed March 13, 2017.

V. HCP Administration

A. Next Meetings

The next Hatchery Committees meetings are on April 19, 2017 (Grant PUD), May 17, 2017 (Grant PUD), and June 21, 2017 (Grant PUD).

VI. List of Attachments

Attachment A	List of Attendees
Attachment B	Draft Wells HCP 2017 Action Plan
Attachment C	Wells Final HCP SOA M&E Report Scheduling
Attachment D	Rocky Reach/Rock Island HCP SOA M&E Report Scheduling
Attachment E	Monitoring and Evaluation Reporting Schedule for the Douglas PUD, Grant PUD and Chelan PUD Hatchery Programs
Attachment F	Steelhead Release Year 2016 Preliminary Results
Attachment G	Draft 2017 Steelhead Release Plan
Attachment H	Draft 2017 Broodstock Collection Protocols v1
Attachment I	Revised Draft Outplanting Surplus Methow Composite Spring Chinook Salmon Adults
Attachment J	Adult Outplanting Calculator

Attachment A
List of Attendees

Name	Organization
Tracy Hillman	BioAnalysts, Inc.
Sarah Montgomery	Anchor QEA, LLC
Catherine Willard*	Chelan PUD
Greg Mackey*	Douglas PUD
Tom Kahler*	Douglas PUD
Todd Pearsons‡	Grant PUD
Peter Graf‡	Grant PUD
Deanne Pavlik-Kunkel†‡	Grant PUD
Bill Gale*	U.S. Fish and Wildlife Service
Matt Cooper*	U.S. Fish and Wildlife Service
Brett Farman*†	National Marine Fisheries Service
Mike Tonseth*	Washington Department of Fish and Wildlife
Brian Lyons†	Washington Department of Fish and Wildlife
Jayson Wahls†	Washington Department of Fish and Wildlife
Keely Murdoch*	Yakama Nation
Casey Baldwin*	Colville Confederated Tribes

Notes:
* Denotes Hatchery Committees member or alternate
† Joined by phone
‡ Joined for the joint HCP-HC/PRCC HSC discussion

Draft 2017 ACTION PLAN
WELLS HCP

WELLS HCP COORDINATING COMMITTEE

1. **Juvenile Fish Bypass**
   a. Gas Abatement Plan (GAP) and Bypass Operating Plan (BOP) to CC........ 5 January 2017
   b. CC comments on GAP/BOP to DCPUD .... 6 February 2017
   c. CC approval of GAP/BOP .... 14 February 2017
   d. Submit final GAP/BOP to FERC for approval .... 28 February 2017
   e. 2017 Bypass operations at Wells .... 9 April 2017 – 19 August 2017

2. **Annual Monitoring of Juvenile Migration Run Timing**
   a. 2017 Skalski passage-dates analysis to DCPUD .... September 2017
   b. 2017 draft passage-dates analysis and post-season bypass report to CC.........October 2017
   c. CC approval of 2017 final report .... December 2017

3. **Expand PIT-tag Detection in Spillway # 2 of the Wells Bypass System**
   a. Biomark installation and testing of expanded system....................................... March 2017
   b. Operation and performance monitoring.............................. 9 April 2017 – 19 August 2017
   c. Technical Advisory Memorandum to CC...November 2017

4. **Fishway Outage Schedule for Fishway Inspection, Maintenance, and Fishway Projects**
   a. West Fishway.. 15 November – 14 December 2017
   b. East Fishway ....19 December 2017 – January 2018
   c. Adult Fishway Trap Coordination Meeting.. April 2017

5. **Multi-Year Sub-yearling Chinook Life-history Study**
   a. Monitor fish tagged in 2011-2013 study years through adult returns.......... December 2018
   b. Draft juvenile life-history report to CC .... June 2017
   c. Final juvenile life-history report .... September 2017
   d. Draft and Final Life-History Report 2019

6. **Review and Approval of 2017 Hatchery Broodstock Collection Protocol**
   a. Draft protocol to CC for review.. February 17, 2017
   b. CC approval of draft protocol .... March 28, 2017
   c. Deadline for submission of protocol to NMFS... April 15, 2017

7. **Pikeminnow Control Program**
   a. Draft 2016 pikeminnow report to HCP CC .... April 2017
   b. Final 2016 pikeminnow report.. June 2017
   c. Pikeminnow removal – Wells Project.. March – November 2017

8. **2020 Survival Verification Study**
   a. Study Plan to HCP CC... September 2017
   b. Approval of Study Plan... December 2017

9. HCP Annual Report

a. Draft 2016 annual report to DCPUD for review..January 12, 2017
b. Draft 2016 annual report to CC for 30-day review....................................February 8, 2017
c. CC comments on draft 2016 report due to Anchor QEA...............................March 7, 2017
d. Final 2016 annual report to DCPUD ....March 23, 2017
e. Final 2016 annual report due to FERC ....March 31, 2017

WELLS HCP HATCHERY COMMITTEE

1. **Implement 5-year Hatchery Monitoring and Evaluation (M&E) Plan**
   a. Ongoing implementation .... January – December 2017
   b. Draft annual report for 2016 to Douglas PUD .... June 2017
   c. Draft annual report to Hatchery Committee (HC) .... August 2017
   d. Final annual report to HC .... September 2017
   e. Draft 2018 implementation plan to HC .... July 2017
   f. HC approval of final 2018 implementation plan .... September 2017
   g. Develop new draft schedule for M&E Reporting .... February 15, 2017
   h. Final new schedule for M&E Reporting .... March 15, 2017

2. **Twisp Population Study**
   a. Implementation .... September – October 2017
   b. 2014, 2015, 2016 Reports .... October 2017

3. **Spring Chinook Egg-to-Fry Study**
   a. Develop study design .... June 2017
   b. Implement study .... August 2017
   c. Draft report .... July 2018

4. **2017 Broodstock Collection Protocol**
   a. Draft to HC for review .... February 9, 2017
   b. HC approval of draft protocols .... March 15, 2017
   c. CC approval of Wells Dam trapping operations .... March 28, 2017
   d. Deadline for submission to NMFS .... April 15, 2017
   e. Implementation .... May 2017 to April 2018

5. **Annual Implementation – Okanagan Sockeye Fish/Water Management Tools**
   a. Water Year 2016-2017 .... October 2016 – September 2017
   b. Record of management decisions .... December 2017

6. **Modernization of the Okanagan Sockeye Fish/Water Management Tools**
   a. Phase 2 .... October 2016 – August 2017
   b. Phase 3 (Final) .... September 2017 – August 2018

7. **Methow Steelhead Relative Reproductive Success Study**
   a. Implementation .... March 2010 – December 2021
   b. Annual report on genetic analysis .... September/October 2017
   c. Biological data in Annual M&E Report (above) .... September 2017
   d. Final report 2021/2022

8. **Hatchery Genetic Management Plans**
   a. Receive new Methow spring Chinook hatchery permit .... February 2017
   b. Implement new spring Chinook permit 2017
   c. Receive new Wells steelhead hatchery permit .... *to be determined*
   d. Receive new Wells summer Chinook hatchery permit .... *to be determined*

9. Wells Hatchery Modernization

a. Construction complete .... August 31, 2017

10. Coho Hatchery Program

a. Develop plans for dividing Twisp Acclimation Pond to accommodate coho 2017

11. Chief Joseph Hatchery Production

a. Hatchery Production (spring/summer Chinook)..2017
b. Monitoring and Evaluation 2017

WELLS HCP TRIBUTARY COMMITTEE

1. **Plan Species Account Annual Contribution**
   a. $176,178 in 1998 dollars ($267,771.65 in 2017 dollars) .... January 2017

2. **Annual Report - Plan Species Account Status**
   a. Submittal of 2016 account-status report to Tributary Committee (TC): .... February 2017
   b. Integration into 2016 HCP Annual Report: .... February 2017

3. **General Salmon Habitat Program**
   a. Project review and funding .... January-December 2017

4. **Small Project Program**
   a. Project review and funding Decision .... January-December 2017

Wells HCP Hatchery Committee
Statement of Agreement

Monitoring and Evaluation Reporting Schedule for the Douglas PUD, Grant PUD and Chelan PUD Hatchery Programs, dated March 13, 2017

(Douglas PUD, NMFS, USFWS, WDFW, YN, and CCT approved on March 13, 2017)

Statement

The Wells HCP Hatchery Committee approves the Monitoring and Evaluation Reporting Schedule for the Douglas PUD, Grant PUD and Chelan PUD Hatchery Programs, dated March 13, 2017. Any future alterations of the schedule will require HCP Hatchery Committee approval.

Background

The Douglas and Chelan HCPs and Grant Settlement Agreement and 2008 NMFS Biological Opinion for Grant PUD specify certain reporting dates or intervals for hatchery monitoring and evaluation (M&E). The Endangered Species Act incidental take permits and the PUD hatchery M&E Plan also have reporting requirements. These reporting time requirements were designed to provide timely information to operators and managers, fulfill permitting requirements, inform other activities such as updating M&E plans, recalculation of hatchery production, evaluation of meeting objectives, status of meeting permit requirements, and adaptive management actions. To date, the reporting timing that has been implemented has not necessarily met the intent of the Wells HCP, and has not been orchestrated to work with the various actions that the Hatchery Committee and NMFS require. This document, Monitoring and Evaluation Reporting Schedule for the Douglas PUD, Grant PUD and Chelan PUD Hatchery Programs, dated March 13, 2017, is the new reporting schedule that is consistent with the Wells HCP, meets reporting requirements under the M&E Plan, meets ESA Section 10 permit requirements, and optimizes the sequence of reporting and the actions that rely on M&E information.

Rocky Reach and Rock Island HCP Hatchery Committees
Statement of Agreement

Monitoring and Evaluation Reporting Schedule for the Douglas PUD, Grant PUD and Chelan PUD Hatchery Programs, dated March 13, 2017

(Chelan PUD, NMFS, USFWS, WDFW, YN, and CCT approved on March 13, 2017)

Statement

The Rocky Reach and Rock Island Habitat Conservation Plans (HCP) Hatchery Committees (HC) approve the Monitoring and Evaluation Reporting Schedule for the Douglas PUD, Grant PUD and Chelan PUD Hatchery Programs, dated March 13, 2017. Any future alterations of the schedule will require HCP Hatchery Committees approval.

Background

Chelan PUD's HCPs specify the need to update the hatchery monitoring and evaluation (M&E) plan every five years and to comprehensively review the hatchery program every 10 years utilizing new information from the M&E program. The National Marine Fisheries Service Section 10(A)(1)(a) and 10(A)(1)(b) Endangered Species Act permits for Chelan PUD's hatchery programs and the *Monitoring and Evaluation Plan for PUD Hatchery Programs* also contain reporting requirements for hatchery M&E information. To date, these reporting requirements have not aligned, which has resulted in a disjointed review and input cycle to inform updates to M&E plans, recalculation of hatchery production, evaluation of M&E objectives, status of meeting permit requirements, and adaptive management actions. The document, Monitoring and Evaluation Reporting Schedule for the Douglas PUD, Grant PUD and Chelan PUD Hatchery Programs, dated March 13, 2017, optimizes the sequence of hatchery M&E reporting and is the new reporting schedule for hatchery M&E information.

Monitoring and Evaluation Reporting Schedule for the Douglas PUD, Grant PUD and Chelan PUD Hatchery Programs

March 13, 2017

Introduction

The Douglas and Chelan PUDs' HCPs, Grant PUD's Settlement Agreement, and the 2008 NMFS Biological Opinion (Biop) for Grant PUD (hereafter referred to collectively as the Agreements) specify certain reporting dates or intervals for hatchery monitoring and evaluation (M&E). The Endangered Species Act (ESA) incidental take permits and the Monitoring and Evaluation Plan for PUD Hatchery Programs (Hillman et al. 2013) also have reporting requirements. These reporting date requirements were designed to provide timely information to operators and managers and fulfill permitting requirements. Additionally, the reports are used to inform other activities such as updating M&E plans, recalculation of hatchery production, evaluation of meeting M&E objectives, status of meeting permit requirements, and adaptive management actions. To date, the past reporting timing has not necessarily met the intent of the Agreements, and has not been orchestrated to align with the various actions that the Hatchery Committees and NMFS require. Subsequently, we have designed a reporting schedule that is consistent with the Agreements, meets reporting requirements under the M&E Plan, meets ESA Section 10 permit requirements, and optimizes the sequence of reporting and the actions that rely on M&E information.

Section 1: Monitoring and Evaluation Reports

Three levels of M&E reporting will be implemented (Table 1). These reports are consistent with past reporting and the M&E Plan, but have been restructured to streamline transfer of information and meet the requirements of the Agreements.

Table 1. M&E Report Types

Report type	Frequency	Content	Function
Data	Annual	Cumulative description of data (raw and derived) and field methods. Basic statics reported.	Informs annual M&E implementation plans
Statistical	5 year	Presentation of statistical analyses and description of statistical methods. Addressed in the Program Review when the two would occur in the same year.	Informs 5 year M&E plan and provides in depth data analysis
Program Review	10 year	Integrates and interprets information from data and statistical reports and also includes integration from other programs and studies. Written in scientific manuscript format. Fulfills HCP "Program Review" requirements. Addresses Statistical Report requirements.	Informs recalculation and adaptive management. Determines if programs are meeting objectives.

The Data Report will be produced annually and will provide data collected in the most recent field year. The report will provide tables of cumulative data, including the most recently collected, and provide summary statistics where appropriate (e.g., mean, standard deviation, etc.). The report will provide a concise description of the field methods that could be used in a scientific publication and describe deviations from previous sampling, standard field practices or sampling plans. This report will provide up to date information for managers and operators, fulfill incidental take reporting requirements, and inform annual adjustments to the implementation of the M&E plan.

The Statistical Report will be produced every ten years on the five year intervals between the Program Review (see below). The report will provide a concise description of the analytical methods used (e.g., similar to a scientific journal article) and the results of the statistical analyses for each objective as described in the M&E plan. The report will also provide the assumptions of the statistical analyses and note any deviations in expected performance of a given analysis (e.g., issues related to normality, dependency, non-constant variance; etc.). The report is not intended to provide interpretation of the results, but will provide the outcomes of the statistical tests. This will provide managers and operators a periodic update of the performance of the hatchery programs.

The Program Review will be produced every ten years and will meet the Program Review as described in the HCPs (Section 8.8 of the Wells HCP, Section 8.7 of the Rocky Reach/Rock Island HCPs) and will address the information reported in the Statistical Report. The report will provide the results of any natural population/hatchery interaction studies (as needed), and determine if the hatchery programs are operating consistent with the goals as outlined in the relevant M&E Plan. The review will determine if hatchery program goals and objectives, as defined in the Hatchery Plan (HCPs Section 8), Section 10 permits, as further defined in the HCPs, have been met or sufficient progress is being made toward their achievement; and determine if hatchery production objectives are being achieved.

Section 2: Required Reports and Actions

The HCPs list required reports or actions. The M&E reporting is either directly described or closely tied to these milestones (Table 2).

Table 2. Required Elements in the Agreements

Element	Document	Section	Frequency	Previous	Next
Survival Studies	HCP	8.4.4	Every 10 years	2010	2020
Recalculation	HCP SSSA/BiOp	8.4.5	Every 10 years Every 10 years	2013	2023
M&E Plan Update	HCP SSSA	8.5 13.1.4	Every 5 years Every 5 years	2013	2018
Program Review	HCP	8.8	Every 10 years	2012	2020
Section 10 Permits	HCP	10.2.5	Every 10 years	2004	2017

Section 3: Schedule

The M&E reporting schedule (Table 3) is designed to be consistent with the Agreements. However, it also has been designed to provide a logical sequence of information based on significant milestones in the HCPs as well as consistency with Grant PUDs settlement agreement and NMFS BiOp. Reporting was designed to provide the Program Review (ten year interval) prior to recalculation in order to have the most up to date data vetted and organized prior to recalculation. The Statistical Report will be produced every ten years. On the five year intervals between the ten year intervals, the Statistical Report material will be addressed in the Program Review. The Data Report will be produced annually (see Table 3). The PUDs also require advanced knowledge of M&E and reporting requirements to facilitate timely contracting. The Agreements terminate in 2052.

Table 3: Schedule of M&E Reporting and Significant Actions under the Agreements

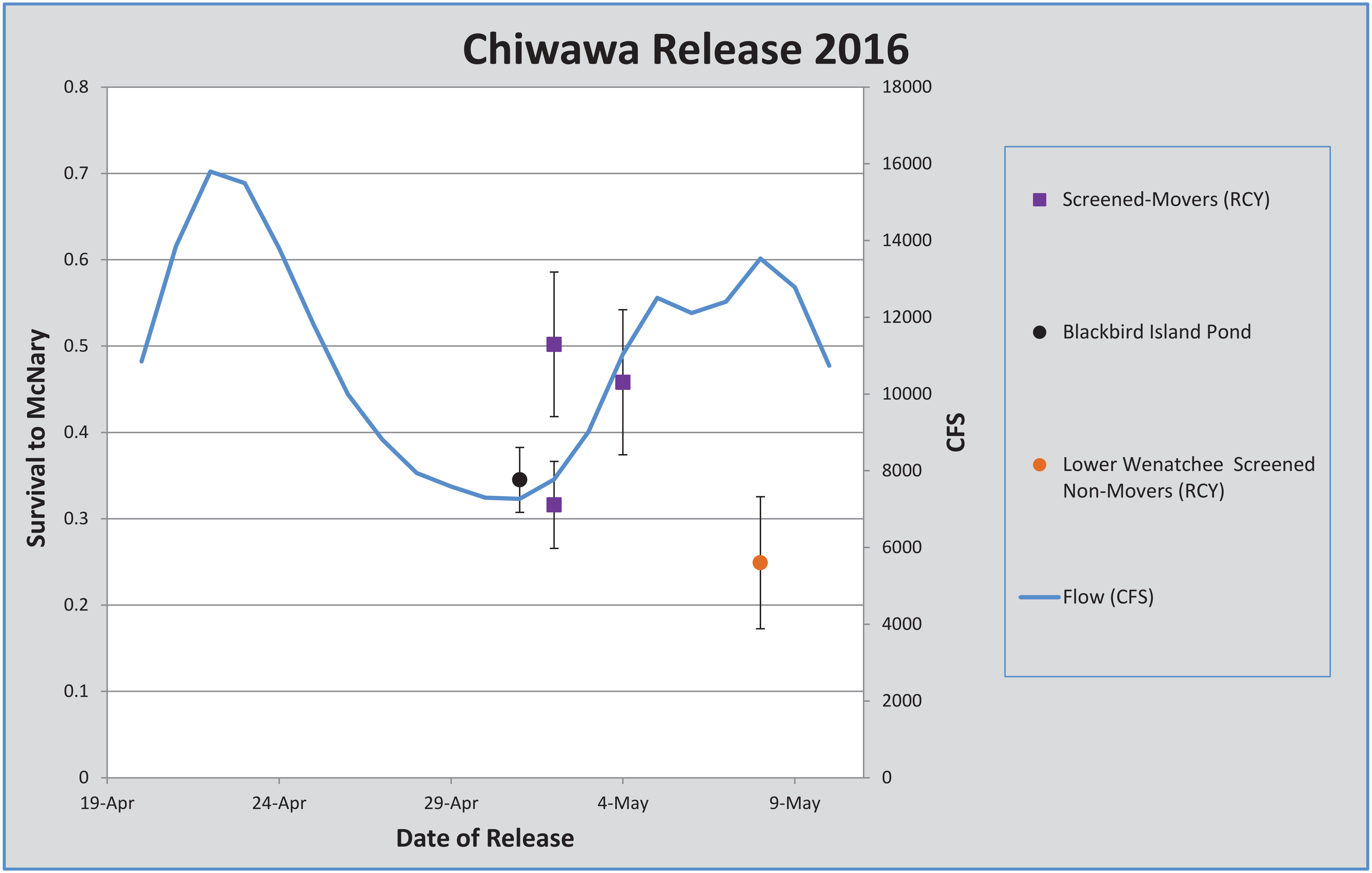
	Year	Recalculation	M&E Review	Program Review	Statistical Report	Data Report	Annual Data	Statistical/Program Review Data
		Recalc finalized						
4	2052	Recalc Brood Collection	M&E Plan Update			Data Report	Adds 2051	
3	2051	Recalc Process				Data Report	Adds 2050	
2	2050			Program Review Completed		Data Report	Adds 2049	Through 2048
1	2049			Program Review Process		Data Report	Adds 2048	
5	2048					Data Report	Adds 2047	
4	2047		M&E Plan Update			Data Report	Adds 2046	
3	2046					Data Report	Adds 2045	
2	2045				Statistical Report Completed	Data Report	Adds 2044	Through 2043
1	2044				Statistical Report Process	Data Report	Adds 2043	
5	2043	Recalc Finalized				Data Report	Adds 2042	
4	2042	Recalc Brood Collection	M&E Plan Update			Data Report	Adds 2041	
3	2041	Recalc Process				Data Report	Adds 2040	
2	2040			Program Review Completed		Data Report	Adds 2039	Through 2038
1	2039			Program Review Process		Data Report	Adds 2038	
5	2038					Data Report	Adds 2037	
4	2037		M&E Plan Update			Data Report	Adds 2036	
3	2036					Data Report	Adds 2035	
2	2035				Statistical Report Completed	Data Report	Adds 2034	Through 2033
1	2034				Statistical Report Process	Data Report	Adds 2033	
5	2033	Recalc Finalized				Data Report	Adds 2032	
4	2032	Recalc Brood Collection	M&E Plan Update			Data Report	Adds 2031	
3	2031	Recalc Process				Data Report	Adds 2030	
2	2030			Program Review Completed		Data Report	Adds 2029	Through 2028
1	2029			Program Review Process		Data Report	Adds 2028	
5	2028					Data Report	Adds 2027	
4	2027		M&E Plan Update			Data Report	Adds 2026	
3	2026					Data Report	Adds 2025	
2	2025				Statistical Report Completed	Data Report	Adds 2024	Through 2023
1	2024				Statistical Report Process	Data Report	Adds 2023	
5	2023	Recalc Finalized				Data Report	Adds 2022	
4	2022	Recalc Brood Collection				Data Report	Adds 2021	

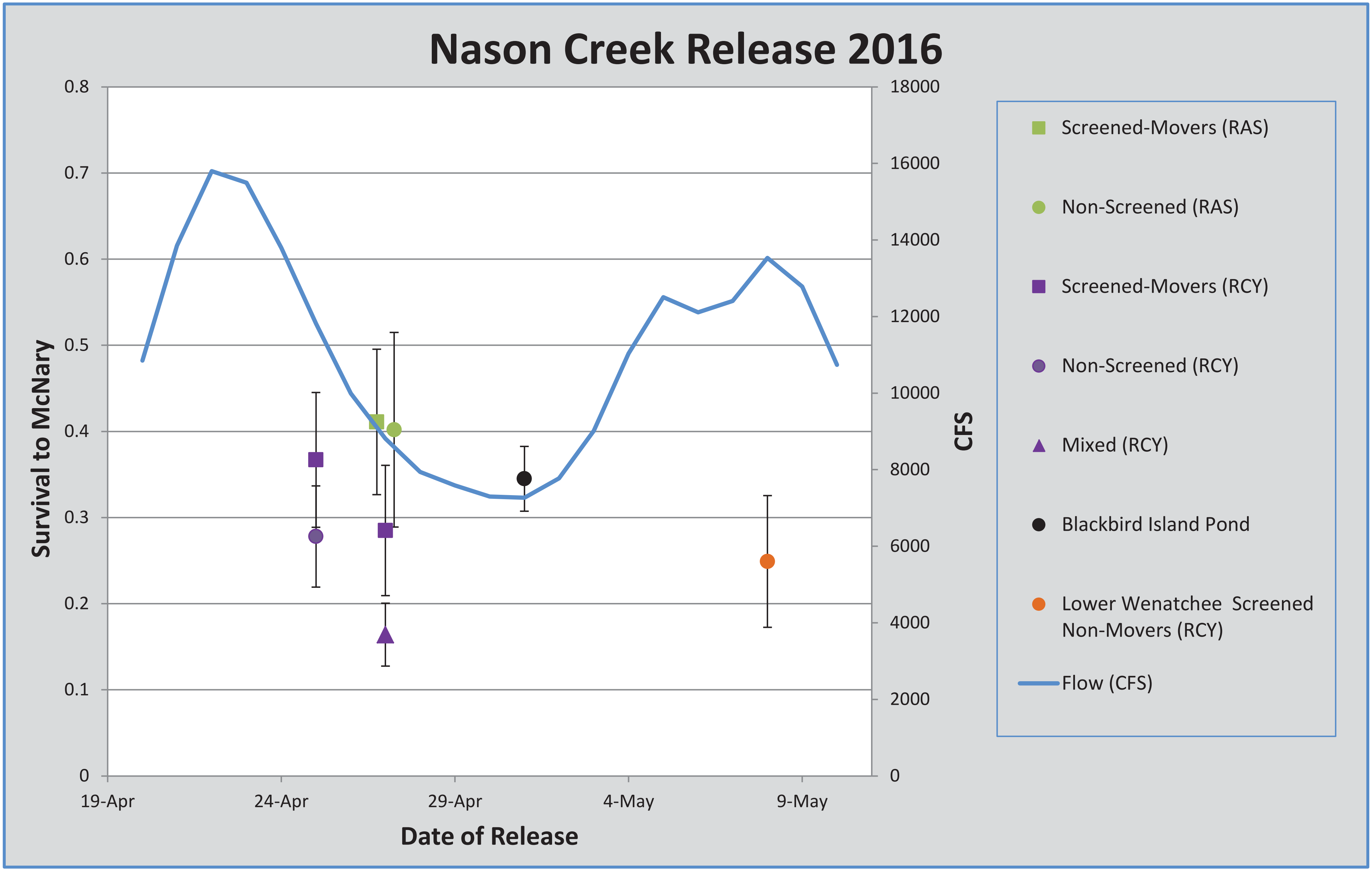
	Year	Recalculation	M&E Review	Program Review	Statistical Report	Data Report	Annual Data	Statistical/Program Review Data
3	2021	Recalc Process	M&E Plan Update			Data Report	Adds 2020	
2	2020			Program Review Completed		Data Report	Adds 2019	Through 2018
1	2019			Program Review Process		Data Report	Adds 2018	
5	2018		M&E Plan Update			Data Report	Adds 2017	
4	2017					Data Report	Adds 2016	
3	2016					Annual Report	Adds 2015	
2	2015					Annual Report	Adds 2014	
1	2014					Annual Report	Adds 2013	
5	2013	Recalc Finalized	M&E Plan Update			Annual Report	Adds 2012	
4	2012	Recalc Brood Collection			5-Year Report	Annual Report	Adds 2011	Through 2010
3	2011	Recalc Process				Annual Report	Adds 2010	
2	2010					Annual Report	Adds 2009	
1	2009					Annual Report	Adds 2008	

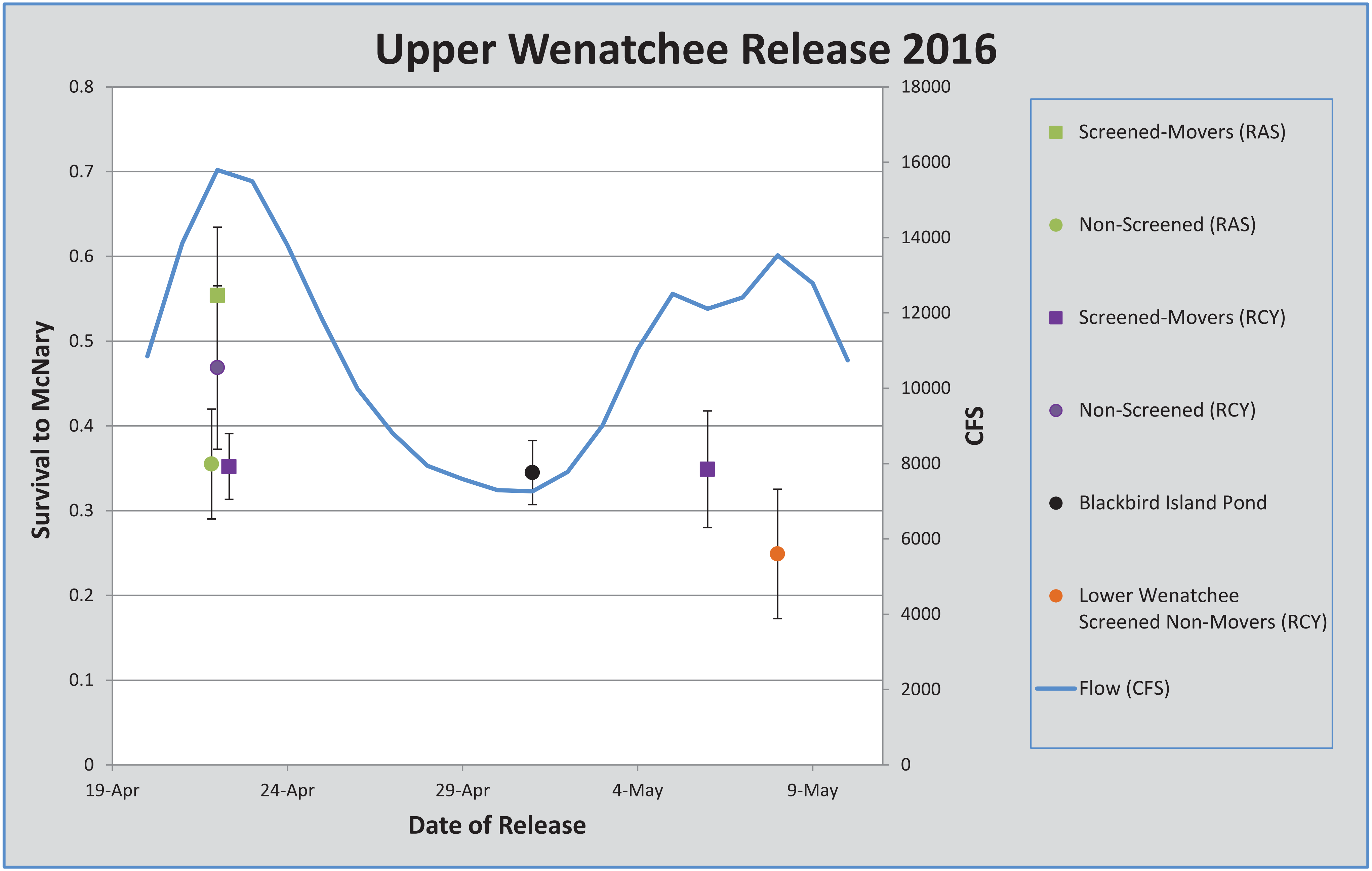
Chiwawa Acclimation Facility

2015 and 2016

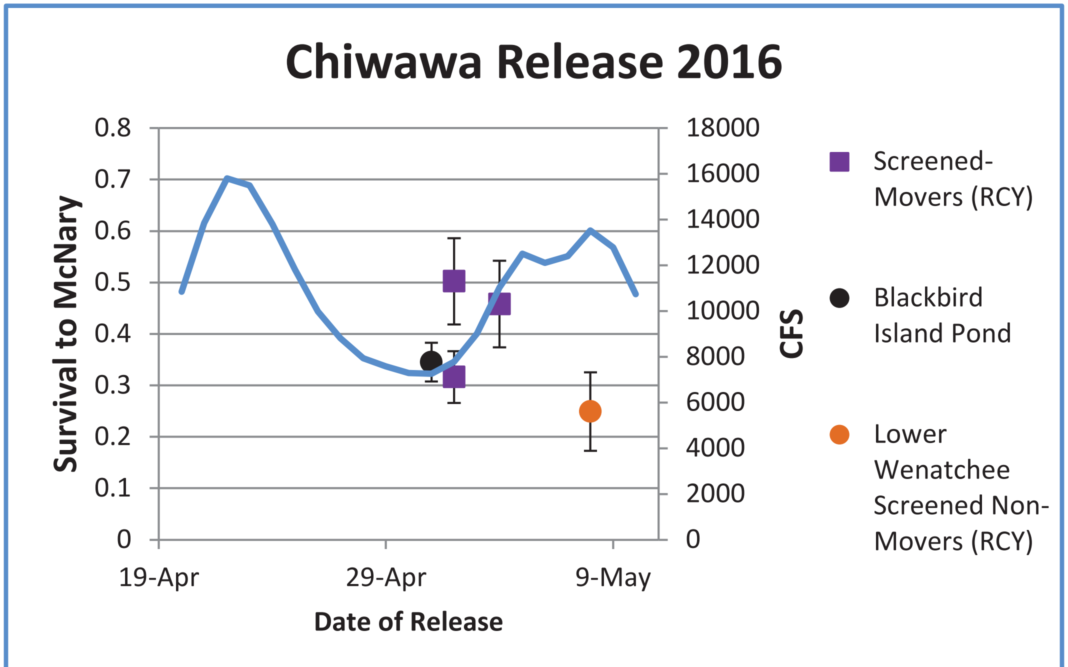
- Screened
    - o Movers and non-movers
- Non-screened

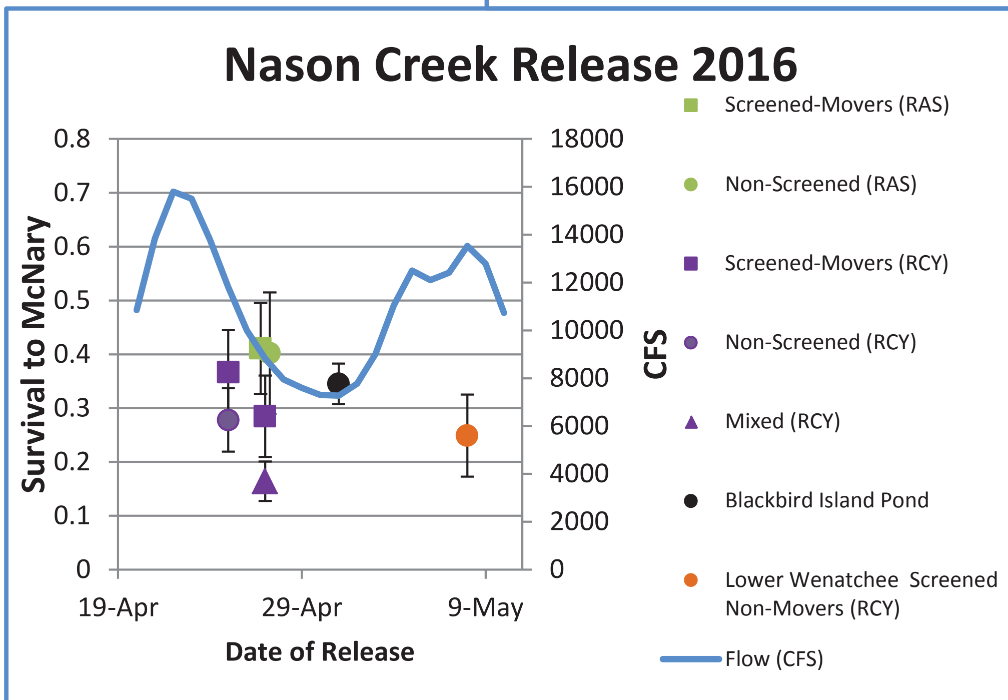

Chiwawa Release 2016
Survival to McNary
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
CFS
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
19-Apr
24-Apr
29-Apr
4-May
9-May
Date of Release
Screened-Movers (RCY)
Blackbird Island Pond
Lower Wenatchee Screened Non-Movers (RCY)
Flow (CFS)

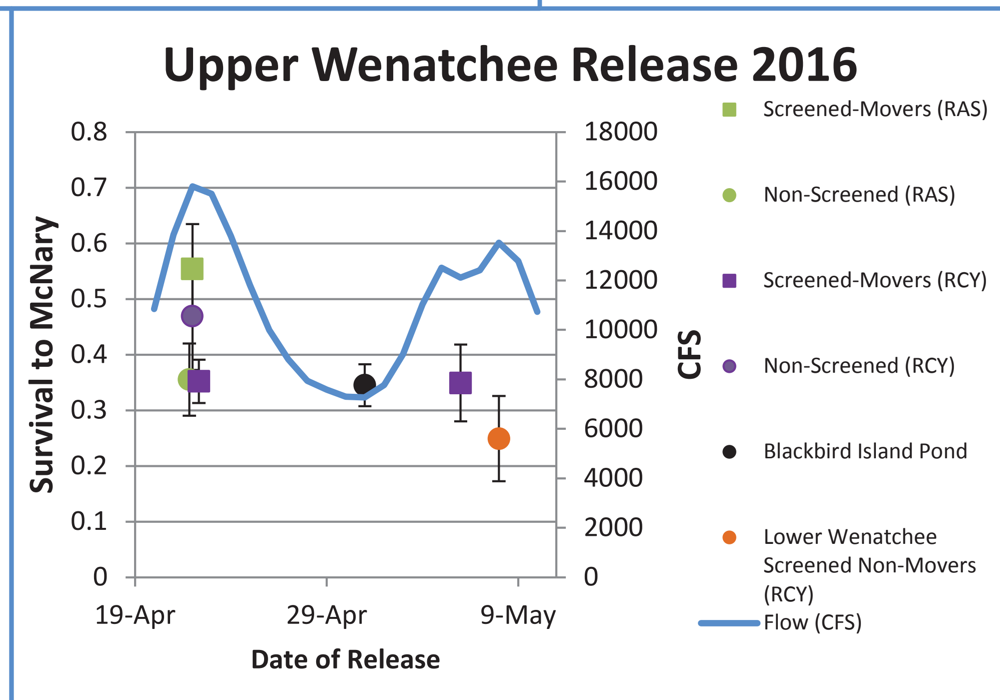

Nason Creek Release 2016
Survival to McNary
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
CFS
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
19-Apr
24-Apr
29-Apr
4-May
9-May
Date of Release
Screened-Movers (RAS)
Non-Screened (RAS)
Screened-Movers (RCY)
Non-Screened (RCY)
Mixed (RCY)
Blackbird Island Pond
Lower Wenatchee Screened Non-Movers (RCY)
Flow (CFS)


Upper Wenatchee Release 2016
Survival to McNary
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
CFS
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
19-Apr
24-Apr
29-Apr
4-May
9-May
Date of Release
Screened-Movers (RAS)
Non-Screened (RAS)
Screened-Movers (RCY)
Non-Screened (RCY)
Blackbird Island Pond
Lower Wenatchee Screened Non-Movers (RCY)
Flow (CFS)

Apparent juvenile survival to McNary by release type and grouped by release location. Each release site includes releases to Blackbird Pond and the non-movers to the lower Wenatchee.



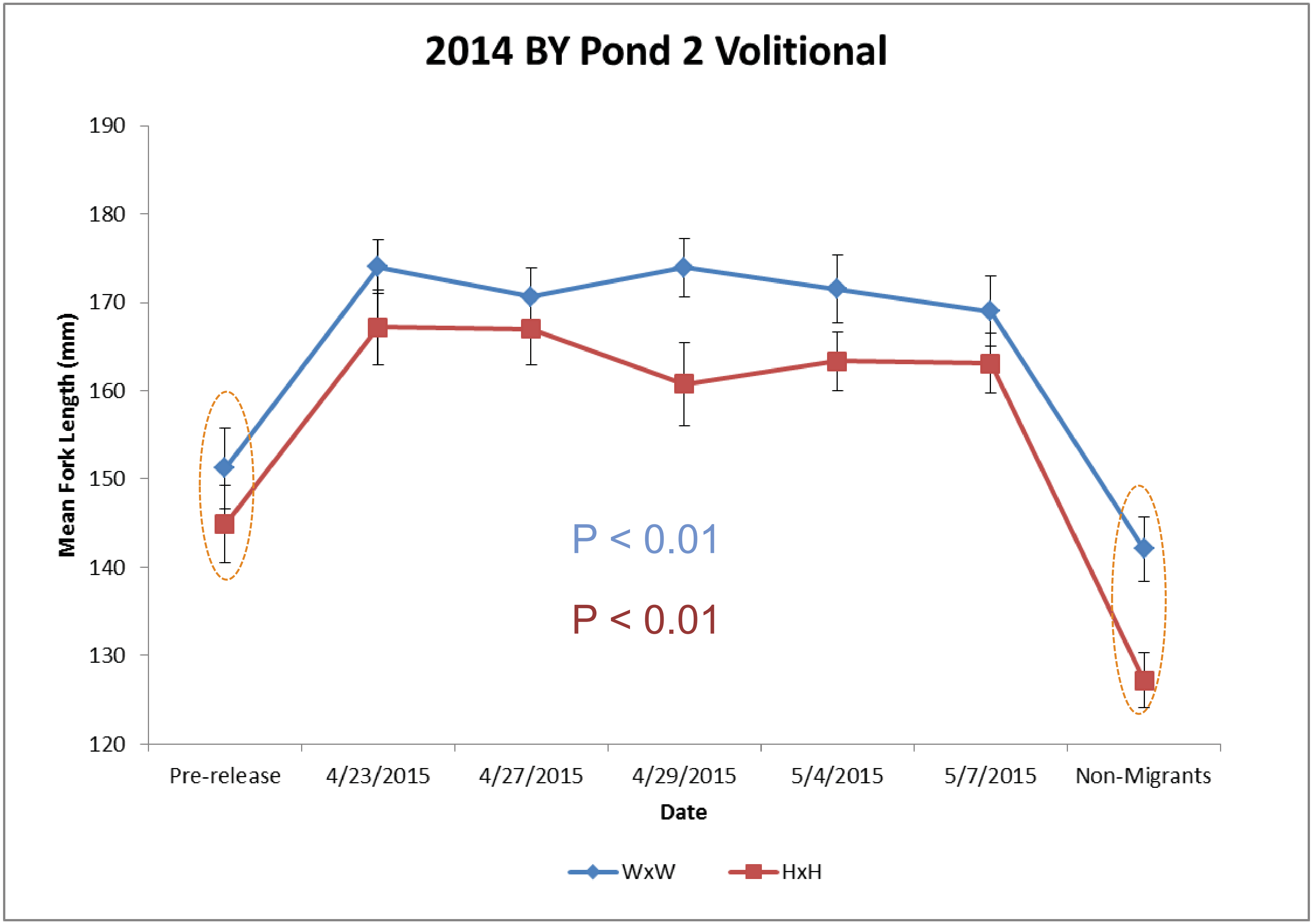




Release dates 4/22/16 to 5/6/16.

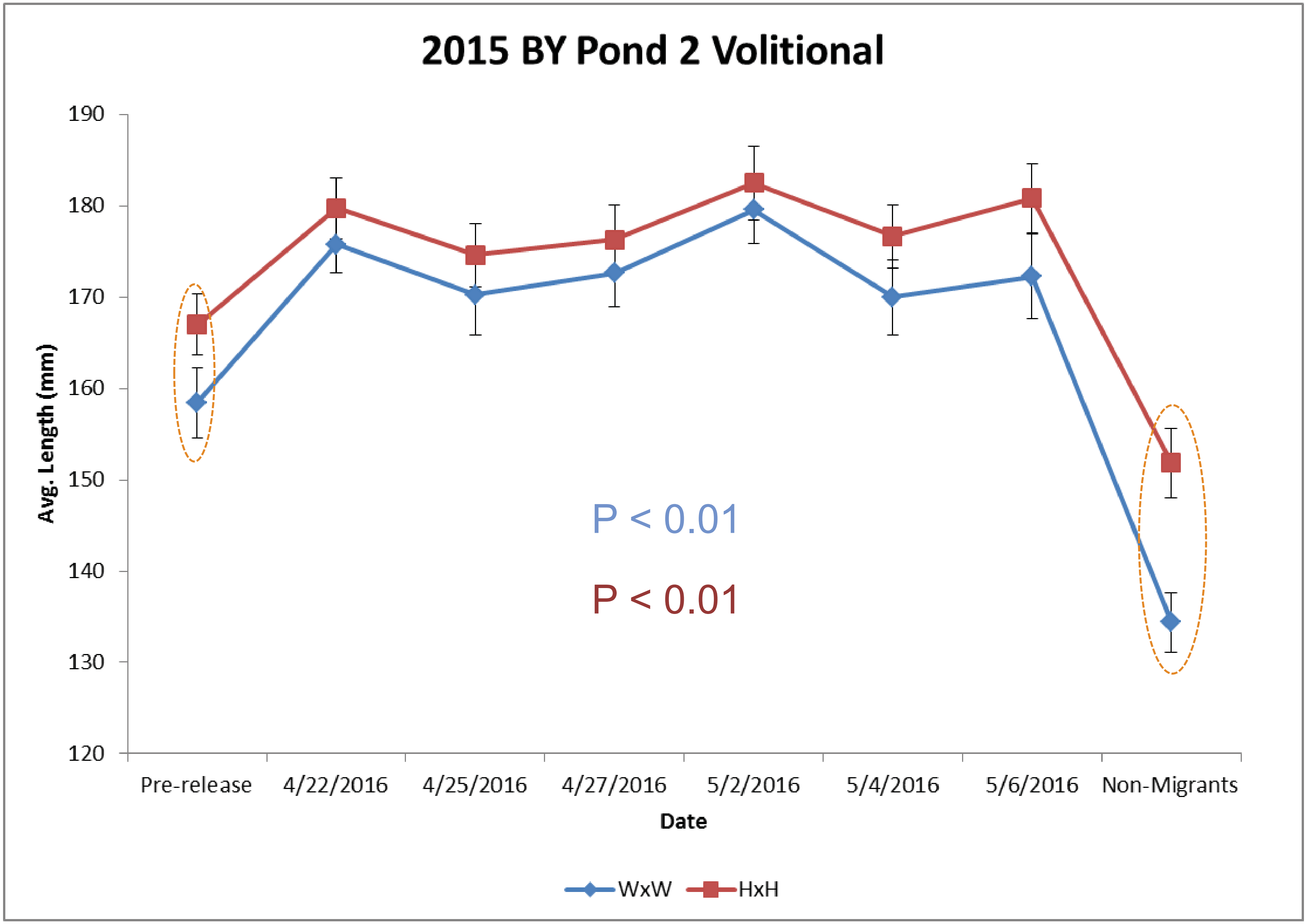
Attachment F

2015 Release



Slide courtesy of Chris Moran

2016 Release



Slide courtesy of Chris Moran

Smolt Index Pond 2

		Smolt Index			
Broodyear	Sample Type	P	T	S	Precocial
2014	Pre-Release	8.0%	88.3%	2.5%	1.3%
	Volitional	0.6%	98.1%	0.6%	0.8%
	Non-Migrants	4.8%	92.5%	0.3%	2.5%
2015	Pre-Release	17.5%	76.5%	4.0%	2.0%
	Volitional	3.6%	81.1%	14.1%	1.2%
	Non-Migrants	23.0%	76.5%	0.3%	0.3%

Slide courtesy of Chris Moran

The percentage of PIT-tagged fish detected in the Wenatchee sub-basin after July 1 of the year of release will be calculated to estimate potential residualism for each release group.

Based on Release Type			
	# of tags	Detected post July 1	%
Screened Movers	11743	7	0.06%
Screened Non-Movers	1659	2	0.12%
Non-Screened	7660	6	0.08%
Based on Rearing Vessel Raceway vs Circular			
Outdoors/Raceway	17806	10	0.06%
Indoors/Circular	3931	5	0.13%
Based on Release Location			
Chiwawa	4374	3	0.07%
Nason	7247	6	0.08%
Upper Wenatchee	6120	3	0.05%
Lower Wenatchee	1659	2	0.12%
Blackbird	2337	1	0.04%
Based on WxW or HxH			
HxH	11069	6	0.05%
WxW	12050	9	0.07%

Potential Residuals

Broodyear	Release Groups	Fish Released	Proportion Residual	Residuals (expanded)	*G*	*P*
2012	Volitional	100,666	0.0026	259	191.0	< .01
	Non-Migrants	34,062	0.0086	292		
2013	Volitional	160,049	0.0020	327	508.4	< .01
	Non-Migrants	45,041	0.0105	471		
2014	Volitional	82,348	0.0028	231	33.8	< .01
	Non-Migrants	49,009	0.0056	276		
2015	Volitional	89,550	0.0005	42	27.9	< .01
	Non-Migrants	35,117	0.0014	51		

Slide courtesy of Chris Moran

DRAFT Memorandum

Date: March 3, 2017

To: Rock Island and Rocky Reach HCP Hatchery Committees

From: Catherine Willard (CPUD), Scott Hopkins (CPUD), Chris Moran (WDFW), and Mclain Johnson (WDFW)

Re: 2017 Wenatchee Steelhead Release Plan (Brood Year 2016)

Background

Chelan PUD is required to produce 247,300 steelhead smolts for release into the Wenatchee River Basin in 2017 as part of the Rock Island and Rocky Reach HCP requirements. As of February approximately 267,035 Wenatchee summer steelhead (142,224 HxH and 124,811 WxW) are on station at the Facility.

Beginning in winter 2011 the Chelan PUD Wenatchee River steelhead program was relocated to the Chiwawa Acclimation Facility ("Facility") (Figure 1) following significant upgrades to accommodate tributary based overwinter acclimation for the Wenatchee steelhead program. Steelhead are transferred from Eastbank Hatchery to the Facility in November and released in April through May. The Facility consists of three, in line circular, dual-drain tanks within an enclosed building and are operated on a partial water reuse system (RAS). The two outer tanks hold steelhead during rearing and the center tank is used solely for receiving fish that are allowed to move from the outer tanks to the center tank during release. Fish are not provided the opportunity to move to the center tank until gates are removed (typically April 20th). When the center tank contains a pre-determined number of fish for a release, fish are loaded into a hatchery truck and truck-planted at one of five release locations. This "screening" method has been used to differentiate between apparent active migrants (fish that move from the outer tanks to the center tank) from apparent non-active migrants (fish that do not move from the outer tank to the center tank).

In addition to the circular vessels, there are three traditional flow-through raceways (RCY) located outside. The smaller of the three, Raceway Three (RCY3), is used to rear steelhead when it is not needed for rearing "high ELISA" spring Chinook juveniles. Raceways One (RCY1) and Two (RCY2) are located adjacent to each other. The wall between the two raceways contains a gated opening that when removed, allows fish to move between the raceways. In addition to removing the gate, the water is lowered in the receiving pond (typically April 20th) to establish a directional flow that apparent active migrant fish may cue to. Similar to the RAS vessels, this set-up allows for a screening method that attempts to differentiate between apparent active- and apparent non-active migrants. When RCY1 contains the pre-determined number of fish suitable for release, fish are loaded into a transport truck and truck-planted at one of five release locations. Historically, this screening method has been termed a volitional release but is currently termed a screening method as this more accurately describes the end result of the action.

2017 Release Strategy Objectives

- Evaluate best hatchery management practices for hatchery releases to optimize homing fidelity, minimize residualism, maximize out-migration survival, and minimize negative ecological interactions (Draft NMFS Wenatchee River Steelhead Section 10 Permit).
- Assess hatchery release practices to inform development of a residualism baseline for the Wenatchee steelhead program consistent with the Draft NMFS Wenatchee River Steelhead Section 10 Permit DRAFT Steelhead Residual Management Plan.
- Utilize data collected from the 2017 Wenatchee River Steelhead release to assess applicable monitoring and evaluation objectives (i.e., Objectives 4 and 6) for the Wenatchee River summer steelhead hatchery program (Hillman et al. 2013).

Methods

The 2017 release strategy will evaluate the effectiveness of the screening method, and the role of rearing vessel (RAS versus RCY) and brood origin on fish performance (e.g., juvenile survival and adult returns). The 2017 release plan methodology will consist only of screened releases; release years 2015 and 2016 evaluated screened and non-screened releases. Additionally, 2,500 PIT tags will be applied to non-movers remaining in RCY2 at the end of the screened release period to increase the PIT sample size of non-movers to better understand their post release performance. As with previous years, the release numbers and locations identified in Table 1 are proportionally based on the spawning distributions in the respective streams.

- Cormack-Jolly–Seber survival probabilities to MCN will be calculated for each release group using recaptures of PIT-tagged fish.
- The percentage of PIT-tagged fish detected in the Wenatchee sub-basin after July 1 of the year of release will be calculated to estimate potential residualism for each release group.

Release Timing

In an effort to more closely align hatchery steelhead releases with the peak outmigration period for wild steelhead and potentially increase smolt to smolt survival, all fish located at the Facility will be released by May 8th; fish acclimated at Blackbird Island Pond will be allowed to volitionally move out of the pond through the end of June (after which time the pond outlet will be closed as in years past).

Release Location

Release locations in 2017 will be the same as the previous two years.

Pre-release Monitoring and Evaluation

Throughout acclimation and release, established sampling, transfer and release protocols will be followed (Hillman et al. 2013). Additionally, to gain another year of data on screened RAS reared steelhead, non-lethal precocial maturation sampling will be conducted and smolt index will be evaluated for steelhead reared in the two RAS vessels (n=200 movers; n= 200 non-movers).

Table 1. Steelhead release numbers and locations, 2017.

Vessel	Origin[1]	Estimated Number Released[2]	Estimated # PIT-tagged	Destination	rkm	Movers or Non-movers
RAS3	WxW	11,971[3]	2,375	Nason	7.0	Movers
RCY1	Mixed	38,210	2,181	Nason	7.0	Movers
RAS1	WxW	11,720[3]	2,375	Nason	7.0	Movers
RAS1	WxW	Unknown	Unknown	Nason	7.0	Non-Movers
RAS3	WxW	Unknown	Unknown	Nason	7.0	Non-Movers
		61,901		**Total**		
RCY1	Mixed	78,299	4,469	U. Wenatchee	79.2	Movers
		78,299		**Total**		
RCY1	Mixed	73,379	4,188	Chiwawa	11.4	Movers
		73,379		**Total**		
RCY1	Mixed	Unknown	Unknown	L. Wenatchee	40.2	Non-movers
RAS1	WxW	Unknown	Unknown	L. Wenatchee	40.2	Non-movers
RAS3	WxW	Unknown	Unknown	L. Wenatchee	40.2	Non-movers
ELISA	HxH	24,952	2,500	Blackbird	40.5	Movers

[1]Mixed = HxH and WxW.
[2]Releases will occur April 20 - May 8; any remaining non-movers will be released by May 8th.
[3]Maximum estimated number of fish to be released; non-movers have not been subtracted from these totals.

Figure 1. Chiwawa Acclimation Facility site description.

REFERENCES

Hillman, T., T. Kahler, G. Mackey, J. Murauskas, A. Murdoch, K. Murdoch, T. Pearsons, and M. Tonseth. 2013b. Monitoring and evaluation plan for PUD Hatchery Programs, 2013 update. Report to the HCP and PRCC Hatchery Committees, Wenatchee, WA.

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March 2, 2017

To: HCP HC and PRCC HSC

From: Mike Tonseth, WDFW

Subject: **DRAFT UPPER COLUMBIA RIVER 2017 BY SALMON AND 2018 BY STEELHEAD HATCHERY PROGRAM MANAGEMENT PLAN AND ASSOCIATED PROTOCOLS FOR BROODSTOCK COLLECTION, REARING/RELEASE, AND MANAGEMENT OF ADULT RETURNS**

The attached protocol was developed for hatchery programs rearing spring Chinook salmon, summer Chinook salmon and summer steelhead associated with the mid-Columbia HCPs; spring Chinook salmon, summer Chinook salmon and steelhead programs associated with the 2008 Biological Opinion for the Priest Rapids Hydroelectric Project (FERC No. 2114); and fall Chinook salmon consistent with Grant County Public Utility District and Federal mitigation obligations associated with Priest Rapids and John Day dams (ACOE funded), respectively. These programs are funded by Chelan, Douglas, Grant County Public Utility Districts (PUDs), and ACOE and are operated by the Washington Department of Fish and Wildlife (WDFW), with the exception of the Omak Creek/Okanogan Basin steelhead Broodstock collection, and acclimation/release of Omak Creek steelhead which is implemented by the Confederated Tribes of the Colville Reservation (CTCR).

This protocol is intended to be a guide for 2017 collection of salmon (2017BY) and steelhead (2018BY) broodstocks in the Methow, Okanogan, Wenatchee, and Columbia River basins. It is consistent with previously defined program objectives such as program operational intent (i.e., conservation and/or harvest augmentation), mitigation production levels (e.g., HCPs and Priest Rapids Salmon and Steelhead Settlement Agreement), changes to programs as approved by the HCP-HC and PRCC-HSC, and to comply with ESA permit provisions, USFWS consultation requirements.

Notable in this year's protocols are:

- Continuing for 2017, no age-2 or 3 males will be incorporated into spring or summer Chinook programs unless necessary to maintain effective population size (minimum female to male ratio of 1:0.75; conservation programs only).

- Use of ultrasonography to determine the sex of each fish retained for brood to ensure achieving the appropriate number of females for program production (does not include Priest Rapids Hatchery).

- Utilization of genetic sampling/assessment to differentiate Twisp River and Methow River Basin natural-origin spring Chinook adults collected at Wells Dam, and CWT interrogation during spawning of hatchery spring Chinook collected at the Twisp Weir and Methow FH to differentiate Twisp and Methow Composite hatchery fish for discrete management of Twisp and Methow Composite production components for the GPUD, CPUD and DPUD programs.

- Collection of only hatchery adult steelhead at Wells Dam/Hatchery for the Lower Methow safety-net (WFH/MFH), and Wells Hatchery Okanogan and mainstem Columbia safety-net programs.

- Collection of spring Chinook for the Nason Creek and Chiwawa programs using combination of Tumwater Dam and the Chiwawa Weir.

- Targeted collection of 100% of the Wenatchee summer Chinook and Wenatchee hatchery origin steelhead broodstock at Dryden Dam to reduce the number of activities that may contribute to delays in fish passage at Tumwater Dam (some adult collections at Tumwater may be necessary if sufficient adults cannot be acquired at Dryden Dam).

- Targeted collection of 100% of the natural origin steelhead broodstock at Tumwater Dam.

- Collection of summer Chinook broodstock from the Chelan Falls Canal Trap (CFCT), sufficient to meet a 576K yearling juvenile Chelan Falls program. Summer Chinook collections at Entiat Hatchery may be used to support the Chelan Falls program if broodstock collection efforts at the CFCT fall short.

- Collection of surplus hatchery origin steelhead from the Twisp Weir (up to 25% of the required broodstock) to produce the 100K Methow safety-net on-station-released smolts (up to 17 adults). The remainder of the broodstock (51) will be WNFH returns collected at WNFH (or by angling/trapping/tangle netting for WNFH program) and/or Methow Hatchery and surplus to the WNFH program needs. Collection of Wells stock may be used if WNFH and Twisp returns are insufficient. The collection of adults will occur in spring of 2018.

- Summer Chinook collections at Wells Dam to support the CJH program may occur if CCT broodstock collection efforts fail to achieve broodstock collection objectives.

- Collection from the Wells Hatchery volunteer channel of Wells summer Chinook to support the YN, Yakima River summer Chinook program.

- Targeted collection of 1,000 adipose present, non-coded wire tagged fall Chinook from the PRD OLAFT.

- Targeted collection of about 400 adipose present, non-coded wire tagged fall Chinook using hook and line efforts in the Hanford Reach.

- Juvenile releases, unless otherwise noted in this document, will follow past conventional practices for each of the respective programs.

- Compositing of the Twisp steelhead conservation program with the WNFH conservation program. Releases into the Twisp and other locations in the basin will be mixture of S_1 and S_2 smolts.

- Release of 50K Methow safety net steelhead smolts into the lower Methow River (Effy's Bridge).

These protocols may be adjusted in-season, based on actual run monitoring at mainstem dams and/or other sampling locations. Additional adaptive management actions as they relate to broodstock objectives may be implemented as determined by the HCP-HC or PRCC-HSC and within the boundaries of applicable permits.

Also included in the 2017 Broodstock Collection Protocols are:

Appendix A: 2017 BY Biological Assumptions for UCR Spring, Summer, and Fall Chinook and 2018 BY Summer Steelhead Hatchery Programs
Appendix B: Current Brood Year Juvenile Production Targets, Marking Methods, Release Locations
Appendix C: Return Year Adult Management Plans
Appendix D: Site Specific Trapping Operation Plans
Appendix E: Columbia River TAC Forecast
Appendix F: Annual Chelan, Douglas, and Grant County PUD RM&E Implementation Plans
Appendix G: DRAFT Hatchery Production Management Plan

Methow River Basin

Spring Chinook

Inclusion of natural-origin fish in the broodstock will be prioritized for the aggregate conservation program in the Methow Basin. Collections of natural-origin fish will not exceed 33% of the Methow Composite (i.e., non-Twisp) and Twisp natural-origin run escapement consistent with take provisions in Section 10 (a)(1)(A) Permits 18925 and 20533.

Hatchery-origin spring Chinook, if needed, will be collected in numbers excess to program production requirements to facilitate BKD management, comply with ESA Section 10 permit take provisions, and to meet programmed production shortfalls with natural origin fish. Based on historical Methow FH spring Chinook ELISA levels above 0.12, any hatchery origin spring Chinook broodstock collection will include hatchery origin spring Chinook in excess to broodstock requirements by approximately 33.3% (based upon the most recent 5-year mean

ELISA results for the Methow/Chewuch program; 11.8% for the Twisp program). For purposes of BKD management and to comply with maximum production levels and other take provisions specified in ESA Section 10 permits 18925 and 20533, culling will include the destruction of eggs from hatchery-origin females with ELISA levels greater than 0.12 and/or that number of hatchery origin eggs required to maintain production at 223,765 yearling smolts. Culling of eggs from natural-origin females will not occur unless their ELISA levels are determined by WDFW Fish Health to be a substantial risk to the program. Progeny of natural-origin females, with ELISA levels greater than 0.12, may be differentially tagged for evaluation purposes. Annual monitoring and evaluation of the prevalence and level of BKD and the efficacy of culling returning hatchery- and natural-origin spring Chinook will continue and will be reported in the annual monitoring and evaluation report for this program.

WDFW genetic assessment of natural-origin Methow spring Chinook (Small et al. 2007) indicated that Twisp natural-origin spring Chinook can be distinguished, via genetic analysis, from non-Twisp spring Chinook with a high degree of certainty. The Wells HCP Hatchery Committee accepted that Twisp-origin fish could be genetically assigned with sufficient confidence and that natural origin collections can occur at Wells Dam. Scale samples and non-lethal tissue samples (fin clips) for genetic/stock analysis will be obtained from adipose-present, non-CWT, non-ventral-clipped spring Chinook (suspected natural-origin spring Chinook) collected at Wells Dam, and origins assigned based on genetic analysis. Natural-origin fish retained for broodstock will be PIT tagged (pelvic girdle) for cross-referencing tissue samples/genetic analyses. Tissue samples will be preserved and sent to the WDFW genetics lab in Olympia Washington for genetic/stock analysis. Spring Chinook collected from Wells will be held until genetic analysis results are received (unless adult holding is not yet available due to the Wells modernization project, in which case fish will be held at Methow FH pending results), then transferred to and retained at Methow Hatchery and spawned for each program depending on results of DNA analysis. Brood collection of NORs at Wells will be based upon assignment of Twisp NORs to the Twisp program and non-Twisp NORs being used to support Methow and Chewuch River releases. Spring Chinook collected at Methow Hatchery will be held at MFH until genetic analysis results are received and then handled accordingly.

The number of natural-origin Twisp and Methow Composite (non-Twisp) spring Chinook retained will be dependent upon the number of natural-origin adults returning and the collection objective limiting extraction to no greater than 33% of the natural-origin spring Chinook return to the Methow Basin. Natural origin fish not assigning to the Twisp or Methow Composite (combined, these make up the entire Methow Basin spring Chinook population) will be released back into the Columbia River.

Weekly estimates of the passage of Wells Dam by natural-origin spring Chinook will be provided through stock-assessment and broodstock-collection activities. This information will facilitate in-season adjustments to collection composition so that extraction of natural-origin spring Chinook remains no more than 33%. Trapping at the Winthrop NFH will be included, if needed, as a result of broodstock shortfalls.

Pre-season run-escapement of Methow-origin spring Chinook to Wells Dam during 2017 is estimated at 3,265 spring Chinook, including 2,292 hatchery and 973 natural origin spring

Chinook (Table 1 and Table 2). In-season estimates of natural-origin spring Chinook will be adjusted proportional to the estimated returns to Wells Dam at weekly intervals and may result in adjustments to the broodstock collection targets presented in this document.
The following broodstock collection protocol was developed based on BKD management strategies, projected return for BY 2017 Methow Basin spring Chinook at Wells Dam (Table 1 and Table 2), and assumptions listed in Appendix A.

The 2017 aggregate Methow spring Chinook broodstock collection will target up to 122 adult spring Chinook (18 Twisp, 104 Methow; Table 3). Based on the pre-season run forecast, Twisp fish are expected to represent about 5% of the CWT tagged hatchery adults and 18% of the natural origin spring Chinook passing above Wells Dam (Tables 1 and 2). Based on this proportional contribution and a collection objective to limit extraction to no greater than 33% of the age-4 and age-5 natural-origin spawning escapement to the Twisp, the 2017 Twisp origin broodstock collection will total 18 wild fish, representing 100% of the broodstock necessary to meet Twisp program production of 30,000 smolts. Methow Composite fish are expected to represent about 42% of the CWT tagged hatchery adults and 82% of the natural origin spring Chinook passing above Wells Dam (Tables 1 and 2). Based on this proportional contribution and a collection objective to limit extraction to no greater than 33% of the age-4 and age-5 natural-origin recruits, the 2017 aggregate Methow broodstock collection will total 104 natural origin spring Chinook. Broodstock collected for the aggregate Methow programs represents 100% of the broodstock necessary to meet the Methow programs production of 223,765 smolts. The Twisp River releases will be limited to releasing progeny of broodstock identified as wild Twisp and or known Twisp hatchery origin fish, per ESA Permit 18925. The Grant/Douglas/Chelan PUD releases will include progeny of broodstock identified as wild non-Twisp origin (or known Methow Composite hatchery origin if needed to meet shortfalls in the production goal) fish. Age-3 males ("jacks") will not be collected for broodstock.

Table 1. Brood year 2012-2014 age class-at-return projection for wild spring Chinook above Wells Dam, 2017.

Brood year	**Smolt Estimate**		**Age-at-return**									
			Twisp Basin					**Methow Basin**				
	Twisp[1]	Methow Basin[2]	Age-3	Age-4	Age-5	Total	SAR[3]	Age-3	Age-4	Age-5	Total	SAR[4]
2012	12,277	35,976	9	71	**11**	91	0.0074	47	615	**126**	788	0.0219
2013	24,605	36,242	19	**142**	21	182	0.0074	48	**619**	127	794	0.0219
2014	28,380	41,353	**21**	164	25	210	0.0074	**54**	707	145	906	0.0219
Estimated 2017 Return			**21**	**142**	**11**	**174**		**54**	**619**	**126**	**799**	

[1] Smolt estimate is based on sub-yearling and yearling emigration (Charlie Snow, personal communication).

[2] Estimated Methow Basin smolt emigration based on Twisp Basin smolt emigration, proportional redd deposition in the Twisp River and Twisp Basin smolt production estimate.

[3] Geometric mean Twisp NOR spring Chinook SAR to Wells Dam estimated using natural origin PIT tag returns (BY 2003-2009; David Grundy, personal communication).

4 Geometric mean Methow NOR spring Chinook SAR to Wells Dam estimated using natural origin PIT tag returns (BY 2003-2009; David Grundy, personal communication).

Table 2. Brood year 2012-2014 age class and origin run escapement projection for UCR spring Chinook at Wells Dam, 2017.

	Projected Escapement											
	Origin								Total			
	Hatchery				Wild				Methow Basin			
Stock	**Age-3**	**Age-4**	**Age-5**	**Total**	**Age-3**	**Age-4**	**Age-5**	**Total**	**Age-3**	**Age-4**	**Age-5**	**Total**
MetComp	188	473	12	**673**	54	619	126	**799**	242	1,092	138	**1,472**
%Total				41.5%				82.1%				56.7%
Twisp	16	47	12	**75**	21	142	11	**174**	37	189	23	**249**
%Total				4.6%				17.9%				9.6%
Winthrop (MetComp)	324	1,189	31	**1,544**					324	1,189	31	**1,544**
%Total				53.9%								33.7%
Total	528	1,709	55	**2,292**	75	761	137	**973**	603	2,470	192	**3,265**

Table 3. Number of broodstock needed for the combined Methow spring Chinook conservation program production obligation of 223,765 smolts, collection location, and mating strategy.

By obligation	Production target	Number of Adults: Hatchery	Number of Adults: Wild	Total
Chelan PUD	60,516		16F/16M	**32**
Douglas PUD	29,123		8F/8M	**16**
Grant PUD	134,126		37F/37/M	**74**
Total	**223,765**		**61F/61/M**	**118**

By program		Number of Adults: Hatchery	Number of Adults: Wild	Total	Collection location	Mating protocol
Twisp	**30,000**		**9F/9M**	**18**	Wells Dam/Twisp Weir	2x2 factorial
MetComp	**193,765**		**52F/52M**	**104**	Wells Dam/Methow Hatchery	2x2 factorial
Total	**223,765**		**61F/61M**	**122**		

Trapping at Wells Dam will occur at the East and West ladder traps beginning on May 1, or at such time as the first spring Chinook are observed passing Wells Dam, and continue through June 20, 2017. Spring Chinook broodstock collection and stock assessment sampling activities authorized through the 2017 Douglas PUD Hatchery M&E Implementation Plan will utilize a combination of trapping on the East and West ladders as per the detailed descriptions of the modified trapping operations for spring Chinook collection in Appendix D (pages 38 and 39).

Natural origin spring Chinook will be retained from the run, consistent with spring Chinook run timing at Wells Dam (weekly collection quota). Collection goals will be developed by Wells M&E staff to identify the most appropriate spatial and temporal approach to achieving the overall brood target. All natural origin spring Chinook collected at Wells Dam for broodstock will initially be held at Well FH (or immediately transferred to Methow FH taking into account the status of adult holding during the modernization project) pending genetic results and then transferred to Methow FH. Fish collected at MFH will remain at MFH or transferred to WNFH.

Trapping at the Twisp Weir for spring Chinook may begin May 1 or at such time as spring Chinook are observed passing Wells Dam and may continue through August 23. The trap may be operated up to five days per week/24 hours per day (provided it is manned during active trapping).

Trapping at the Methow Outfall trap and Winthrop NFH ladder operations will run concurrent with the Twisp Weir. Pending development of an adult management plan for spring Chinook in the Methow basin, hatchery-origin adults captured at the Methow Outfall (surplus to the Methow Hatchery program) will be transferred to the WNFH for incorporation into WNFH brood as supported by the HGMP's of both facilities.

Steelhead

Douglas PUD and Grant PUD steelhead mitigation programs above Wells Dam utilize adult broodstock collections from multiple sources and locations such as at Wells Dam, Twisp Weir, Methow Hatchery volunteer trap, WNFH volunteer trap, Okanogan River Basin and angling in Methow River (Table 5). Generally incubation/rearing occur for the Methow safety net, Okanogan, and Columbia River release at Wells Fish Hatchery (FH) with incubation/early rearing at Methow Hatchery for the DPUD conservation program. Broodstock for the composited conservation programs (DPUD and USFWS) is achieved via hook-and-line in the Methow Basin and the Twisp Weir. Broodstock for the Methow safety net program is achieved primarily through returns to WNFH and surplus fish removed at Methow Hatchery and the Twisp Weir.

Specific program brood sources are structured as follows:

Wells Hatchery – Conservation Releases

The Wells Hatchery conservation releases are a composite of locally collected Twisp wild broodstock and adults collected by the USFWS in the mainstem Methow River. Adults are collected in the spring of the current spawn year.

Wells Hatchery – Methow River Release

The Wells Hatchery Methow River release (Methow safety net program) uses locally collected hatchery origin broodstock representative of the Twisp and WNFH conservation programs and as needed, the Methow safety-net program. Adults are collected in concert with adult management activities at the Twisp Weir, Methow Hatchery, WNFH, and through hatchery fish intercepted during natural origin brood hook and line collection for the USWFS Winthrop conservation program. As a backup to potential collection shortfalls in the Methow safety net program as a result of uncertainties in spring collection efficiencies, a portion of the Methow program will be augmented with collection of hatchery origin adults (30) occurring in the fall at Wells Dam. These fall-collected Wells stock fish will be considered surplus to any spring-collected Methow and Okanogan broodstock, and eggs and/or fry from these surplus broodstock may be utilized for other programs in the upper Columbia.

Wells Hatchery-Columbia River Release

The Wells Hatchery Columbia River releases will use returns to Wells Hatchery and may be augmented with adult returns to the Methow Hatchery and Winthrop FH if needed to fulfill the program. To ensure the safety-net programs (Methow and Okanogan) have broodstock, a portion of the broodstock requirement (60 adults) will be collected at Wells Dam in the fall of 2017, and held at Wells Hatchery (Table 5). These fall-collected Wells stock fish will be considered surplus to the spring-collected Methow and Okanogan broodstock, and eggs and/or fry from these surplus broodstock may be utilized for other programs in the upper Columbia.

Winthrop NFH – Methow River Release

The USFWS Methow River release will primarily use natural origin fish collected through hook and line collection efforts in the Methow River each spring and adults collected at the Twisp Weir. In the event NO collection falls short of the target, hatchery origin returns to WNFH will be prioritized, followed by excess hatchery returns to Methow Hatchery. Transfer of adult and/or gametes/eggs between program will be carefully choreographed to ensure fish are being utilized in the most efficient and effective manner.

Okanogan River releases

The Okanogan River uses a combination of natural origin adults collected in Omak Creek and hatchery origin adults collected in Omak Creek or elsewhere in the Okanogan Basin through CCT collection efforts. As a backup to potential collection shortfalls in the Okanogan, a portion of the Okanogan program will be augmented with collection of hatchery origin adults (30) occurring in the fall at Wells Dam. These fall-collected Wells stock fish will be considered surplus to any spring-collected Methow and Okanogan broodstock, and eggs and/or fry from these surplus broodstock may be utilized for other programs in the upper Columbia.

Steelhead programs located upstream of Wells Dam and at Wells Hatchery are presented in Table 4.

Table 4. 2018 brood year Steelhead Programs at Wells Hatchery and Upstream of Wells Dam

Program	Hatchery	Owner	Release Location	Release Target	Broodstock Collection Locations
DPUD Conservation	Methow Hatchery (incubation); Wells Hatchery (rearing)	Douglas PUD	Twisp River @ Buttermilk Bridge	24,000 (S_1)	MetComp WxW
DPUD Conservation	Methow Hatchery (incubation); Wells Hatchery (rearing)	Douglas PUD	WNFH on-station or as part of a rotational release plan to be developed by the JFP	24,000 (S_1)	MetComp WxW
Methow Safety-Net	Wells Hatchery	Douglas PUD	Methow Hatchery	50,000	HxH: Twisp Weir (up to 25%) + WNFH Hatchery (75%) or WNFH 1st, MFH 2nd to make up balance
Methow Safety-Net	Wells Hatchery	Douglas PUD	Methow River @ Effy's Bridge	50,000	HxH: Twisp Weir (up to 25%) + WNFH Hatchery (75%) or WNFH 1st, MFH 2nd to make up balance
Mainstem Columbia Safety-Net	Wells Hatchery	Douglas PUD	Wells Hatchery	160,000	HxH: Wells FH/Dam returns (1st option); Methow FH/WNFH (2nd option)
WNFH Conservation Program	WNFH	USFWS	WNFH (up to 176K), Twisp River @ Buttermilk Bridge (24K), other locations as determined by the JFP	Up to 200,000 (S_2)	Maximize use of NOR, up to 55 pair captured by hook and line in the Methow River above Twisp, up to 12 pair from the Twisp Weir, volunteers to WNFH, and tangle netting in Spring Creek.
Omak Creek	Wells Hatchery	Grant PUD	Omak Creek	Up to 40,000[1]	Okanogan Basin/Omak Creek (up to 16 wild or hatchery)
Okanogan	Wells Hatchery	Grant PUD	Okanogan Basin	Up to 90,000[1]	42 Wells Stock collected at Wells Dam/Hatchery or at tributary locations in the Okanogan Basin operated by the CCT

[1] The Grant PUD programs will total 100,000 smolts, +-10% (58 broodstock). Broodstock collection number, origin, location, and smolt numbers will be consistent with those detailed in National Marine Fisheries Service (NMFS) letter to Randall Friedlander (CCT) and Jeff Grizzel (GPUD) dated February 27, 2014 and detailed in Table 4 and Table 5 herein.

The following broodstock collection protocol was developed based on mitigation program production objectives (Table 6), biological assumptions (Appendix A), and the probability that sufficient adult steelhead will return in 2017/2018 to meet production objectives absent a preseason forecast at the present time.

For the 2018 brood steelhead programs operating above Wells Dam, a total of 350 adults (152 natural origin and 198 hatchery origin adults) are estimated to be needed to fulfill the respective mitigation obligations (Table 6). To support these obligations and to ensure sufficient backup adults are on hand in the event tributary based collection efforts fall short of targets, trapping at Wells Dam and/or Wells FH will selectively retain up to 257 hatchery origin steelhead (west [and east, as necessary] ladder and volunteer trap collection; Table 5). As a note, all potential broodstock will be scanned for PIT tags at collection. Any adult determined to have been part of the Yakama Nations kelt reconditioning program will be released in the vicinity it was collected.

Methow Conservation Program (DPUD)

In the spring of 2018, 24 wild steelhead will be targeted at the Twisp Weir and transferred to the Winthrop Hatchery for spawning, incubation, and possibly early rearing (to facilitate viral testing of progeny resulting from live spawning females for the YN kelt reconditioning program), after which they will be moved to Wells Hatchery for the balance of rearing (Table 5).

Methow Safety Net Program

Up to 14 surplus hatchery-origin Twisp-stock steelhead (to meet up to 25% of the 100K Methow Safety-Net release) will be targeted at the Twisp Weir and moved to Wells Hatchery for spawning. No less than 46 hatchery adults will be targeted at WNFH and if needed/available, Methow Hatchery volunteer traps to meet the balance of the program needs (Table 6). Up to 30 hatchery origin Wells stock collected and held at the Wells Hatchery will be used as a final option if broodstock collection at the Twisp Weir, and WNFH and MH traps are unsuccessful (Table 5). If needed, WNFH HO fish identified through PIT tag detections, collected at the MFH outfall may be transferred to WNFH for use in the Spawning Channel Evaluation Project rather than retained for broodstock. Coordination between USFWS and WDFW hatchery staff will occur during the season to determine prioritization.

Methow Conservation Program (USFWS)

Approximately 110 natural origin adults (55 pair) will targeted for retention through hook and line collection efforts in the Methow River (Table 6). In the event of a shortage, excess hatchery steelhead from the Twisp Weir and volunteer returns to the WNFH will be utilized as needed to augment WNFH broodstock. Should there be inadequate surplus steelhead from these sources, excess hatchery steelhead (presumed Methow Safety-Net origin) captured at the Methow Hatchery volunteer trap will be used to fulfill the program. Up to 24 additional NO adults from the Twisp Weir will be transferred to WNFH and combined to form a pooled composite conservation program that will support both DPUD and USFWS conservation programs.

Okanogan Hatchery/Endemic Program

Fifty-eight (58) adult steelhead will be targeted in the Okanogan Basin, including up to 16 natural-origin adults collected from Omak Creek for a 40K endemic program operated by the CCT and funded by GCPUD as part of their 100K UCR steelhead mitigation obligation (Table 5). Additionally, up to 30 hatchery adult steelhead will be targeted at Wells Dam/Hatchery as a back-up collection contingency due to unknown broodstock collection efficiencies in the Okanogan River Basin (Table 5).

Table 5. Broodstock collection locations, number, and origin by program.

Program	Number of Adults[1]		Primary collection location	Number of backup adults[2]	Backup collection location(s)	Total adult collection[1]	
	Hatchery	Wild				Hatchery	Wild
DPUD Columbia R.	108		Wells FH/Dam Wells Dam		Methow FH	108	
DPUD Methow R.	68		Twisp weir (14) Methow FH (46)	Up to 30	WNFH[3] Wells Dam	98	
DPUD Met. Conservation		24	Twisp weir	NA	NA		24
GPUD Okanogan R.	0-58[6]	0-58[7]	Omak Cr. Okanogan R. Wells FH[5]	30	Wells Dam	0-88	0-58
USFWS Methow R.		110	Methow R. WNFH[4]	NA	Methow FH		110
Total (PUD programs)	**176-234**	**24-82**		**60**		**206-294**	**24-82**
Total (All programs)	**176-234**	**134-192**		**60**		**206-294**	**134-192**

[1] Assumes a 1:1 sex ration (see table 6).
[2] All backup broodstock are hatchery origin adults.
[3] May include hatchery origin adults collected via the USFWS hook and line efforts for natural origin fish in the Methow River and adult returns to WNFH.
[4] May also include excess hatchery origin adults collected at Methow FH and the Twisp Weir.
[5] Spring collection of hatchery origin steelhead as needed to meet program shortfall for the Okanogan Program.
[6] Dependent upon number of NOR broodstock collected in the Okanogan Basin to achieve 58 total broodstock for the Okanogan program.
[7] Depending upon NOR abundance, trapping efficiency, and issuance of a new Section 10 Permit for the Okanogan steelhead program to allow, up to 100% wild collected in the Okanogan Basin to achieve program broodstock target.

Table 6. Number of broodstock needed to produce approximately 608,000 smolts for the above Wells Dam 2018 brood summer steelhead programs. Includes primary collection location(s) and mating strategy. *Broodstock totals do not include additional fish that may be collected at other locations as a backup for shortfalls from primary collection sources.*

Program	Production target/request	Number of Adults		Total	Collection location	Mating protocol
		Hatchery	Wild			
DPUD[1] Columbia R.	160,000	54F/54M		**108**	Wells Dam/Twisp Weir/	1:1
DPUD[2] Methow R.	100,000	34F/34M		**68[4]**	Twisp Weir, MFH, WNFH, Wells Dam	1:1
DPUD Methow Conservation	48,000		12F/12M	**24**	Twisp Weir/USFWS	2x2 Factorial
GPUD Okanogan R.[3]	100,000	21F/21M	8F/8M	**58[5]**	Okanogan R./Omak Creek	1:1/2x2[7]
USFWS	200,000		55F/55M	**110[6]**		2X2 Factorial

Total[4]	**608,000**	**109F/109M**	**75F/75M**	**368**

[1] Mainstem Columbia releases at Wells Dam. Target HxH parental adults as the hatchery component.
[2] Methow hatchery release of HxH fish produced from either adults returning from the Winthrop conservation program, adults trapped at MFH, and/or surplus hatchery adults from the Twisp weir.
[3]Okanogan Basin releases, including Omak Creek is100,000 smolts as part of GCPUD's 100K summer steelhead obligation and targets 58 adults in the Okanogan Basin, including up to 16 natural origin adults to fulfill the Okanogan Basin Production of 100,000 smolts comprised of natural origin and locally-adapted steelhead returning to the Okanogan River. Upon issuance of a new Section 10 permit for the Okanogan Steelhead program, up to 58 natural origin steelhead may be collected in the Okanogan Basin to fulfill the broodstock target, consistent with the Section 10 Permit provisions. Retention of progeny from these fish will be dependent upon success of CCT trapping efforts in Okanogan Basin tributaries.
[4] Up to an additional 30 hatchery adults will be collected at Well FH as a fall back to shortfalls in collections for the Methow safety net.
[5] Up to an additional 30 hatchery origin adults will be collected at Wells Dam as backup to potential shortfalls in Okanogan Basin collection efforts.
[6] Collection priority: 1) hook and line, 2) adult returns to WNFH, 3) excess adult returns to Methow Hatchery.
[7] A 1:1 mating protocol will be used for all HxH crosses within the Okanogan. The Okanogan endemic program (WxW) will utilize a minimum 2x2 factorial mating to minimize potential negative effects associated with a small effective population size.

Overall collection for the PUD programs will be 294 fish (a combination of program specific and back-up adults; Table 5) and limited to no more than 33% of the entire run and/or 33% of the natural origin return. Hatchery and natural origin collections will be consistent with run-timing of hatchery and natural origin steelhead at Wells Dam and the Twisp Weir. Trapping at the Wells Dam ladders will occur between 01 August and 31 October, up to three days per week, and up to 16 hours per day, as required to meet broodstock objectives. Trapping will be concurrent with summer Chinook broodstocking efforts through 15 September on the west ladder (Appendix D). Operational criteria and dates for the Twisp Weir are still under construction.

Adult return composition including number, origin, age structure, and sex ratio will be assessed in-season at Priest Rapids and Wells dams. Broodstock collection adjustments may be made based on in-season monitoring and evaluation. If collection of adults from the east ladder trap is necessary, access will be coordinated with staff at Wells Dam due to the rotor rewind project.

Adult Collection – DPUD and USFWS Conservation Programs – All adults collected as part of the DPUD (formerly Twisp) and USFWS conservation programs will be transferred, held, and spawned at WNFH.
Rearing - At either the eyed egg stage or early ponded fry stage (to be determined after discussions with fish health), a sufficient number of progeny will be transferred to DPUD facilities for rearing to a yearling smolt stage (S_1). WNFH will rear the balance of the production to a two year smolt (S_2).

Release – At release, 24K S1 smolts and 24K S_2 smolts from the conservation program will be direct planted into the Twisp River at the Buttermilk Bridge.

The remaining S_1 smolts will either be transferred to WNFH for release concurrent with the S_2 release or combined with a comparable number of S_2's for release elsewhere in the Methow Basin.

The Methow safety net program will be split into two release components, the first of which will occur directly from MFH consistent with past practices. The second 50K group will be adequately PIT tagged and direct released in the lower Methow at Effy's Bridge.

Surplus UCR Juvenile Steelhead Management

In the event excess juvenile are produced from the over-collection efforts to support the Methow safety net and /or Okanogan safety net programs which rely on spring adult collections, the parties agree that distribution of juveniles will follow the following priority matrix:

1. Used to support shortfalls in the WNFH production obligation provided fish health and/or marking requirements for the program can be met.

2. Used to support any shortfalls in the Wells Columbia River release provided fish health and/or marking requirements for the program can be met.

3. Used to support shortfalls in the Ringold SHD program provided fish health and/or marking requirements for the program can be met.

4. Out-planted to landlocked lakes within Okanogan County and/or Colville Reservation provided fish health requirements can be met or provided stocking allotments are not exceeded (as determined by WDFW and/or CCT fishery managers).

In addition, surplus fish, including broodstock, will be distributed at the earliest possible life-stage (e.g., prespawn adults, eyed-egg, fry) per WDFW policy.

Summer/fall Chinook

The summer/fall Chinook mitigation program in the Methow River utilizes adult broodstock collections at Wells Dam and incubation/rearing at Eastbank Fish Hatchery. The total production level target is 200,000 summer/fall Chinook smolts for acclimation and release from the Carlton Acclimation Facility.

The TAC 2017 Columbia River UCR summer Chinook return projection to the Columbia River (Appendix D) and BY 2012, 2013, and 2014 spawn escapement to tributaries above Wells Dam indicate sufficient summer Chinook will return past Wells Dam to achieve full broodstock collection for supplementation programs above Wells Dam. The following broodstock collection protocol for the Methow summer Chinook program was developed based on initial run expectations of summer Chinook to the Columbia River, program objectives, and program assumptions (Appendix A).

For 2017, up to 118 natural-origin summer Chinook at Wells Dam west (and east, if necessary) ladder(s), including 59 females for the Methow summer Chinook program (Table 7). Collection will be proportional to return timing between 01 July and 15 September. Summer Chinook stock assessment will run concurrent with summer Chinook broodstock collection at the west ladder trap. Trapping may occur up to 3-days/week, 16 hours/day (48 cumulative hours per week). Age-3 males ("jacks") will not be collected for broodstock.

Should use of Wells Dam be needed to meet any shortfalls in broodstock for summer/fall Chinook programs occurring in the Okanogan Basin, the CCT will notify the HCP-HC and Wells

HCP Coordinating Committee/PRCC-HSC and coordinate with Douglas PUD, Grant PUD, and WDFW to facilitate additional broodstock collection effort. Summer Chinook broodstock collection efforts at Wells Dam, should they be required to meet CJH program objectives, will be conducted concurrent with broodstock collection efforts for the Methow summer Chinook program and or steelhead collection efforts for steelhead programs above Wells Dam.
If the probability of achieving the broodstock goal is reduced based on passage at the west ladder or actual natural-origin escapement levels, broodstock collections may be expanded to the east ladder trap and/or origin composition will be adjusted to meet the broodstock collection objective. If collection of adults from the east ladder trap is necessary, access will be coordinated with staff at Wells Dam due to the rotor rewind project.

Table 7. Number of broodstock needed for Grant PUDs Methow summer Chinook production obligation of 200,000 smolts, collection location, and mating strategy.

Program	Production target	Number of Adults		**Total**	Collection location	Mating protocol
		Hatchery	Wild			
Methow	200,000		59F/59M	**118**	Wells Dam	1:1
Total	**200,000**		**118**	**118**		

Rearing – Early rearing growth will be modulated for a targeted size at release of approximately 18 fpp. Beginning on or about February 1, fish will be fed to satiation to maximize spring growth regardless of end size.

Release - The summer Chinook salmon acclimated at the Carlton Acclimation Facility will be forced released using the following criteria.

- all fish will be released during darkness (e.g., 9:00 PM or later),
- all fish will be released when Columbia River and Methow River flows are predicted to be satisfactory,
- all fish will be released no later than May 7 regardless of flow conditions,
- attempts will be made to have a steady release of fish to reduce collisions on the PIT antenna array.

Satisfactory flows in the Columbia occur when spilling flows are started and flows in the Methow River are satisfactory when flows are high and turbid. Releases will not occur until satisfactory flows in the Columbia occur, but could occur if Methow River flows are not satisfactory due to insufficient snow pack.

Columbia River Mainstem below Wells Dam

Summer/fall Chinook

Collection at the Wells FH volunteer channel will be used to collect the broodstock necessary for the Wells FH yearling (320,000) and sub-yearling (484,000) programs.
Because of CCT concerns about sufficient natural origin fish reaching spawning grounds and to ensure sufficient NOR's being available to meet the CCT summer Chinook program, incorporation of natural origin fish for the Wells program or programs with broodstock originating from the Wells volunteer channel, will be limited to fish collected in the Wells volunteer channel. The following broodstock collection protocol was developed based on mitigation objectives and program assumptions (Appendix A).

WDFW will target 494 run-at-large summer Chinook from the volunteer ladder trap at Wells Fish Hatchery outfall for the Wells sub-yearling and yearling programs, and up to 178 for the YN 275K-350K green egg request for the Yakima summer Chinook program (Table 8). Due to fish health concerns associated with the volunteer collection site (warming Columbia River water during late August), the volunteer collection will begin July 11 and terminate by August 31.

Summer/fall Chinook mitigation programs that release juveniles directly into the Columbia River between Wells and Rocky Reach dams have traditionally been supported through adult broodstock collections at the Wells Hatchery volunteer channel. For 2017, broodstock collection for the Chelan Falls summer Chinook program will be prioritized at the Chelan Falls Canal Trap (CFCT) which was successfully piloted in 2016, beginning July 1 through September 15. Collection efforts in the EBO in 2015 and 2016 were insufficient to meet the adult requirements for the Chelan Falls program necessitating development of alternate collection locations/strategies. If shortfalls in adult needs are expected and the number of females needed to meet program has not been reached by August 15^{th}, the HCP HC will discuss whether broodstock collection may default to surplus summer Chinook from the Entiat NFH or other HCP approved location to make up the difference. The 2017 broodstock target for the Chelan Falls program is 358 adults (Table 8). The total production level supported by this collection is up to 576,000 yearlings for the Chelan Falls program.

Table 8. Number of broodstock needed for the combined Chelan and Douglas PUD Columbia River below Wells summer Chinook production obligations of 1,380,000 smolts, collection location, and mating strategy. Also includes broodstock necessary for outside programs that rely on adult collection at Well Hatchery in 2017.

Program	Production target	Number of Adults[2]		**Total**	Collection location	Mating protocol
		Hatchery	Wild			
Wells 1+	320,000	94F/94M		**188**	Wells VC[3]	1:1
Wells 0+	484,000	153F/153M		**306**	Wells VC[3]	1:1
Chelan Falls 1+	576,000	179F/179M		**358**	EB outfall	1:1
Yakama Nation	350,000[1]	89F/89M		**178**	Wells VC[3]	NA

Total	1,730,000	515F/515M		1,030	

[1] The YN request is for between 275K and 350K green eggs to support the Yakima River summer Chinook program.
[2] The number of adults collected for these programs may indirectly incorporate natural origin fish; however, because they are volunteers, the number is likely to be less than 10% of the total.
[3] Wells Hatchery volunteer channel trap.

Wenatchee River Basin

In 2016 the Eastbank Fish Hatchery (FH) is expecting to rear spring Chinook salmon for the Chiwawa River and Nason Creek acclimation facilities located on the Chiwawa River and Nason Creek. The program production level target for the Chiwawa program (Chelan PUD obligation) in 2016 is 144,026 smolts, and based upon the biological assumptions (Appendix A) will require a total broodstock collection of about 80 natural origin spring Chinook (Table 10). The spring Chinook production obligation for Grant PUD in the Wenatchee Basin is 223,670 smolts (125,000 conservation and 98,670 safety net) and based upon the biological assumptions (Appendix A) will require a total broodstock collection of 142 adults (70 natural origin and 72 hatchery origin; Table 10).

Pre-season run-escapement of Wenatchee spring Chinook to Tumwater Dam during 2016 is estimated at 2,101 spring Chinook, including 1,359 hatchery and 752 natural origin spring Chinook (does not include age-3 males; Table 9). In-season estimates of natural-origin spring Chinook to Tumwater Dam will be provided through stock-assessment and broodstock-collection activities. This information will facilitate in-season adjustments to collection composition so that extraction of natural-origin spring Chinook remains no more than 33%.

Table 9. Age-4 and age-5 class return projection for wild and hatchery spring Chinook to Tumwater Dam during 2017.

	Chiwawa Basin			Nason Cr. Basin			Wenatchee Basin to Tumwater Dam		
	Age-4	Age-5	Total	Age-4	Age-5	Total	Age-4	Age-5	Total
Estimated wild return	418	108	**526**	123	32	**155**	614	159	**773**
Estimated hatchery return	3,238	63	**3,301**	1,336	0	**1,336**	4,574	63	**4,637**
Total	3,656	171	**3,827**	1,459	32	**1,491**	**5,188**	**222**	**5,410**

Table 10. Number of broodstock needed for the combined Wenatchee spring Chinook production obligation of 367,969 smolts, collection location, and mating strategy.

Program	Production target	Number of Adults		**Total**	Collection location	Mating protocol
		Hatchery	Wild			
Chiwawa Conservation	144,026	18F/18M	37F/37M	**74[1]**	Chiwawa Weir and Tumwater Dam[4]	2x2 factorial
Nason	125,000	0	35F/35M	**77[2]**	Tumwater	2x2 factorial

Conservation					Dam[4]	
Nason Safety net	98,670	34F/34M[3]	0	**68**	Tumwater Dam	1:1
Total	**367,969**	**104**	**144**	**255[2]**		

[1] Includes 36 hatchery origin adults (represents ~50% of the adult target) to ensure the Chiwawa production goal is met if insufficient NO adults are collected).
[2] Includes ~10% additional NO fish for the Nason program to account for fish that may assign back to the White River spawning aggregate. No more than 70 NO fish will be retained for spawning.
[3] Due to the lack of returning hatchery fish from the Nason program (first age-4 returns are expected in 2017), Chiwawa hatchery fish will only be collected to satisfy the Nason Cr. safety net program if in-season estimates of returning conservation fish fall short of expectations.
[4] Collection of NO fish at Tumwater for the Chiwawa program will include previously PIT tagged adults (NO juveniles PIT tagged at the Chiwawa smolt trap).

Chiwawa River Conservation Program Broodstocking:

- Based upon estimates of returning previously PIT tagged NO fish to Tumwater Dam (Table 11), approximately 30 previously PIT-tagged NO spring Chinook from the Chiwawa River could be collected at TWD between June 1 and July 15, concurrent with Nason Creek brood stocking, adult management, RM&E, and the RRS Study.
- The balance of adults needed to meet the Chiwawa Conservation program (up to ~74 total or ~37 females) would be collected at the Chiwawa Weir.
    - Weir operations would be on a 24 hour up/24 hour down schedule from about June 15 through August 1 (not to exceed 15 cumulative trapping days). Timing of trap operation would be based on NO fish passage at TWD and would use estimated travel times (derived from PIT tags) to the lower Chiwawa PIT tag antenna array.
    - In the absence of adequate redd count data (i.e. until 2018) to calculate the 10% threshold, if after 15-days of weir operation, 67 bull trout encounters, or 15 August, the NO broodstock target is not reached, the balance of the mitigation obligation will be met through hatchery fish already retained for the Chiwawa program at TWD.
    - Additionally, no more than 10 percent of the estimated mean number of adult bull trout in the Chiwawa Basin (using a rolling five year average derived from expanded redd counts) may be encountered during broodstock collection without concurrence from the USFWS. Sufficient redd data to calculate a five year average is expected to be available as early as 2018.
    - To ensure the production target is met for the Chiwawa program, in the event that insufficient NO adults are collected for the conservation program, HO adults (presently estimated at 50% of the total broodstock requirement, however may be adjusted up or down depending on the run) would be collected at TWD to make up the shortfall (see Table 10) between June 1 and July 15.
    - Historic and in-season data for NO spring Chinook timing to the lower Chiwawa array from TWD will be used to determine optimal dates for collection.

- Any bull trout that are caught at the Chiwawa trap will be immediately removed and released at a site ~10KM upstream of the weir to prevent fallback/impingement and to mitigate for potential delay. Handling and transport will be conducted by WDFW hatchery staff.
- If a bull trout is killed during trapping, despite implementing conservation measures, trapping activities will cease and not continue until additional measures to minimize risks to bull trout can be discussed with the USFWS.

Table 11. PIT tagged natural origin adults to Tumwater Dam for the most recent 5-years (2012-2016) with conversion rates from Bonneville Dam.

	Detections at Bonneville Dam		Detections at Tumwater Dam			
Return year	Nason	Chiwawa	Nason	Conversion rate	Chiwawa	Conversion rate
2012	7	60	5	0.714	52	0.867
2013	2	29	2	1.000	22	0.759
2014	6	66	1	0.167	29	0.439
2015	9	42	6	0.667	28	0.667
2016	8	34	8	1.000	24	0.706
Mean	6.4	46.2	4.4	0.710	31.0	0.688
Geomean	5.7	44.0	3.4	0.603	29.5	0.671

Nason Creek Conservation Program Broodstocking:

- Up to ~77 NO spring Chinook (to allow for up to 10 percent of White River NO fish estimated to be encountered at Tumwater Dam MSA; Table 10) would be collected at TWD between June 1 and July 15.
  - Only 70 NO adults (35 females) will be retained to produce the 125K Nason Conservation program.
  - Collection of additional HO fish may occur in the event NO collection/retention falls short of expectation.
  - Brood stock collection would run concurrent with adult management, RM&E, and the Spring Chinook Relative Reproductive Success Study. The GAPS microsatellite panel and existing GAPS plus WDFW spring Chinook Wenatchee baseline will be used for genotyping and GSI analyses similar to methods used in 2013.

- Decision Rules:
  - Any fish that assigns to the White River with greater than 90% surety will be released in the White River.

  - Unassigned fish (individuals that can't be assigned to the Wenatchee Population or Leavenworth NFH), will be released upstream of Tumwater Dam.
  - In the event more fish assign to Nason or Chiwawa than are needed to meet the conservation program, the excess with the lowest assignment probabilities will be returned to the river upstream of Tumwater Dam.

Nason Creek Safety Net Program Broodstocking:

- Up to ~68 HO spring Chinook adults (from safety net program – identified by snout wire + body wire) would be targeted at TWD (Table 10) between June 1 and July 15, concurrent with NO brood stock collection, adult management, RM&E, and the Spring Chinook Relative Reproductive Success (RRS) Study.

Nason Creek spring Chinook Rearing/Release Strategy:

Rearing – Early rearing growth will be modulated for a targeted size at release of approximately 18 fpp. Beginning on or about February 1, fish will be fed to satiation to maximize spring growth regardless of end size.

Release - Spring Chinook salmon acclimated at the Nason Creek Acclimation Facility will be forced released using the following criteria.

- all fish will be released during darkness (e.g., 9:00 PM or later),
- all fish will be released when Columbia River and Nason Creek flows/condtions are predicted to be satisfactory,
- all fish will be released no later than May 7 regardless of flow conditions,
- attempts will be made to have a steady release of fish to reduce collisions on the PIT antenna array.

Satisfactory flows in the Columbia occur when spilling flows are started and flows in Nason Creek are satisfactory when flows are high and turbid. Releases will not occur until satisfactory flows in the Columbia occur, but could occur if Nason Creek flows are not satisfactory due to insufficient snow pack.

**NOTE: Due to the uncertainty of having a reliable surface water intake structure (compromised by heavy bedload movement during fall [2015] and winter [2016] freshets) at the Nason Creek Acclimation Facility in time for acclimation of this brood year, alternate rearing strategies and/or locations may need to be considered by the HSC.

Steelhead

The steelhead mitigation program in the Wenatchee Basin uses broodstock collected at Dryden and Tumwater dams located on the Wenatchee River. Per ESA section 10 Permit 1395 provisions, broodstock collection will target adults necessary to meet a natural origin – conservation (WxW) oriented program, not to exceed 33% of the natural origin steelhead return to the Wenatchee Basin and a hatchery origin (HxH) – safety net program. The conservation and safety net programs each make up approximately half of the 247,300 production obligation. Based on these limitations and the assumptions listed in Appendix A, the following broodstock collection protocol was developed:

WDFW will retain a total of 140 mixed origin steelhead for broodstock for a smolt release objective of 247,300 smolts (Table 12). The 70 hatchery origin adults will be targeted at Dryden Dam and if necessary Tumwater dam. The 70 natural origin adults will be targeted for collection at Tumwater Dam. Collection will be proportional to return timing between 01 July and 14 November. Collection may also occur between 15 November and 5 December at both traps, concurrent with the Yakama Nation coho broodstock collection activities. Only adipose present coded wire tagged hatchery fish (or previously PIT tagged WxW hatchery progeny) will be retained for the safety net program. Adult return composition including number, origin, age structure, and sex ratio will be assessed in-season at Priest Rapids and at Dryden Dam. In-season broodstock collection adjustments may be made based on this monitoring and evaluation. To better ensure achieving the appropriate females equivalents for program production, the collection will include the use of ultrasonography to determine the sex of each fish retained for broodstock.

In the event steelhead collections fall substantially behind schedule, WDFW may initiate/coordinate adult steelhead collection in the mainstem Wenatchee River by hook and line. In addition to trapping and hook and line collection efforts, Tumwater and Dryden dams may be operated between February and early April the subsequent spring to supplement broodstock numbers if the fall trapping effort provides fewer than the required number of adults.

Table 12. Number of broodstock needed for the combined 2018 BY Wenatchee summer steelhead production obligation of 247,300 smolts, collection location, and mating strategy.

Program	Production target	Number of Adults		Total	Collection location	Mating protocol
		Hatchery	Wild			
Wenatchee Conservation[1]	123,650	0	35F/35M	**70**	TWD[3]/Dryden LBT-RBT[4]	2x2 factorial
Wenatchee Safety net[2]	123,650	35F/35M	0	**70**	Dryden LBT-RBT[4] /TWD[4]	1:1
Total	**247,300**	**70**	**70**	**140**		

[1] Broodstock collection for the conservation program will occur primarily at Tumwater Dam and will only fall back to Dryden Dam trapping facilities if a shortfall is expected.
[2] Broodstock collection for the safety net program will occur primarily at the Dryden Dam trapping facilities to minimize activities at TWD that could increase unintended delays on non-target fish. Collection at Tumwater Dam will only occur if shortfalls in broodstock are expected at Dryden Dam.
[3] TWD=Tumwater Dam.
[4] Dryden LBT-RBT= Dryden Dam left and right bank trapping facilities.

Summer/fall Chinook

Summer/fall Chinook mitigation programs in the Wenatchee River Basin utilize adult broodstock collections at Dryden and Tumwater dams, incubation/rearing at Eastbank Fish Hatchery (FH) and acclimation/release from the Dryden Acclimation Pond. The total production level target for BY 2016 is 500,001 smolts (181,816 GCPUD mitigation and 318,185 CCPUD mitigation).

The TAC 2017 Columbia River UCR summer Chinook return projection to the Columbia River (Appendix D) and BY 2012, 2013 and 2014 spawner escapement to the Wenatchee River indicate sufficient summer Chinook will return to the Wenatchee River to achieve full broodstock collection for the Wenatchee River summer Chinook supplementation program. Review of recent summer/fall Chinook run-timing past Dryden and Tumwater dam indicates that previous broodstock collection activities have omitted the early returning summer/fall Chinook, primarily due to limitations imposed by ESA Section 10 Permit 1347 to minimize impacts to listed spring Chinook. In an effort to incorporate broodstock that better represent the summer/fall Chinook run timing in the Wenatchee Basin, the broodstock collection will front-load the collection to account for the disproportionate collection timing. Approximately 43% of the summer/fall Chinook destined for the upper Basin (above Tumwater Dam) occurs prior to the end of the first week of July; therefore, the collection will provide 43% of the objective by the end of the first week of July. Weekly collection after the first week of July will be consistent with run timing of summer/fall Chinook during the remainder of the trapping period. With concurrence from NMFS, summer Chinook collections at Dryden Dam may begin up to one week earlier. Based on these limitations and the assumptions listed in Appendix A, the following broodstock collection protocol was developed:

WDFW will retain up to 262 natural-origin, summer Chinook at Dryden and/or Tumwater dams, including 131 females (Table 13). To better ensure achieving the appropriate females for program production, the collection will implement the draft Production Management Plan, including ultrasonography to determine the sex of each fish retained for broodstock. Trapping at Dryden Dam may begin 27 June and terminate no later than 15 September and operate up to 7-days/week, 24-hours/day. Trapping at Tumwater Dam if needed may begin 15 July and terminate no later than 15 September and operate up to 48 hours per week for broodstock related activities.

Table 13. Number of broodstock needed for the combined 2017 BY Chelan and Grant PUD Wenatchee summer Chinook production obligations of 500,001 smolts, collection location, and mating strategy.

Program	Production target	Number of Adults		Total	Collection location	Mating protocol
		Hatchery	Wild			
Chelan PUD	318,185		83F/83M	**172**		
Grant PUD	181,816		48F/48M	**98**		
Total	**500,001**		**131F/131M**	**262**	Dryden LBT-RBT[1] /TWD[2]	1:1

[1] Dryden LBT-RBT= Dryden Dam left and right bank trapping facilities.
[2] TWD=Tumwater Dam.

Priest Rapids Fall Chinook

Collection of fall Chinook broodstock at Priest Rapids Hatchery (PRH) will generally begin in early September and continue through about mid-November. Juvenile release objectives specific to Grant PUD (5,599,504 sub-yearlings), and Federal (1,700,000 sub-yearlings at PRH + 3,500,000 smolts at Ringold Springs Hatchery – collection of broodstock for the federal programs are conditional upon having contracts in place with the ACOE), mitigation commitments. Biological assumptions are detailed in Appendix A. For the Ringold Springs production, adult collection, holding, spawning and incubation occurs at PRH until the eyed-egg stage. Eyed eggs are transferred to Bonneville Hatchery until they are transferred for spring acclimation and release at Ringold Springs.

For 2017 up to 1,000 adipose present, non-coded wire tagged (high proportion of natural origin) fall Chinook adults will be targeted at the OLAFT). Additional NO adults targeted as a continued pilot evaluation through hook-and-line angling efforts in the Hanford Reach to increase the proportion of natural origin adults in the broodstock to meet integration of the hatchery program will also be incorporated into the program. It is estimated that approximately 400 adults may be collected through the hook-and-line efforts. Close coordination between broodstock collections at the volunteer channel, the OLAFT and through hook-and-line efforts in the Hanford Reach will need to occur so over collection is minimized. Fish surplus to production needs will be culled at the earliest possible life-stage (e.g, brood collected, brood spawned, eggs). Presumed NOR's collected and spawned from either hook-and-line caught broodstock or OLAFT collections will be prioritized for PRH programs (i.e. OLAFT and Hanford Reach angler caught fish will be externally marked, held in a separate pond from volunteer collected fish, spawned first each week, and to the extent possible segregated and reserved for the GPUD program).

Grant PUD staff will work closely with WDFW hatchery and M&E staff to maintain separation of gametes/progeny of OLAFT and angling collected adults at spawning and through incubation/early rearing.

Based upon the biological assumptions in Appendix A, an estimated 4,219 females will need to be collected (3,536 spawned) to meet the 10,799,054 smolts required to meet the current three up-river bright (URB) programs which rely on adults collected at the Priest Rapids Hatchery volunteer channel trap, hook-and-line efforts on the Hanford Reach, and/or the Priest Rapids Dam off ladder trap (OLAFT; Table 14).

To increase the probability of incorporating a higher percentage of NOR's from the volunteer channel, adipose present, non-CWT males and females will be prioritized for retention and males older than 3 will be prioritized. In addition, preliminary information suggests that the pNORs is higher in the later part of the trapping period than the earlier period. As data become available, the PRCC-HSC may choose, in-season, to retain a disproportionately high number of broodstock from the latter half of the returns to the volunteer trap.

Implementation Assumptions

1) Broodstock may be collected at any or all of the following locations/means: the PRD off ladder trap (OLAFT – operated 4-days per week/8 hrs/day to collect up to 1,000 presumed NOR's), hook-and-line angling (ABC) in the Hanford Reach (actual numbers collected are uncertain but will contribute to the overall brood program and pNOB), and the Priest Rapids Hatchery volunteer channel trap.

2) Assumptions used to determine egg/adult needs is based upon current program performance metrics.

3) Broodstock retained from the volunteer channel will exclude to the degree possible, age-2 and 3 males (using length at age; i.e. retain males ≥ 75 cm) to address genetic risks/concerns of younger age-at-maturity males producing offspring which return at a younger age (decreased age-at-maturity) and also decrease the probability of using hatchery origin fish in the broodstock that are skewed towards earlier ages at maturity.

4) Only adipose present, non-CWT males and females will be retained for broodstock from volunteer channel collected broodstock unless a shortage is expected.

5) Only progeny of adipose present, non-wired fish encountered through hook-and-line angling and at the OLAFT will be prioritized for retention into the program.

6) Broodstock collected from the OLAFT and by hook-and-line will exclude age-2 and to the degree possible age-3 fish (<75 cm) to minimize genetic risks/concerns of younger age-at-maturity males producing offspring which return at a younger age (decreased age-at-maturity) and to ensure the highest proportion of NOR's in the collection (e.g. collection of 1 in 5 age-3 fish for broodstock from the OLAFT).

7) All gametes of fish spawned from hook-and-line broodstocking efforts and/or OLAFT collections will be incorporated into the PRH based programs.

8) Real time otolith reading and an alternative mating strategy will be implemented in 2017 similar to 2015 and 2016 unless the PRCC-HSC agrees that the PNI objective in 2017 can be met without implementing 1x4 matings. Otoliths from males from the OLAFT and ABC collections will be collected during the peak spawning week and read prior to spawning. If the male is natural origin, then it will be spawned with 4 females, otherwise it will be spawned with two.

9) All eggs or juveniles leaving PRH (including surplus) will have a unique otolith mark so that returning adults can be identified.

10) Natural origin broodstock collection at the volunteer trap will be prioritized for the GPUD program by collecting fish when the probability of encountering natural origin fish is highest and balancing run-time representation.

Table 14. Number of broodstock needed for the combined Grant PUD and ACOE fall Chinook production obligations of 10,799,504 sub-yearling smolts at Priest Rapids and Ringold Springs hatcheries, collection location, and mating strategy.

Program	Production target	Number of Adults	**Total**
Grant PUD	5,599,504	2,234F/1,145M	**3,379**
ACOE-PRH	1,700,000	681F/350M	**1,031**
ACOE – Ringold[1]	3,500,000	1,397F/716M	**2,113**
Total	**10,799,504**	**4,312F/2,211M**	**6,523**

Collection location	Estimated number of adults		Total	Collection location	Mating protocol
	Hatchery	Wild			
Priest Rapids Hatchery	**3,266F/1,683M**	**119F/55M**	**5,123**	PRH volunteer trap	1:2
OLAFT[2]	**307F/153M**	**360F/180M**	**1,000**	PRD off-ladder trap	1:2, 1:4
ABC[3]	**23F/45M**	**113F/219M**	**400**	Hanford Reach	1:2, 1:4
Total	**3,596F/1,881M** (5,477; 84.0%)	**592F/454M** (1,046; 16.0%)	**6,523**		

[1] As of brood year 2009, Priest Rapids Hatchery is taking sufficient eggs to meet the 3,500,000 sub-yearling smolt release at Ringold-Meseberg Hatchery funded by the ACOE – late incubation of this program occurs at Bonneville.
[2] Estimated number of fall Chinook females and males to be acquired from the OLAFT in 2017. F/M ratios were derived through run at large data. Estimates of H/W were derived through otolith results.
[3] ABC fish are adults collected from hook and line collection efforts on the Hanford Reach. Estimates of F/M were derived through 2012-2014 spawn numbers. Estimates of and H/W were derived through otolith results from 2012 and 2014.

Appendix A

2017 Biological Assumptions for UCR spring, summer, and Fall Chinook and Summer Steelhead Hatchery Programs

Program	Mean Values for 2012-2016								Mean Values 2010-2014 Brood
	ELISAs		Fecundity		Prespawn Survival				
	H	W			H		W		
	≥ 0.12	≥ 0.2	H	W	M	F	M	F	G-E-R Survival[1]
Methow SPC	0.170	0.052	3,563	4,197	0.986	0.993	0.978	0.983	0.913
Twisp SPC	0.105	0.059	3,413	4,144	1.000	1.000	1.000	0.971	0.913
Twisp SHD	[redacted]	[redacted]	[redacted]	5,323	[redacted]	[redacted]	1.000	1.000	0.76
Wells SHD	[redacted]	[redacted]	5,619	5,957	0.971	0.938	0.900	0.820	0.61
Okanogan Safety Net	[redacted]	[redacted]	5,483	[redacted]	[redacted]	1.000	[redacted]	[redacted]	0.80
Wells SUC 1+	0.021	0.000	4,099	4,604	0.976	0.982	0.992	0.989	0.87
Wells SUC 0+	0.021	0.000	4,099	4,604	0.976	0.982	0.992	0.989	0.80
YN Green Eggs	0.021	0.000	4,099	4,604	0.976	0.982	0.992	0.989	NA
Methow SUC	0.000	0.024	[redacted]	4,569	[redacted]	[redacted]	0.977	0.973	0.783
Chelan Falls 1+	0.022	[redacted]	4,072	[redacted]	0.988	0.982	[redacted]	[redacted]	0.825
Wenatchee SUC	0.000	0.033	[redacted]	4,834	[redacted]	[redacted]	0.975	0.954	0.856
Wenatchee SHD	[redacted]	[redacted]	5,672	5,691	1.000	0.994	0.981	0.952	0.657
Nason SPC	0.123	0.041	[redacted]	4,441	[redacted]	[redacted]	0.989	0.977	0.870
Chiwaw SPC	0.123	0.015	3,847	4,696	0.993	0.985	0.994	0.971	0.882
Priest Rapids FAC 0+	[redacted]	[redacted]	3,703	[redacted]	0.824	0.845	[redacted]	[redacted]	0.817
ACOE @PRH	[redacted]	[redacted]	3,703	[redacted]	0.824	0.845	[redacted]	[redacted]	0.817
ACOE @Ringold	[redacted]	[redacted]	3,703	[redacted]	0.824	0.845	[redacted]	[redacted]	0.768

[1] Green egg to release survival.

Appendix B

Projected Brood Year Juvenile Production Targets, Marking Methods, Release Locations, Release Size, Release Type

Brood Year	Production Group	Program Size	Marks/Tags[3]	Additional Tags	Release Location	Release Year	Release Size (fpp)	Release Type
Summer Chinook								
2017	Methow SUC 1+ (GPUD)	200,000	Ad +CWT	5,000 PIT minimum	Methow River at CAF	2019	13-18	Forced
2017	Wells SUC 0+ (DPUD)	480,000	Ad + CWT	3K-5K PIT	Columbia R. at Wells Dam	2018	50	Forced
2017	Wells SUC 1+ (DPUD)	320,000	Ad + CWT		Columbia R. at Wells Dam	2019	10	Volitional
2017	Chelan Falls SUC 1+ (CPUD)	576,000	Ad + CWT	10,000 PIT	Columbia R. at CFAF	2019	13	Forced
2017	Wenatchee SUC 1+ (CPUD/GPUD)	500,001	Ad + CWT	5,000 PIT minimum	Wenatchee R. at DAF	2019	10-15	Forced
2017	CJH SUS 1+	500,000	Ad + 100K CWT	5,000 PIT	CJH	2019	10	Volitional
2017	CJH SUS 0+	400,000	Ad + 100K CWT	5,000 PIT	CJH	2018	50	Volitional
2017	Okanogan SUS 1+	266,666	Ad + CWT	5,000 PIT	Omak Pond	2019	10	Volitional
2017	Okanogan SUS 1+	266,666	Ad + CWT		Riverside Pond	2019	10	Volitional
2017	Okanogan SUS 1+	266,666	Ad + CWT		Similkameen Pond	2019	10	Volitional
2017	Okanogan SUS 0+	300,000	Ad + CWT	5,000 PIT	Omak Pond	2018	50	Forced
Spring Chinook								
2017	Methow SPC (PUD)	108,249	CWT only	7,000 PIT	Methow R. at MFH	2019	15	Volitional
2017	Methow SPC (PUD)	25,000[1]	CWT only	7,000 PIT	Methow R. at GWP (YN)	2019	15	Volitional
2017	Methow SPC (PUD)	60,516	CWT only	TBD	Chewuch R. at CAF	2019	15	Volitional
2017	Twisp SPC (PUD)	30,000	CWT only	5,000 PIT	Twisp R. at TAF	2019	15	Volitional
2017	Methow SPC (USFWS)	400,000	Ad + CWT	10,000 PIT	Methow River at WNFH	2019	17	Volitional
2017	Okanogan SPC[4] (CCT)	200,000	CWT only	5,000 PIT	Okanogan R. at	2019	15	Volitional

					Tonasket Pond			
2017	Chief Joe SPC[5] (CCT)	700,000	Ad + 200K CWT	5,000 PIT?	Columbia R. at CJH	2019	15	Forced
2017	Chiwawa R. SPC (CPUD) (conservation)	144,026	CWT only	5,000 PIT minimum	Chiwawa River at CPD	2019	22	Short term volitional
2017	Nason Cr. SPC (GPUD) (conservation)	125,000	CWT body tag	5,000 PIT	Nason Cr. at NAF	2019	18	Forced
2017	Nason Cr. SPC (GPUD) (safety net)	98,670	Ad + CWT		Nason Cr. at NAF[9]	2019	18	Forced
Fall Chinook								
2017	Priest Rapids FAC 0+ (ACOE)	1.7M	Ad + Oto	Approximately 43,000 spread across the fish released from PRH	Columbia River at PRH	2018	50	Forced
2017	Priest Rapids FAC 0+ (GPUD)	600,000	Ad+CWT+ Oto		Columbia River at PRH	2018	50	Forced
2017	Priest Rapids FAC 0+ (GPUD)	600,000	CWT + Oto		Columbia River at PRH	2018	50	Forced
2017	Priest Rapids FAC 0+ (GPUD)	1M[2]	Ad + Oto		Columbia River at PRH	2018	50	Forced
2017	Priest Rapids FAC 0+ (GPUD)	3.4M	Oto only		Columbia River at PRH	2018	50	Forced
2017	Ringold Springs FAC 0+ (ACOE)	3.5M	Ad + Oto		Columbia River at RSH	2018	50	Forced
Steelhead								
2018	Wenatchee Mixed (HxH/WxW) (CPUD)	66,771	Ad + CWT (HxH) CWT only (WxW)	Estimated 5,400 PIT[7]	Nason Cr. direct release	2019	6	Forced/Volitional
2018	Wenatchee Mixed (HxH/WxW) (CPUD)	53,170	Ad + CWT (HxH) CWT only (WxW)	Estimated 4,300 PIT[7]	Chiwawa R. direct release	2019	6	Forced/Volitional
2018	Wenatchee Mixed (HxH/WxW) (CPUD)	102,359	Ad + CWT (HxH) CWT only (WxW)	Estimated 8,278 PIT[7]	Wenatchee R. direct release	2019	6	Forced/Volitional
2018	Wenatchee HxH (CPUD)	25,000	Ad + CWT	Estimated 2,022 PIT[7]	Wenatchee R. at BBP	2019	6	Volitional

2018	MetComp WxW (DPUD)	24,000	CWT only	5,000 PIT	Twisp River at Buttermilk Bridge	2019	6	Direct Plant
2018	MetComp WxW (DPUD)	24,000	CWT only	5,000 PIT	Methow River at WNFH or other locations	2019	6	Direct Plant
2018	Wells HxH (DPUD)	50,000	Ad only	5,000 PIT	Methow River at MFH	2019	6	Volitional
2018	Wells HxH (DPUD)	50,000	Ad only	5,000 PIT	Methow River at Effy's Bridge	2019	6	Direct Plant
2018	Wells HxH (DPUD)	160,000	Ad only	5,000 PIT	Columbia R. at Wells Dam	2019	6	Volitional
2018	MetComp WxW (USFWS)	150,000	Ad + CWT	10,000 PIT	Methow R. at WNFH	2019	4-6	Volitional
2018	MetComp WxW (USFWS)	24,000	Ad + CWT		Twisp R. at Buttermilk Bridge	2019	4-6	Direct Plant
2018	MetComp WxW (USFWS)	24,000	Ad + CWT		Methow R. at WNFH or other locations TBD in conjunction with DPUD S_1	2019	4-6	Volitional/Direct Plant
2018	Okanogan HxH/HxW (CCT/GPUD)	Up to 100K [6]	Ad /CWT (TBD) [8]	Up to 20,000 PIT [9]	Okanogan/Similkameen Omak, Salmon, Antoine, other tribs. (TBD)	2019	5-8	Volitional capture Wells; dropped planted in tributaries?
2018	Okanogan WxW (CCT/GPUD)	Up to 100K [6]	Body/snout CWT/Alternate fin clip (TBD)[7]	Up to 20,000 PIT [8]	Okanogan/Similkameen Omak, Salmon, Antoine, other tribs. (TBD)	2019	5-8	Volitional

[1] Release of fish at the Goat Wall Pond remote acclimation site operated by the YN is conditional upon HC and HSC approval.
[2] Externally marking of this group is presently funded by WDFW. Marking of this 1M fish is contingent on *US v. Oregon* Policy Committee approval for 2017.
[3] Presently all CWT's are applied to the snout.
[4] The Okanogan SPC program derives its juveniles from a 200K transfer of Methow SPC from WNFH as part of a reintroduction effort. Fish are released into the Okanogan Basin.
[5] The Chief Joe Hatchery SPC program presently receives surplus adults from the Leavenworth NFH. Juveniles are released on station from CJH.
[6] Total Okanogan release not to exceed 100K + 10%.
[7] PIT number s to each release site are estimated and not actual.
[8] Dependent upon conditions in pending Section 10 Permit.
[9] Total PIT tag release in the Okanogan 20,000
[10] Beginning with the 2017 brood, adult returns from the Nason conservation program will be utilized to meet the Nason safety net program and will receive a supplemental body tag (blank wire either at the base of the adipose or the caudal peduncle) in addition to the adipose clip and snout CWT so that they can be differentiated and prioritized at TWD.

Appendix C

Return Year Adult Management Plans

At a gross scale, adult management plans will include all actions that <u>may</u> be taken within the current run year to address surplus hatchery fish (if any). At the time of submission for this document, spring Chinook will probably be the only group where a reasonable pre-season forecast may be available to lay out what the expected surplus is, how many can be expected to be removed through each action, etc. Preseason forecasts for steelhead will be available in September

Wenatchee Spring Chinook

Pre-season estimates for age-4 and age-5 adults project a total of 5,410 (773 natural origin [14.3%] and 4,637 hatchery origin [85.7%]) spring Chinook back to Tumwater Dam in the Wenatchee Basin. Approximately 3,827 Chiwawa and 1,491 Nason spring Chinook are to reach Tumwater Dam in 2017, of which about 681 (12.8%) and 4,637 fish (87.2%) are expected to be natural and hatchery origin spring Chinook, respectively. The balance of about 92 natural origin spring Chinook expected back are destined to the remaining spawning aggregates (Table 1). In-season assessment of the magnitude and origin composition of the spring Chinook return above Tumwater Dam will be used to provide in-season adjustments to hatchery/wild composition and total broodstock collection, consistent with ESA Section 10 Permits 18118 and 18121.

Table 1. Age-4 and age-5 class return projection for wild and hatchery spring Chinook to Tumwater Dam during 2017.

	Chiwawa Basin[1]			Nason Cr. Basin[1]			Wenatchee Basin to Tumwater Dam[2]		
	Age-4	Age-5	Total	Age-4	Age-5	Total	Age-4	Age-5	Total
Estimated wild return	418	108	**526**	123	32	**155**	614	159	**773**
Estimated hatchery return	3,238	63	**3,301**	1,336	0	**1,336**	4,574	63	**4,637**
Total	3,656	171	**3,827**	1,459	32	**1,491**	**5,188**	**222**	**5,410**

[1] Reflects NOR estimates to Tumwater Dam and has not been adjusted for pre-spawn mortality.
[2] Wenatchee Basin to Tumwater Dam total includes NORs to the White, Little Wenatchee, and Chiwawa rivers and Nason Creek.

Absent conservation fisheries or adult removal at Tumwater Dam (TWD), the expected number of age-4 and age-5 Hatchery Origin Returns (HOR) for the upper Wenatchee River Basin as a whole is estimated to be approximately six times the expected number of Natural Origin Returns (NORs; 6.3 times the number of NOR's in the Chiwawa River and 8.6 times the number of NOR's in Nason Creek). The combined HO and NO returns will represent about 4.2 times the number of adults needed to meet the interim Chiwawa run escapement to TWD of 900 fish indicating a disproportionate number of hatchery origin spring Chinook will be on the spawning grounds in the fall of 2017 (Table 2). The combined HO and NO returns will represent about 3 times the number of adults needed to meet the interim Nason run escapement to TWD of 500 fish indicating a disproportionate number of hatchery origin spring Chinook will be on the spawning grounds in the fall of 2017 (Table 3).

Additional Adult Management

2017 adult management actions are intended to provide for near 100% removal of age-3 hatchery males (jacks), and unknown hatchery origin adults (ad-/cwt-) and up to about 93% of the age-4 and age-5 hatchery origin adults (about 1,717 males and 1,288 females according to current models, Table 2). In addition, approximately 68 HO and 144 NO adults will be removed between TWD and the Chiwawa Weir and retained for broodstock to support meeting the combined Grant and Chelan PUD Wenatchee spring Chinook obligation, the balance will be surplused at TWD and used for tribal and/or food bank disbursements or nutrient enhancement projects.

Table 2. Run escapement and spawning escapement of Chiwawa River hatchery and natural origin fish to Tumwater Dam and the Chiwawa River in 2017.

	To Tumwater Dam		To Chiwawa River		Adults surplused at TWD[3]	Total Chiwawa spawners
	Wild	Hatchery	Wild[1,2]	Hatchery[2]		
Females[4]	305	1,850	228	73	1,717	**301**
Males[4]	221	1,388	156	55	1,288	**211**
Sub-total	526	3,238	384	128	3,005	**512**
Pre-spawn survival[6]			0.85	0.55		
Expected PNI						**0.80**
Expected pHOS						**0.25**

[1] Wild broodstock needs of 74 wild NO fish (37 females/37 males) for the Chiwawa conservation program have already been accounted for in this total as well as pre-spawn mortality.
[2] Adjusted for pre-spawn mortality.
[3] Does not include age-3 hatchery males "jacks" removed during adult management activities at TWD or through a conservation fishery.
[4] Age-4 and age-5 fish only. Gender proportions were made based upon a 5-year average sex ratio for hatchery and wild fish of the same age class.
[5] This should result in approximately 301 redds in the Chiwawa Basin under the assumption that each female produces only one redd.
[6] Estimated survival from Tumwater to spawn.

Table 3. Run escapement and spawning escapement of Nason Creek hatchery and natural origin fish to Tumwater Dam and Nason Creek in 2017.

	To Tumwater Dam		To Nason Creek		Adults surplused at TWD[3]	Total Nason spawners
	Wild	Hatchery	Wild[1,2]	Hatchery[2]		
Females[4]	90	763	47	159	440	**206**
Males[4]	65	573	26	120	321	**146**
Sub-total	155	1,336	73	279	761	**352**
Pre-spawn survival[6]			0.85	0.55		
Expected PNI						**0.56**
Expected pHOS						**0.79**

[1] Wild broodstock needs of 70 wild NO fish (35 females/35 males) for the Nason conservation program have already been accounted for in this total as well as pre-spawn mortality.
[2] Adjusted for pre-spawn mortality and HO broodstock needs of 68 fish (34 females/34 males).
[3] Does not include age-3 hatchery males "jacks" removed during adult management activities at TWD or through a conservation fishery.
[4] Age-4 and age-5 fish only. Gender proportions were made based upon a 5-year average sex ratio for hatchery and wild fish of the same age class.
[5] This should result in approximately 206 redds in Nason Creek under the assumption that each female produces only one redd.
[6] Estimated survival from Tumwater to spawn.

Wenatchee Summer Steelhead

Depending on the outcome of preseason and in-season estimates of hatchery and natural origin steelhead to the Wenatchee Basin during the annual run cycle monitoring at the Priest Rapids Dam Off Ladder Trap (OLAFT), removal of surplus adult steelhead may occur at Tumwater Dam or in combination with a conservation fishery.

A more detailed run forecast will be available in September 2017. Adult management plans will be finalized then and appended to this document.

Methow Spring Chinook

Pre-season estimates project a total of 3,265 (973 natural origin [29.8%] and 2,292 hatchery origin [70.2%]) spring Chinook back to Methow Basin. Of the 2,292 hatchery returns, about 748 are estimated to be from the conservation program with the balance of 1,544 from the WNFH safety net program (Table 5).

Table 5. Brood year 2012-2014 age class and origin run escapement projection for UCR spring Chinook at Wells Dam, 2017.

	Projected Escapement											
	Origin								**Total**			
	Hatchery				**Wild**				**Methow Basin**			
Stock	**Age-3**	**Age-4**	**Age-5**	**Total**	**Age-3**	**Age-4**	**Age-5**	**Total**	**Age-3**	**Age-4**	**Age-5**	**Total**
MetComp	188	473	12	**673**	54	619	126	**799**	242	1,092	138	**1,472**
%Total				41.5%				82.1%				56.7%
Twisp	16	47	12	**75**	21	142	11	**174**	37	189	23	**249**
%Total				4.6%				17.9%				9.6%
Winthrop (MetComp)	324	1,189	31	**1,544**					324	1,189	31	**1,544**
%Total				53.9%								33.7%
Total	528	1,709	55	**2,292**	75	761	137	**973**	603	2,470	192	**3,265**

Some level of adult management will be required to limit the number of hatchery spring Chinook on the spawning grounds. Because a conservation fishery is not yet possible under current permit limitations, adult management will need to occur through operation of the volunteer channel traps located at both the Methow Hatchery (MH) and Winthrop NFH (WNFH).

Presently hatchery fish from MH are prioritized to: a) contribute to the supplementation of the natural populations (up to either the escapement objectives or PNI/pHOS goal), b) make up shortfalls in natural origin brood for the MH conservation program, and c) to support the 400K safety net program at WNFH. As such WNFH will operate their return channel to support removal of excess safety net fish. MH will operate its volunteer trap and will provide surplus hatchery adults (in excess to the MH needs) to WNFH to support the safety net program, to support removal of excess safety net and conservation fish, or retain adults to facilitate testing translocation of conservation fish to under-seeded spawning areas as approved by the HCP HC and PRCC HSC.

Specific actions are as follows:

Twisp River Spring Chinook: spring Chinook in the Twisp River will be managed separately from the rest of the basin.

a. Adipose-clipped fish encountered at the Twisp Weir will be removed (putative WNFH returns or strays from outside of the basin).
b. Age-3 hatchery males will be removed and euthanized or transported to WNFH.
c. Adult management will be performed to maintain pHOS ≤0.50. pNOB will be >0.50 and may be allowed to fluctuate between 0.50 and 1.0 in order to achieve a pHOS ≤0.50.
d. Wild fish will be collected as broodstock – up to ~18 individuals, but not to exceed 33% of the wild run. Hatchery fish may be collected as broodstock dependent on collection success of wild fish and provided that Twisp-program pNOB may not be less than 0.50.
e. The Twisp Weir will be fished for the duration of the broodstock collection, only, in 2017. Adult management activities will be incidental to broodstock collection. Once broodstock collection is completed, the weir will be opened to fish passage to limit delay/trapping effects on bull trout. Tentatively, during broodstock collection, the weir will be fished from 6:00 AM to 9:00 PM on a daily basis. Deviation from this schedule may be implemented based on the run size and catch efficiency for broodstock.

Methow River (MFH and WNFH) and Chewuch River Spring Chinook (MetComp):

a. Stock assessment will be performed at Wells Dam during the spring Chinook broodstock collection. This information on stock, hatchery:wild, and male:female composition coupled with fish counts, will be used in conjunction with fish counts at Wells Dam to adjust in-season adult management targets.
b. MetComp returns will be managed by removing volunteers at WNFH and Methow Hatchery using the outfall traps at these facilities.
    i. All hatchery-origin age-3 males will be removed
        1. Gender identified by ultrasound.
    ii. The Methow and Winthrop FH volunteer traps will be fished continuously (24 h per day/7 d per week) throughout the run and fish removed at least once daily (depending on specific facility limitations), or as often as needed when fish are

present. Adjustments to the operation of the trapping facilities will be made based upon capture/extraction rates as well as bull trout encounters and take limitations.

iii. Trapping will cease at Methow Hatchery if:
   1. Removal of MFH and WNFH origin adults meets the targets established (in this document and as adjusted in-season), or
   2. If overall hatchery bull trout take is likely to be exceeded. However, in-season adjustment may be made to reduce the likelihood of bull trout encounters including, but not limited to: limiting 1) the time of day trap is fished, 2) hours per day fished, 3) days per week fished.

iv. Trapping will cease at Winthrop Hatchery if:
   1. Removal of WNFH and MFH origin adults meets the targets established (in this document and as adjusted in-season), or
   2. If overall hatchery bull trout take is likely to be exceeded. However, in-season adjustment may be made to reduce the likelihood of bull trout encounters including, but not limited to: limiting 1) the time of day trap is fished, 2) hours per day fished, 3) days per week fished.

v. All adipose clipped returns encountered at WNFH and MFH volunteer traps will be removed.
   1. Returns to WNFH will be retained at WNFH for broodstock or surplusing.
   2. Returns to MFH will be transferred to WNFH for broodstock (WNFH safety net and Okanogan 10(j) programs) or surplusing.

vi. Conservation program returns may also be transported to specific reaches of the Methow and/or Chewuch Rivers to meet the minimum spawning escapement objective or to experimentally augment spawner distribution (such an action will require an approved study or implementation plan by the HCP HC and PRCC HSC, and be permissible under current ESA permits.

Based on the preseason forecast for wild and hatchery spring Chinook to the Methow Basin, once NO broodstock requirements are fulfilled and accounting for an estimated prespawn mortality for NO fish of 50% (42% for HO fish), there will be approximately 426 NO spawners. Based upon the sliding PNI scale for NO run sizes >300 fish, the initial goal for 2017 will be to manage for a minimum spawning escapement of 548 spawners; to achieve this, an estimated 67.4% of the hatchery returns (1,862 HO fish) will need to be removed (Table 6). This will result in approximately 122 hatchery origin spawners on the spawning grounds after accounting for prespawn mortality.

Table 6. Calculated targets and projected adult management results for Methow spring Chinook in 2017.

Wild Spawning Escapement	pNOB[2]	pHOS	PNI Target[3]	Allowable Hatchery Spawners	Hatchery surplus	Hatchery Broodstock (WNFH + 10j)	Proportion of Hatchery Fish to Remove	Total spawning escapement
426[1]	1.00	0.223	0.82	122	0 MH	472	0.674[4]	548
					1,544 WNFH			
				Adjusted for Pre-spawn loss	Total Surplus			
				290	1,390			

[1] Adjusted for prespawn mortality. Includes about 78 NO fish expected to go into the Twisp River basin.
[2] pNOB of conservation program only.
[3] Based on 3-pop model and assumes a minimum of 75% conservation program adults for WNFH broodstock.

[4] Assumes a 90% conversion of hatchery fish to hatchery outfalls. Value includes hatchery adults needed to meet WNFH and Okanogan 10(j) production components.

In-season assessment of the magnitude and origin composition of the spring Chinook return above Wells Dam will be used to provide in-season adjustments to hatchery/wild composition and total broodstock collection, consistent with ESA Section 10 Permits 18925, 18927, and 20533.

Methow Summer Steelhead

Depending on the outcome of preseason and in-season estimates of hatchery and natural origin steelhead to the Methow Basin during the annual run cycle monitoring at the Priest Rapids Dam Off Ladder Trap (OLAFT), removal of surplus adult steelhead may occur at the Twisp Weir (primarily as an action related to the steelhead RSS to meet a 1:1 hatchery:wild spawning composition upstream of the weir), the Wells Hatchery Volunteer Channel, volunteer returns to the Methow Hatchery and Winthrop NFH, or in combination with a conservation fishery.

A more detailed run forecast will be available in September 2017. Adult management plans will be finalized then and appended to this document.

Okanogan Summer Steelhead

Depending on the outcome of preseason and in-season estimates of hatchery and natural origin steelhead to the Okanogan Basin during the annual run cycle monitoring at the Priest Rapids Dam Off Ladder Trap (OLAFT), removal of surplus adult steelhead may utilize a conservation fishery or in combination with removal through spring Okanogan tributary weir operations.

A more detailed run forecast will be available in September 2017. Adult management plans will be finalized then and appended to this document.

Appendix D

Site Specific Trapping Operation Plans

Tumwater Dam

For 2017, WDFW and Chelan PUD are proposing the following plan (a summary of activities by month for Tumwater Dam is summarized in Table 1):

1) **Real-time monitoring and trap operations:** Throughout all trapping activities described in this plan, the two PIT tag antennae arrays within the Tumwater Dam ladder (weir 15 and 18, see Appendix 2), will be monitored by WDFW and Chelan PUD and detections of previously PIT tagged fish will be evaluated to determine the median passage time of fish between first detection at weir 15 and last detection at weir 15 or weir 18. Median passage estimates will be updated with every 10 PIT-tagged fish encountering weir 15. If the median passage time is greater than 48 hours, trapping will cease and fish will be allowed to exit via the ladder (i.e., bypass the trap). If trapping has been stopped, PIT tag passage monitoring will continue and trapping will resume if and when the median passage time is less than 24 hours. In summary, real-time PIT tag monitoring will occur both when the trap is operational and when fish are bypassed. This will provide an opportunity to evaluate trapping effects versus baseline passage rates through the ladder for future operations.

2) **Improved Fish Handling Efficiency**: Several infrastructure improvements at Tumwater allow WDFW and other operators to cycle through sampled fish more quickly. These improvements consist of an additional holding tank and an improved conveyance system between the trap and holding tank. The facility improvements and additional staffing by WDFW (3 operators instead of 2) during peak spring Chinook and sockeye passage (i.e. June 1 and July 15), will ensure that the trapping denil is operated constantly allowing unimpeded passage through the trap. Historically, the trapping denil has been periodically shut down while fish were being processed.

3) **Enhanced effort for Tumwater trapping operations from June 1 and July 15**: The Tumwater trap will be operated in an active-manned trapping condition (the ladder bypass will not be used however, fish may still ascend the denil [steep pass] unimpeded). The trap will be checked a minimum of 1x per day. More frequent trap checks will be made as fish numbers increase. Between June 16 and July 15 the Tumwater trap will be actively manned 24 hours/day 7 days/week utilizing two- three person crews (two people will sample fish and the third will maintain operation of the steep pass so that it will not be closed to passage). This represents an additional person to keep the denil operating constantly. If during this period staff are not available (due to logistical, funding, or other issues) to keep the denil operating continuously, the trap will be opened to allow for nighttime passage (this is in addition to passage required under a detected delay event).

4) **Enhanced effort and limited Tumwater trapping operations from July 16 to August 31**: The trap will be operated 3 days/week for up to 16 hours/day (not to exceed 48 hours per week) to support broodstock collection activities for summer Chinook and sockeye run composition sampling (CRITFC) and sockeye spawner escapement PIT tagging. Video enumeration and full passage will occur when trapping is not occurring.

5) **Planned Tumwater trapping operations from September 1 until mid-December:** The trap will return to a 24 hours/7day/week manned or unmanned active trapping for steelhead and Coho broodstock collection and adult steelhead management. During this time period bull trout are rare and spring Chinook are not present at Tumwater. For this trapping period, real-time monitoring will continue to be implemented.

6) **Operations at Tumwater from mid-December until about mid-February:** During this period the trapping facility is not operated due to having been winterized. Only video enumeration and full passage are available during this period.

7) **Planned Tumwater trapping operations from mid-February through May:** The trap will return to a 24 hours/7day/week manned or unmanned active trapping for adult steelhead management and spawner escapement tagging. Beginning on or about May 1, limited spring Chinook broodstocking, run comp sampling, etc. may also occur. For this trapping period, real-time monitoring will continue to be implemented.

8) **Limitation in staffing or other unforeseen problems**: If WDFW staff are not available to operate the trapping facility (according to this plan) for any reason, then full passage will be allowed (fish will be allowed to bypass the trap and exit the ladder directly), until staff are able to return.

9) **Unforeseen scenarios and in season observations**: If during the trapping period, observations from field staff warrant reconsideration of any part of the plan as described above, WDFW and Chelan PUD will alert the Hatchery Committee and work cooperatively with the Services to determine whether changes are needed to further minimize incidental take or otherwise ensure that take is maintained at the manner and extent previously approved by the Services

Table 1. Summary of broodstock collection, spawner escapement tagging, adult management, run composition sampling, and reproductive success activities anticipated to be conducted at Tumwater Dam in 2017. Blue denotes steelhead, brown spring Chinook, orange sockeye, pink summer Chinook, and green Coho.

Activity	Month											
	Jan	Feb	Mar	Apr	May	June	Jul	Aug	Sep	Oct	Nov	Dec
SHD pHOS mgt[1]		15 Feb				15 June			1 Sep			15 Dec
Su. SHD BS collection[2]									1 Sep		15 Nov	
Su. SHD Spawner Esc. tagging[3]		15 Feb				15 June			1 Sep			15 Dec
Spring Chinook RSS[4]					1 May		15 Jul					
Sp Chinook run comp[5]					1 May		15 Jul					
Sp Chinook pHOS mgt[6]					1 May		15 Jul					
Sp Chin stray mgt[7]					1 May		15 Jul					
Sockeye run comp[8]							15 Jul	15 Aug				
Sockeye spawner esc tagging[9]							15 Jul	15 Aug				
Su. Chin BS collection[10]							1 Jul		15 Sep			
Coho BS collection[11]									1 Sep		30 Nov	

[1] Adult management of the 2017 brood will end in June 2017. However it is anticipated that adult management will occur for the 2018 brood beginning 1 September or earlier if conducted in conjunction with broodstock collection activities at Tumwater Dam for other species.
[2] Summer steelhead broodstock collection will be prioritized at Dryden Dam traps. However if broodstock objectives cannot be met at Dryden then trapping may occur at Tumwater concurrent with other activities.
[3] SHD spawner composition tagging at Tumwater Dam will run concurrent with SHD adult management and other (broodstock) activities at Tumwater Dam.
[4] The spring Chinook RSS will run from 1 May through about 15 July or at such time or at such time the sockeye return develops at Tumwater Dam.
[5] Spring Chinook run composition sampling will run concurrent with the RSS.
[6] Spring Chinook pHOS management will end in July consistent with the arrival of the sockeye return and run concurrent with RSS activities.
[7] Removal of unknown hatchery origin spring Chinook strays at Tumwater Dam will run concurrent with the RSS.
[8] Sockeye run composition sampling will occur at Tumwater Dam beginning no earlier than 15 July. Trapping at Tumwater Dam for run composition sampling will follow a 3d/week, 16hrs/d (48 hrs/week) trapping schedule consistent with permit 1347.
[9] Sockeye spawner escapement sampling will occur at Tumwater Dam beginning no earlier than 15 July. Trapping at Tumwater Dam for spawner escapement tagging will follow a 3d/week, 16hrs/d (48 hrs/week) trapping schedule consistent with permit 1347.
[10] Summer Chinook broodstock collection will be prioritized at Dryden Dam. However if broodstock objectives cannot be met at Dryden Dam then trapping may occur at Tumwater Dam. Trapping at Tumwater Dam for summer Chinook broodstock will follow a 3d/week 16hr/day (48 hrs/week) trapping schedule and may run concurrent with other broodstock collection, run sampling, or adult management activities.
[11] Coho trapping will be conducted at both Dryden and Tumwater Dams. Trapping at Tumwater Dam for Coho broodstock will follow a 3d/week 16hr/day (48 hrs/week) trapping schedule and may run concurrent with other broodstock collection, run sampling, or adult management activities. Collection is permitted through December 7 of each year but typically ceases by the end of November.

Dryden Dam

For 2017, WDFW and Chelan PUD are proposing the following plan (a summary of activities by month for the right and left bank Dryden Dam traps is summarized in Table 2):

The Dryden Dam left and right bank trapping facilities will operate up to five days per week, 24 hours per day beginning July 1 and continue until as late as November 15. Both traps, if operated, will do so on concurrent days and will be checked and cleared every 24 hours, or sooner if it appears that run contribution to the facilities exceeds reasonable limits for adult holding.

If daily river temperatures meet or exceed 21° C (69.8° F) trapping activities and fish handling will cease until temperatures drop below this threshold. This may require reducing trap operation to only nighttime hours with early morning traps checks to ensure the safety of the fish.

Table 2. Summary of broodstock collection, spawner escapement tagging, adult management, run composition sampling, and/or reproductive success activities anticipated to be conducted at Dryden Dam trapping facilities in 2017. Blue denotes steelhead, brown spring Chinook, orange sockeye, pink summer Chinook, and green Coho.

Activity	Month											
	Jan	Feb	Mar	Apr	May	June	Jul	Aug	Sep	Oct	Nov	Dec
Left Bank												
Su. SHD BS collection[1]							1 Jul				15 Nov	
Su. SHD Run Comp.							1 Jul				15 Nov	
Su. SHD spawner esc. Tagging[2]							1 Jul				15 Nov	
Su. Chinook run comp							1 Jul		15 Sep			
Su. Chin BS collection[3]							1 Jul		15 Sep			
Coho BS collection									1 Sep		30 Nov	
Right Bank												
Su. SHD BS collection[1]							1 Jul				15 Nov	
Su. SHD Run Comp.							1 Jul					
Su. SHD spawner esc. Tagging2							1 Jul				15 Nov	
Su. Chinook run comp							1 Jul		15 Sep			
Su. Chin BS collection[3]							1 Jul		15 Sep			
Coho BS collection[4]									1 Sep		30No v	

[1] Summer steelhead broodstock collection will be prioritized at Dryden Dam traps. However if broodstock objectives cannot be met at Dryden then trapping may occur at Tumwater concurrent with other activities.
[2] SHD spawner composition tagging at Dryden Dam will run concurrent with other (broodstock or M&E) activities at Dryden Dam.
[3] Summer Chinook broodstock collection will be prioritized at Dryden Dam. However if broodstock objectives cannot be met at Dryden Dam then trapping may occur at Tumwater Dam. Trapping at Dryden Dam for summer Chinook broodstock will follow an up to 5d/week 24hr/day trapping schedule and may run concurrent with other broodstock collection, run sampling, or adult management activities.
[4] Coho trapping will be conducted at both Dryden and Tumwater Dams. Trapping at Dryden Dam for Coho broodstock will follow an up to 5d/week 24hr/day trapping schedule and may run concurrent with other broodstock collection, run sampling, or adult management activities. Collection is permitted through December 7 of each year but typically ceases by the end of November.

Wells Dam Ladder and Hatchery Volunteer Traps

For 2017, WDFW and Douglas PUD are proposing the following plan (A summary of activities by month for the Wells Dam East/West ladder and Wells FH volunteer traps is summarized in Table 3):

1). **East Ladder Trap:**

The East ladder trap will only be operated as needed to meet broodstock collection objectives and other management activities if they cannot be adequately fulfilled through the West ladder and Wells FH volunteer trap operations or if construction activities on the hatchery modernization preclude use of either the West ladder or volunteer traps.

If the East ladder trap is used, it may begin as early as May 1 and will operate under a maximum 5-days per (operation will be limited to no more than three consecutive days)/12 hours per day or 60 cumulative hours per week and will run concurrent with any trapping activities occurring at the West ladder trap. Anticipated trap operation is not expected to go beyond November 15.

For all species except coho after September 26, when the West ladder trap is operational, and the East ladder trap is used, it may begin as early as May 1 and will operate under a maximum 3-day per week/16 hours per day or 48 cumulative hours per week and will run concurrent with any trapping activities occurring at the West ladder trap. For coho trapping, the East ladder trap may be operated, concurrent with the West ladder trap, 5 days per week/ 9 hours per day September 27 through October 9, and 7 days per week/16 hours per day beginning October 10. Trap operators will bypass Chinook, steelhead, and sockeye during coho trapping. Anticipated trap operation is not expected to go beyond November 15.

If daily river temperatures meet or exceed 21º C (69.8º F) trapping activities and fish handling will cease until temperatures drop below this threshold. This may require reducing trap operation to only nighttime hours with early morning traps checks to ensure the safety of the fish.

2). **West Ladder Trap:**

The West ladder may begin as early as May 1 for spring Chinook broodstock collection and will operate under a maximum 5-days per week (operation will be limited to no more than three consecutive days)/12 hours per day or 60 cumulative hours per week and will run concurrent with any trapping activities occurring at the East ladder trap. Anticipated trap operation is not expected to go beyond November 15.

If daily river temperatures meet or exceed 21º C (69.8º F) trapping activities and fish handling will cease until temperatures drop below this threshold. This may require reducing trap operation to only nighttime hours with early morning traps checks to ensure the safety of the fish.

3). **Wells FH Volunteer Trap:** The Wells FH volunteer trap may begin as early as July 1 for summer Chinook broodstock collection and operate through mid-June of the following year for steelhead broodstock collection and adult management if needed. The trap may operate up to seven days per week/24 hours per day to facilitate broodstock collection and adult management actions.

If daily river temperatures meet or exceed 21º C (69.8º F) trapping activities and fish handling will cease until temperatures drop below this threshold. This may require reducing trap operation to only nighttime hours with early morning traps checks to ensure the safety of the fish.

Table 3. Summary of broodstock collection, spawner escapement tagging, adult management, run composition sampling, and/or reproductive success activities anticipated to be conducted at Wells Dam in 2017. Blue denotes steelhead, brown spring Chinook, pink summer Chinook, and green Coho.

Activity	Month											
	Jan	Feb	Mar	Apr	May	June	Jul	Aug	Sep	Oct	Nov	Dec
East/West Ladders												
Su. SHD BS collection[1]									1 Sep		15 Nov	
Su. SHD run comp.									1 Sep		15 Nov	
Su. SHD Spawner Esc. Tagging[2]									1 Sep		15 Nov	
Sp Chinook BS collection					1 May		15 Jul					
Sp Chinook run comp					1 May		15 Jul					
Su. Chin BS collection[3]							1 Jul		15 Sep			
Coho BS collection[5]									15 Sep		15 Nov	
Wells Volunteer Trap												
Su. SHD BS collection[1]									1 Sep		15 Nov	
SHD pHOS mgt.[6]		15 Feb				15 June			1 Sep			15 Dec
Su. Chin BS collection[4]							1 Jul		15 Sep			
Su. Chin Surplussing							1 Jul			30 Oct		

[1] Summer steelhead broodstock collection will be prioritized at West ladder and volunteer traps. However if broodstock objectives cannot be met at either of those two locations then trapping may occur at the East ladder concurrent with other activities.
[2] SHD spawner composition tagging at Wells Dam will run concurrent with other (broodstock or M&E) activities at Wells Dam.
[3] Summer Chinook broodstock collection for the Methow (Carlton) program will be prioritized at the West ladder trap. However if broodstock objectives cannot be met at the West ladder then trapping may occur at the East ladder. Trapping at the west and/or East ladders for summer Chinook broodstock will follow an up to 3d/week 16hr/day (48 cumulative hours) trapping schedule and may run concurrent with other broodstock collection, run sampling, or adult management activities.
[4] Summer Chinook broodstock collection for the Wells Hatchery programs will be prioritized at the Wells Hatchery volunteer trap. Trapping at the volunteer channel may occur up to 7 days per week, 24 hours per day and may include broodstock collection and/or adult management.
[5] Coho trapping may be conducted at both East and/or West ladders. Trapping at Wells Dam ladder traps for Coho broodstock will follow an up to 3d/week 16hr/day trapping schedule and may run concurrent with other broodstock collection, run sampling, or adult management activities. Trapping at the Wells Dam ladder will cease no later than November 15.
[6] Adult management of the 2017 brood will end in June 2017. However it is anticipated that adult management will occur for the 2018 brood beginning 1 September or earlier if conducted in conjunction with broodstock collection activities at the Wells Hatchery volunteer channel for other species.

Methow Hatchery Volunteer and Twisp Weir Traps

For 2017, WDFW and Douglas PUD are proposing the following plan (A summary of activities by month for Methow Hatchery volunteer trap and the Twisp Weir is summarized in Table 4):

Specific operation details for the Methow Hatchery volunteer trap and Twisp Weir are still being worked through. Once those details have been fleshed out more thoroughly, this section will be updated.

If daily river temperatures meet or exceed 21° C (69.8° F) trapping activities and fish handling will cease until temperatures drop below this threshold. This may require reducing trap operation to only nighttime hours with early morning traps checks to ensure the safety of the fish.

Table 4. Summary of broodstock collection, spawner escapement tagging, adult management, run composition sampling, and/or reproductive success activities anticipated to be conducted at Methow Hatchery and the Twisp Weir in 2017. Blue denotes steelhead, brown spring Chinook, and green Coho.

Activity	Month											
	Jan	Feb	Mar	Apr	May	June	Jul	Aug	Sep	Oct	Nov	Dec
Methow Hatchery[1]												
SHD pHOS mgt.			1 Mar			15 Jun			1 Sep		15 Nov	
Sp. Chinook BS collection					1 May			30 Aug				
Sp. Chinook pHOS mgt.[2]					1 May			30 Aug				
Twisp Weir[3]												
Steelhead RSS			1 Mar		30 May							
Su. SHD BS collection				1-30 Apr								
SHD pHOS mgt.			1 Mar		30 May							
Sp. Chinook BS collection						1 June		15 Aug				
Sp. Chinook pHOS mgt.						1 June		22 Aug				

[1] Specific details on how operation of the Methow Hatchery volunteer trap will work for SHD adult management are still being worked out at this time.
[2] Adult management for spring Chinook at the Methow Hatchery volunteer trap will run concurrent with broodstock collection.
[3] Specific details on how operation of the Twisp Weir will work for 2016 to include the steelhead RSS, broodstock collection, and adult management and spring Chinook broodstock collection and adult management is still being worked out at this time.

Priest Rapids Dam Off Ladder Trap (OLAFT)

Table 5. Summary of broodstock collection, VSP monitoring, and/or run composition sampling activities anticipated to be conducted at the Priest Rapids Dam Off Ladder Trap (OLAFT) in 2017. Blue denotes steelhead, purple fall Chinook, and orange sockeye.

Activity	Month											
	Jan	Feb	Mar	Apr	May	June	Jul	Aug	Sep	Oct	Nov	Dec
SHD VSP Monitoring[1]							1 Jul				15 Nov	
Fall Chin. BS collection[2]									1 Sep		15 Nov	
Fall Chinook Run Comp.[3]									1 Sep		15 Nov	
Sockeye BS Collection[4]						22 Jun	10 Jul					

[1] Steelhead VSP monitoring targets up to 15% of the annual return over Priest Rapids Dam. Presently that requires operation of the OLAFT up to 3 days/ week, 8 hours per day. The trap is opened to passage each night.
[2] To acquire the target 1,000 adipose present, non-CWT adult fall Chinook for broodstock, the OLAFT is operated up to 5 days per week, 8 hours per day. Three of the five days are concurrent with the SHD VSP monitoring. The trap is opened to passage each night.
[3] Fall Chinook run composition runs concurrent with SHD VSP monitoring and/or fall Chinook broodstock collection activities.
[4] Sockeye broodstock collection to support YN reintroduction efforts in the Yakima is based upon abundance based sliding scale. Depending on the strength of the return and allowable allocation, the trap may be operated up to 5 days per week, 8 hours per day beginning about 22 June and running through about 10 July. The trap is opened to passage each night.

Appendix E

Columbia River TAC Forecast

Table 1. 2017 Columbia River at mouth salmon and steelhead returns – actual and forecast.

Columbia River Adult Salmon Returns: Actual and Forecasted *a*				
		2016 Forecast	**2016 Return**	**2017 Forecast**
Spring Chinook	***Upriver Total***	**188,800**	**187,816**	**160,400**
Upper Columbia (total)		27,600	26,632	19,300
Upper Columbia wild		*5,000*	*na*	*3,700*
Snake River Spring/Summer (total) b		124,800	116,282	95,800
Snake River wild b		*23,700*	*24,840*	*15,100*
Summer Chinook	***Upper Columbia***	**93,300**	**91,048**	**63,100**
Sockeye	***Total***	**101,600**	**354,466**	**198,500**
Wenatchee		57,800	c	54,200
Okanogan		41,700	c	137,900
Yakima		na	c	4,000
Deschutes		na	c	1,000
Snake River b		*2,100*	c	*1,400*
a/ Numbers may not sum due to rounding				
b/ 2016 return is based on TAC run reconstruction methodology c/ TAC is still evaluating post-season distribution to individual tributaries				
Provided by the *U.S. v Oregon* Technical Advisory Committee (TAC)				

Appendix F[MT1]

Annual Chelan, Douglas, and Grant County PUD RM&E Implementation Plans

Chelan PUD
The Final 2017 Chelan Hatchery Monitoring and Evaluation Implementation Plan (PDF) is available at the HCP Hatchery Committees Extranet Homepage. Please use the following procedure:

* Visit: https://extranet.dcpud.net/sites/nr/hcphc/
* Login using "Forms Authentication" (for non-Douglas PUD employees)

Douglas PUD
The Final 2017 DCPUD ME Implementation Plan (PDF) is available at the HCP Hatchery Committees Extranet Homepage. Please use the following procedure:

* Visit: https://extranet.dcpud.net/sites/nr/hcphc/
* Login using "Forms Authentication" (for non-Douglas PUD employees)

Grant PUD

2017 GPUD Hatchery ME Implementation Plan for the Wenatchee Basin and Methow Summer Chinook Salmon
https://partner.gcpud.org/sites/ResCom/PRCCHatchery/Final/2016%20GPUD%20Hatchery%20ME%20Implementation%20Plan%20for%20the%20Wenatchee%20Basin_FINAL.pdf?Web=1

2017 Priest Rapids Hatchery Implementation Plan
https://partner.gcpud.org/sites/ResCom/PRCCHatchery/Final/PRH%20ME%202016-17%20Implementation%20plan%20final.pdf?Web=1

Appendix G

DRAFT
Hatchery Production Management Plan

The following management plan is intended to provide life-stage-appropriate management options for Upper Columbia River (UCR) PUD salmon and steelhead mitigation programs. Consistent, significant over-production or under-production risks the PUD's not meeting the production objectives required by FERC and overages in excess of 110% of program release goals violates the terms and conditions set forth for the implementation of programs under ESA and poses potentially significant ecological risks to natural origin salmon communities.

Under RCW 77.95.210 (Appendix A) as established by House Bill 1286, the Washington Department of Fish and Wildlife has limited latitude in disposing of salmon and steelhead eggs/fry/fish. While this RCW speaks more specifically to the sale of fish and/or eggs WDFW takes a broader application of this statute to include any surplus fish and/or eggs irrespective of being sold or transferred.

We propose implementing specific measures during the different life-history stages to both improve the accuracy of production levels and make adjustments if over-production occurs. These measures include (1) Improved Fecundity Estimates, (2) Adult Collection Adjustments, (3) Within-Hatchery Program Adjustments, and (4) Culling.

<u>Improved Fecundity Estimates</u>

A) Develop broodstock collection protocols based upon the most recent 5-year mean in-hatchery performance values for female to spawn, fecundity, green egg to eye, and green egg to release.
B) Use portable ultrasound units to confirm gender of broodstock collected (broodstock collection protocols assume a 1:1 male-to-female ratio). Ultrasonography, when used by properly trained staff will ensure the 1:1 assumption is met (or that the female equivalents needed to meet production objective are collected). Spawning matrices can be developed such that if broodstock for any given program are male limited sufficient gametes are available to spawn with the females.

<u>Adult Collection Adjustments</u>

C) Make in-season adjustments to adult collections based upon a fecundity-at-length regression model for each population/program and origin composition need (hatchery/wild). This method is intended to make in-season allowances for the age structure of the return (i.e. age-5 fish are larger and therefore more fecund than age-4 fish), but will also make allowances for age-4 fish that experienced more growth through better ocean conditions compared to an age-5 fish that reared in poorer ocean conditions.

<u>Within-Hatchery Program Adjustments</u>

D) At the eyed egg inventory (first trued inventory), after adjustments have been made for culling to meet BKD management objectives, the over production will be managed in one or more of the following actions as approved by the HCP-HC or PRCC-HSC:

- Voluntary cooperative salmon culture programs under the supervision of the department under chapter 77.100 RCW;
- Regional fisheries enhancement group salmon culture programs under the supervision of the department under this chapter;
- Salmon culture programs requested by lead entities and approved by the salmon funding recovery board under chapter 77.85 RCW;
- Hatcheries of federally approved tribes in Washington to whom eggs are moved, not sold, under the interlocal cooperation act, chapter 39.34 RCW; and
- Governmental hatcheries in Washington, Oregon, and Idaho; or
- Culling for diseases such as BKD and IHN, consistent with the Salmonid Disease Control Policy of the Fisheries Co-managers of Washington State; or
- Distribution to approved organizations/projects for research.

E) At tagging (second inventory correction) fish will be tagged up to 110% of production level at that life stage. If the balance of the population combined with the tagged population amounts to more than 110% of the total release number allowed by Section 10 permits then the excess will be distributed in one or more of the following actions as approved by the HCP-HC or PRCC-HSC:

- Voluntary cooperative salmon culture programs under the supervision of the department under chapter 77.100 RCW;
- Regional fisheries enhancement group salmon culture programs under the supervision of the department under this chapter;
- Salmon culture programs requested by lead entities and approved by the salmon recovery funding board under chapter 77.85 RCW;
- Hatcheries of federally approved tribes in Washington to whom eggs are moved, not sold, under the interlocal cooperation act, chapter 39.34 RCW; and
- Transfer to another resource manager program such as CCT, YN, or USFWS program;
- Governmental hatcheries in Washington, Oregon, and Idaho;
- Placement of fish into a resident fishery (lake) zone, provided disease risks are within acceptable guidelines; or
- Culling for diseases such as BKD and IHN, consistent with the Salmonid Disease Control Policy of the Fisheries Co-managers of Washington State; or
- Distribution to approved organizations/projects for research.

F) In the event that a production overage occurs after the above actions have been implemented or considered, and deemed non-viable for fish health reasons in accordance with agency aquaculture disease control regulations (i.e. either a pathogen is detected in a population that may pose jeopardy to the remaining population or other programs if retained or could introduce a pathogen to a watershed where it had not previously been detected) then culling of those fish may be considered.

All, provisions, distributions, or transfers shall be consistent with the department's egg transfer and aquaculture disease control regulations as now existing or hereafter amended. Prior to department determination that eggs of a salmon stock are surplus and available for sale, the department shall assess the productivity of each watershed that is suitable for receiving eggs.

Out-planting Surplus Methow Composite Spring Chinook Salmon Adults-DRAFT

Background

The Hatchery Committees (HCs) recently reviewed the "Evaluation of Hatchery Programs Funded by Douglas County PUD 5-year Report 2006-2010". As a result, Objective 6 monitoring question Q6.1.1: "Is the stray rate of hatchery fish less than 5% for the total brood year return?" was identified as not meeting the target for the Chewuch River final acclimated fish. The HCs determined that methods to improve homing would have uncertain success, be difficult to implement, and challenging to statistically evaluate. In an effort to achieve the goal of increased hatchery-origin spawner abundance in identified reaches that a higher rate of homing would convey, the HCs agreed to pilot adult out-planting of surplused Methow Composite spring Chinook into the Chewuch River.

The goal of this pilot evaluation is to determine if surplused Methow Composite spring Chinook adults collected and held at the Methow Hatchery, and subsequently out-planted into the Chewuch River, remain in the Chewuch River and subsequently spawn. This pilot evaluation will be conducted in an effort to determine if adult-outplanting can be an effective tool to increase spawner abundance, spawner distribution, and natural production in the Chewuch River in years of low abundance. It is a low-risk management tool that has been used in many locations such as the Wenatchee and Willamette watersheds.

2017 Out-planting of Surplus Methow Composite Spring Chinook Salmon Adults Objectives:

- During spawning surveys, estimate the number of females trapped and out-planted to the Chewuch River that exhibit spawning behavior, construct a redd, and/or spawned (determined by egg voidance).
- Assess the ability of transporting adult spring Chinook to the Chewuch River to provide the overall number of hatchery spawners allowable under ESA permit conditions.
- Assess how many days fish were held from trapping to out-planting and from out-planting to spawner success.
- Estimate spawner distribution of males and females within the Chewuch River post release and compare results to retention time in the Chewuch River and spawner success.
- Assess the proportion of out-planted males and females that remain in the Chewuch River compared to out-planted males and females determined to have left the Chewuch River.

Methods

Up to 200 hatchery-origin spring Chinook salmon adults (jacks will be excluded) returning to the Methow Hatchery, in excess of broodstock needs for the Methow Hatchery and Winthrop National Fish Hatchery (NFH), will be collected, held and out-planted to targeted spawning reaches of the Chewuch River. The specific number of fish to be held and out-planted will be based upon permit limitations, availability of fish, and pHOS level as agreed to by the HC. A female to male ratio of 1.0:0.2 will be implemented unless run composition assessment for the run at large suggests a deviation from this level.

- Out-plant a maximum of 200 hatchery-origin spring Chinook adults (jacks will be excluded) at a female to male ratio of 1.0:0.2 will be implemented unless run composition assessment for the run at large suggests a deviation from this level.

- The number of adults shall be consistent with the terms and conditions of the ESA incidental take permits for the Methow Hatchery (#18925; #18927; #20533) according to the decision tree below:

1. If the natural origin run to the Methow basin is estimated to be <100, then pHOS in the Chewuch will be =-0.002x+0.8 (where x=estimate of the natural origin run size in the Chewuch River), else,
2. If the natural origin run to the Methow sub-basin is estimated to be ≥100 and <300, then pHOS in the Chewuch River will be =-0.0013x+0.8 (where x=estimate of the natural origin run size in the Chewuch), else,
3. If the natural origin run to the Methow sub-basin is estimated to be ≥300, then pHOS in the Chewuch River will be =0.8(1-e^(-0.006x) (where x=estimate natural origin run size in the Chewuch).
4. In each case, the number of hatchery origin fish to be released in the Chewuch will be calculated as
    a. Find the allowable basin pHOS based on estimated natural-origin spawning escapement to the Methow sub-basin and the estimated pHOS for the Methow Hatchery program (Twisp + MetComp).
    b. Use this pHOS to estimate how many hatchery-origin fish can be allowed in the Chewuch River based on the expected natural-origin spawning escapement to the Chewuch River.
    c. Calculate how many additional, surplus hatchery-origin fish shall be transported and released to the Chewuch River to remain within permit limits.
    d. A spreadsheet “Adult Outplanting Calculator.xls” is available to perform these calculations (Attachment A).

Holding and Out-planting

Surplus hatchery-origin adults returning to the Methow Hatchery will be held (duration of holding period will be variable based upon when the individual was collected) and out-planted approximately one week before estimated peak spawning (i.e., during the latter part of August/early September). If the fish being held for subsequent out-planting experience a disease outbreak, the fish will not be out-planted. All out-planted adults will be PIT-tagged and marked with a visible mark. Depending on availability of fish for out-planting, up to 100 adults will be released into each of one of two sites; if fish availability is limited, all fish will be out-planted into the upper release site. One site will be above the upper Chewuch River PIT tag instream PIT tag antenna array (CRU) and the other below CRU and above the Winthrop (CRW) PIT tag antenna array (Figure 1). Release locations will be determined based on accessibility, suitable spawning habitat, distance from the hatchery, distance from PIT tag arrays, and areas that are not being utilized by spawners already in the system.

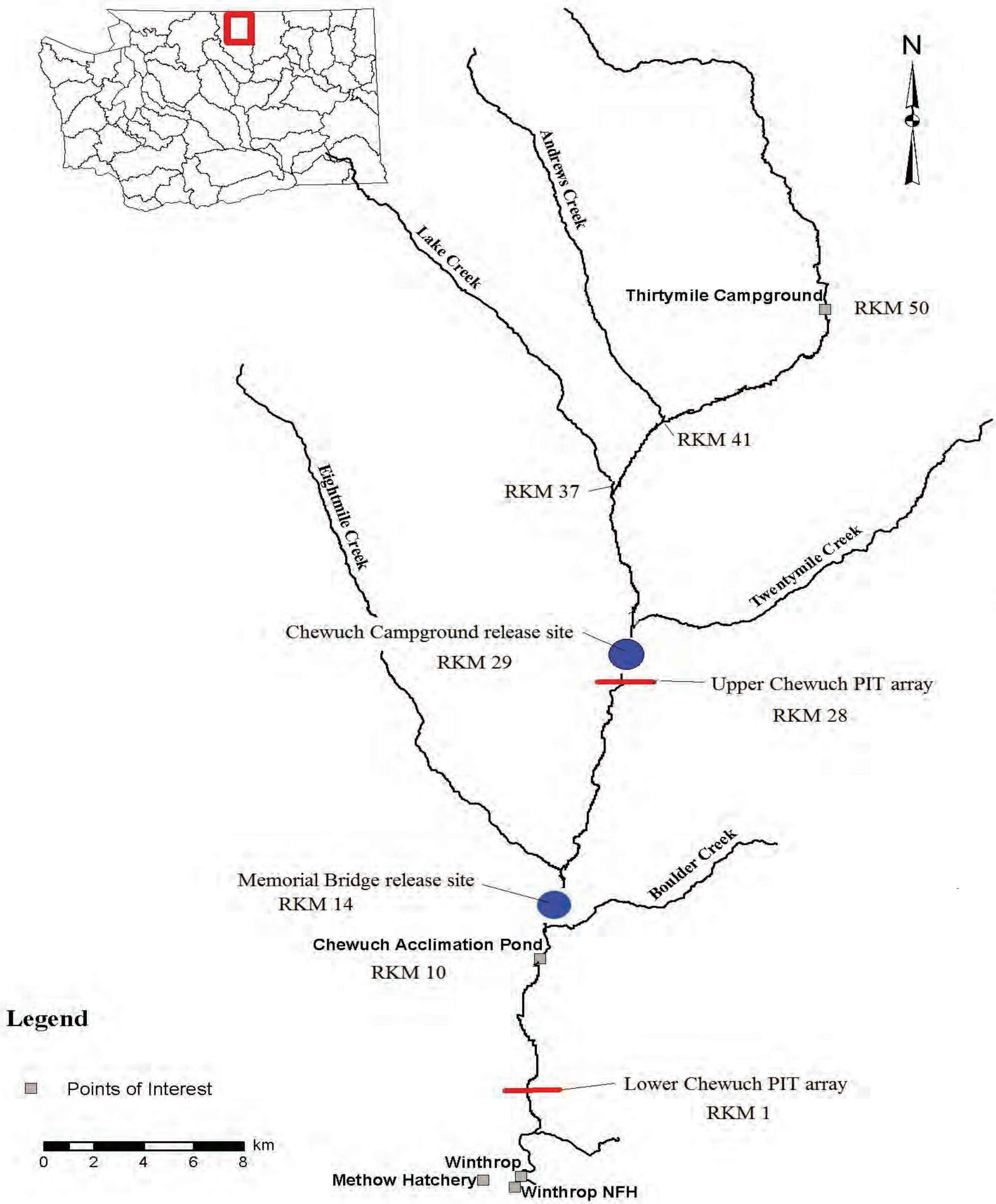
Evaluation

The association of the out-planted adults with redds will be documented during spawner surveys (e.g., identification of out-planted adults on redds). Potential spawning success of females will be documented by estimating the proportion of eggs that are retained within female carcasses sampled during carcass recovery surveys. Carcass location and redds determined to be constructed by out-planted adults will be documented using a GPS device.

Post release PIT detections at the CRW PIT tag antenna array, non-Chewuch River PIT detections, and out-planted adults returning to the Methow Hatchery and Winthrop NFH will be used to estimate the proportion of out-planted spring Chinook salmon that left the Chewuch River.

The results of this pilot evaluation will be summarized and presented to the HCs during the February 2018 meeting. The results of the 2017 out-planting effort may be used to inform potential future decisions and/or actions regarding out-planting methodology.

Figure 1. Release site locations for out-planting surplus Methow spring Chinook, 1) Chewuch Campground release site and, 2) Memorial Bridge release site.



			allowable pHOS			
Estimated inputs			**<100**	**>=100<300**	**>=300**	**PNI for >=300**
Methow Basin	wild	600	NA	NA	0.242347	0.7781
	pNOB	0.8500				
Chewuch escapement	wild	200				
Chewuch escapement	hatchery	45				
Hatchery surplus	on hand	200				
Hatchery Escapement Needed ----->>>>			NA	NA	64	
Outplant	hatchery fish		NA	NA	19	

FINAL

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ANCHOR QEA

Memorandum

To: Wells, Rocky Reach, and Rock Island HCPs Hatchery Committees

Date: May 19, 2017

From: Tracy Hillman, HCP Hatchery Committees Chairman

cc: Sarah Montgomery, Anchor QEA, LLC

Re: Final Minutes of the April 19, 2017, HCP Hatchery Committees Meeting

The Wells, Rocky Reach, and Rock Island Hydroelectric Projects Habitat Conservation Plans (HCPs) Hatchery Committees meeting was held at the Grant PUD office in Wenatchee, Washington, on Wednesday, April 19, 2017, from 9:00 a.m. to 12:00 p.m. Attendees are listed in Attachment A to these meeting minutes.

Action Item Summary

- Andrew Murdoch (Washington Department of Fish and Wildlife [WDFW]) will write an overview of proposed expanded sampling at the off-ladder fish trap (OLAFT) at Priest Rapids Dam (Item I-A). *(Note: this item is ongoing.)*
- Hatchery Committees representatives will review the Hatchery Monitoring and Evaluation (M&E) Plan Objectives before the Hatchery Committees May 17, 2017, meeting (Item I-A). *(Note: this item is ongoing.)*
- Hatchery Committees representatives will review McLain Johnson's (WDFW) Genetic Monitoring Update for discussion at the Hatchery Committees May 17, 2017, meeting (Item I-A). *(Note: Sarah Montgomery distributed the update on April 6, 2017.)*
- Brett Farman and Charlene Hurst will provide an update to the Hatchery Committees on the differences between Endangered Species Act (ESA) Section 7, Section 10, and Section 4(d) coverage in regards to permitting for some HCP programs (Item II-B).
- Mike Tonseth will organize a workgroup to discuss the future of the Twisp Steelhead Program and define its proposed actions for consultation (Item II-D).
- Catherine Willard and Keely Murdoch will provide coho salmon recalculation numbers to the Hatchery Committees for discussion at the Hatchery Committees May 17, 2017, meeting (Item III-A).
- Keely Murdoch will provide the latest Yakama Nation (YN) Coho Salmon Master Plan to Sarah Montgomery for distribution to the Hatchery Committees (Item III-A).
- Hatchery Committees representatives will discuss internally the brood year stray rate target and prepare for further discussion at the Hatchery Committees May 17, 2017, meeting (Item II-E).

- Matt Cooper will invite Penny Swanson (National Oceanic and Atmospheric Administration) to give a presentation about epigenetics at the Hatchery Committees May 17, 2017, meeting (Item IV-B). *(Note: Cooper asked Montgomery to add a talk by Mackenzie Gavery to the May 17, 2017 agenda.)*

Decision Summary

- The Hatchery Committees representatives present approved the Outplanting Adults Plan (for spring Chinook salmon in the Chewuch River) as follows: Chelan PUD, Douglas PUD, U.S. Fish and Wildlife Service (USFWS), WDFW, National Marine Fisheries Service (NMFS), YN, and Colville Confederated Tribes (CCT) approved on April 19, 2017. Grant PUD (Priest Rapids Coordinating Committee Hatchery Sub-Committee [PRCC HSC]) also indicated approval during the joint HCP-HC/PRCC HSC session (Item II-C).

Agreements

- There were no agreements discussed during today's meeting besides the decision listed in the above section.

Review Items

- There are no items currently out for review.

Finalized Documents

- Sarah Montgomery sent an email to the Hatchery Committees on April 20, 2017, notifying them that the Final Outplanting Adults Plan is now available for download from the Hatchery Committees Extranet site.

I. Welcome

A. Review Agenda, Review Last Meeting Action Items, and Approve the March 13, 2017, Meeting Minutes (Tracy Hillman)

Tracy Hillman welcomed the Hatchery Committees and asked for any additions or changes to the agenda. No revisions were requested.

The Hatchery Committees reviewed the revised draft March 13, 2017, meeting minutes. Sarah Montgomery said there are several outstanding comments to be discussed, which the Hatchery Committees reviewed and addressed. Hatchery Committees representatives present approved the draft March 13, 2017, meeting minutes, as revised.

Action items from the Hatchery Committees meeting on March 13, 2017, and follow-up discussions were addressed *(note: italicized text below corresponds to agenda items from the meeting on March 13, 2017)*:

- *McLain Johnson (Washington State Department of Fish and Wildlife [WDFW]) will revise the timeline for conducting genetic analysis for HCP program species incorporating suggestions provided during the Hatchery Committees January 18, 2017, meeting (Item I-A).*
  This item is complete. Johnson sent the revised timeline to the Hatchery Committees on April 6, 2017.
- *McLain Johnson and WDFW geneticists will perform a power analysis to inform genetic analysis intervals and intensity for HCP program species (Item I-A).*
  This item is complete. Johnson sent a memo regarding genetic analysis intervals to the Hatchery Committees on April 6, 2017, and will be discussed at the May 17, 2017, Hatchery Committees meeting.
- *Andrew Murdoch (WDFW) will write an overview of proposed expanded sampling at the off-ladder fish trap (OLAFT) at Priest Rapids Dam (Item I-A).*
  Mike Tonseth said this item is ongoing.
- *Hatchery Committees representatives will review the Hatchery Monitoring and Evaluation (M&E) Plan Objectives before the Hatchery Committees April 19, 2017, meeting (Item IV-A).*
  This is ongoing and will be discussed during the Hatchery Committees May 17, 2017, meeting.
- *Casey Baldwin will discuss internally the steelhead marking strategy in the draft 2017 Broodstock Collection Protocols and provide feedback to Mike Tonseth (Item IV-D).*
  This item is complete.
- *Keely Murdoch will discuss internally the Yakama Nation (YN)'s egg requests for their summer Chinook salmon program (Item IV-D).*
  This item is complete. Murdoch provided input to Mike Tonseth.
- *Hatchery Committees representatives will discuss internally WDFW's proposal for collection and rearing for the Twisp Steelhead program in 2017 and provide a vote by March 30, 2017 (note: this includes adult collection at the Twisp Weir, transfer to Winthrop National Fish Hatchery (NFH), spawning as part of aggregate composite population. and incubation to eyed-egg or fry stage at Winthrop NFH, then transfer to Methow Fish Hatchery [FH]; Item IV-E).*
  This item is complete.
- *Catherine Willard will revise the draft study plan, "Outplanting Surplus Methow Composite Spring Chinook Salmon Adults to Increase Natural Production in the Chewuch River," and distribute it to the Hatchery Committees for approval at the April 19, 2017, meeting (Item IV-F).*
  This item is complete and will be discussed today.

- *Tracy Hillman will preliminarily revise the brood-year (BY) stray rate target language in the Hatchery M&E Plan for further discussion at the Hatchery Committees April 19, 2017, meeting (Item IV-G).*
  Hillman said edits to language in the M&E Plan depend on further discussion of brood year stray rate targets.
- *Tracy Hillman will assess the relationship over the last 10 years between exceeding BY stray rate targets and exceeding recipient stray rate targets (Item IV-G).*
  This item is complete and will be discussed today.

II. Joint HCP-HC/PRCC HSC

A. USFWS Bull Trout Consultation Update (Matt Cooper)

Matt Cooper said Karl Halupka (USFWS) sent him an update on USFWS consultations, which he summarized as follows:

- Halupka received comments on the draft biological opinion (BiOp) for the batch of Wenatchee subbasin programs, and USFWS is working on incorporating the comments into the BiOp. Halupka expects the BiOp will be finalized in May 2017.
- The USFWS discussed the consultation process for mainstem programs with NMFS.

Catherine Willard asked if Halupka plans to send the draft BiOp to the applicants for review once more before it is finalized. Cooper said he does not expect so. Mike Tonseth asked if Halupka has an update for the Hatchery Committees on the consultation process for Methow steelhead. Bill Gale said Halupka is generally following the consultation schedule set by NMFS.

B. NMFS Consultation Update (Brett Farman/Charlene Hurst)

Charlene Hurst said NMFS is prioritizing consultations that need to be finished in 2017 per the United States v. Oregon Management Agreement. Hurst said NMFS is currently drafting proposed actions for the consultations and any proposed actions should be sent to herself or Karl Halupka.

Hurst said Emi Kondo (NMFS) is working on the consultations for unlisted programs. She said the draft BiOp is almost complete, but more programs need to be added. The upper Columbia River unlisted programs will be addressed after the Leavenworth program consultation is finished.

Hurst said she recently requested information regarding consultation for steelhead programs, which she expects to be completed faster than other consultations. She said the proposed action will need to be finished by June 2017 so that the BiOp can be completed by December 2017, and more work is needed on the gene flow model. She said she set up monthly meetings for the steelhead consultation and asked if any other parties would like to be included in those meetings. Bill Gale asked for Hurst to include himself and Matt Cooper. Keely Murdoch asked to be included and said all Hatchery Committees members should be invited to these coordination meetings and discussions to avoid future slowdown of the consultation process. Kirk Truscott asked that he and Casey Baldwin be included and said steelhead for the Okanogan programs are reared at Wells Fish Hatchery (FH). Todd Pearsons also asked to be included and said if steelhead rearing at Wells FH for the Okanogan programs is not covered under the Tribal Resources Management Plan, then it should be included with this consultation. Greg Mackey said gene flow targets are still undetermined and asked for more information from Hurst on proportionate natural influence (PNI) goals. He said non-governmental organizations have been interested in using proportion of hatchery-origin spawners (pHOS) standards to evaluate hatchery programs. Hurst said the Hatchery and Genetic Management Plans (HGMPs) reference a PNI goal of 0.67, which she said would be a reasonable standard to apply to the programs. She said for the pHOS standard, the Hatchery Scientific Review Group (HSRG) guideline is 30% for integrated programs, so 30% would be a reasonable standard to use for these programs. She said a sliding scale or other technique, and a long-term timeline could help programs attain this goal. Gale asked if Hurst is referencing "effective" pHOS or "straight" pHOS. She said NMFS does not typically use effective pHOS, and Gale said the HSRG largely references effective pHOS. Gale noted that HSRG guidelines for integrated programs mention that the guidelines may not be applicable for depressed or threatened populations; rather, the guidelines are for an ideal hatchery-wild population interaction. He said a depressed population with low abundance may not be able to achieve a pHOS of 30%. Hurst said NMFS will consider the HSRG guidelines when discussing sliding scales and pHOS targets.

Pearsons asked Hurst which programs are bundled for this consultation. Hurst said the steelhead consultation bundle includes the Winthrop program, Wells complex programs (Wells FH, Twisp, and Methow FH), and any releases under the Wells Steelhead HGMP. She said the consultation for unlisted programs will result in one BiOp, which includes Wenatchee summer Chinook salmon, Chelan Falls summer Chinook salmon, Wells summer Chinook salmon, Priest Rapids fall Chinook salmon, Methow summer Chinook salmon, and Ringold upriver bright fall Chinook salmon (which is included with the rest for efficiency). The bundle does not include Similkameen summer Chinook salmon, which is bundled with Chief Joseph programs. Hurst said the type of permit under this BiOp is undecided and could be Section 7 coverage with United States v. Oregon as the federal nexus or Section 10 including a National Environmental Policy Act process with permits issued in 2018. Pearsons asked how each permit coverage type would affect the programs. Hurst said she would discuss the program implications of each coverage type with NMFS legal counsel and update the Hatchery Committees.

Gale asked if Entiat summer Chinook salmon are the only unlisted program not included in the bundle besides Okanogan summer Chinook salmon. Hurst confirmed and said the Entiat program already has coverage. Gale said the Entiat summer Chinook salmon program has a BiOp that will expire and he would like to get the expiration modified. Hurst said she would look into this.

C. Spring Chinook Salmon Out-planting in the Chewuch River (Catherine Willard)

Catherine Willard shared a document titled, "Draft Outplanting Adults Plan," which Sarah Montgomery distributed to the Hatchery Committees on March 24, 2017. Willard said she updated the draft based on discussions during the March 13, 2017, Hatchery Committees meeting and summarized the changes as follows:

- Fish will not be outplanted if they have a disease outbreak
- Further clarification of release sites is included
- Results will be summarized in a report and presented to the Hatchery Committees

Mike Tonseth asked why the results will be presented in February 2018 and said it would be helpful to present them before February so the first draft of the 2018 Broodstock Collection Protocols can incorporate any study elements. Willard said the results can be presented in January or sooner and made that revision in the document.

Bill Gale suggested further clarifying language regarding disease outbreaks to "exhibit disease concerns as identified by fish health personnel" and this edit was made. Tonseth mentioned that internal WDFW meetings indicate that the standard practice of inoculating hatchery fish is currently being phased out, while current practices and rates of culling will likely remain. He said this is being studied further.

The Hatchery Committees representatives present approved the Outplanting Adults Plan (for spring Chinook salmon in the Chewuch River) as follows: Chelan PUD, Douglas PUD, USFWS, WDFW, NMFS, YN, and CCT approved on April 19, 2017. Grant PUD (PRCC HSC) also indicated approval. (Montgomery distributed the Final Outplanting Plan on April 20, 2017 [Attachment B].)

Tonseth brought up a related conversation—the Final 2017 Broodstock Collection Protocols, which were recently discussed and approved by the Hatchery Committees. Tonseth said during the second round of revisions to the protocols, the HCP Hatchery Committees approved the protocols, and then the protocols were sent on to the Wells HCP Coordinating Committee for review; however, this occurred before the PRCC HSC had approved the protocols. Grant PUD made a comment in Appendix C in response to edits by Kirk Truscott and Keely Murdoch regarding prioritization of fish in the Methow program that was not addressed and discussed before the protocols were approved. Todd Pearsons added that it is important for parties who are on the HCP Hatchery Committees and the PRCC HSC (i.e., YN, CCT, NMFS, USFWS, WDFW) to designate to all committees when they are voting on an item that pertains to all committees and to include the PRCC HSC facilitators in any email responses to a vote request. Montgomery added that she only tracks approval for HCP Hatchery Committees items, but will make sure to include the PRCC HSC facilitators and Grant PUD in those email discussions.

The unaddressed comment in Appendix C (Adult Management) was about how fish would be used in years of low abundance for meeting the safety net component at Winthrop NFH or a production shortfall at Methow FH, versus being used to meet escapement objectives in tributaries. Pearsons said if escapement objectives are met, the fish should be outplanted for experimental reasons; however, if there is a shortage of fish spawning in the natural environment, outplanting could be prioritized over populating the safety-net program. Gale asked how managers would know if enough fish are present on spawning grounds. Tonseth said WDFW is looking into using passive integrated transponder (PIT)-tag detection data to estimate how many fish will be present on spawning grounds in various locations. Gale said the outplanting experiment may or may not work, so the prioritization discussion should occur after the utility of translocating adults is demonstrated. Pearsons said outplanting adults poses few risks to natural spawners and asked again in the case of few fish on spawning grounds whether managers should outplant adults or populate the safety-net program. Murdoch said Appendix C includes the language, "as long as both programs [Methow conservation and Winthrop safety-net] meet full production," meaning that program targets should be met and then any extra conservation program fish could be outplanted instead of put into the safety-net program.

Tonseth reminded everyone that Appendix C is about adult management and fish discussed in this section are surplus to broodstock needs (i.e., escapement objectives are already met). Tonseth said he agrees that there should be a higher priority for putting conservation fish on spawning grounds if needed to meet escapement objectives. Gale said the outplanting study has not been tested yet, so while these are interesting discussions and concepts, it might make the most sense to perform the study before discussing this in too much detail. He added that the discussion pertains more to the Joint Fisheries Parties (JFP) than the HCP Hatchery Committees. Truscott agreed and said hatchery production should not be shorted until outplanting is tested. Pearsons clarified that the question is about whether conservation fish would be put on spawning grounds instead of used in the safety-net program. Gale added that any escapement numbers should be evaluated using the 3-population PNI model. Truscott said he would not want to reduce broodstock numbers for the Winthrop program to test adult translocation, because the Winthrop program is important for long-term management and gene flow in the basin. He said if the translocation study works, though, a loss to production might be defensible in order to increase natural productivity. Greg Mackey summarized that there are tradeoffs at stake: fish spawning in the wild could contribute directly to conservation, while approximately 90% of the Winthrop program will be taken out when they return to Winthrop NFH, which would be directing conservation fish to adult management. Mackey said by the time the outplanting will occur, managers will understand the general shape and size of the run from counts at Wells Dam. Tonseth said as the JFP develops the Methow spring Chinook salmon management plan, more guidance will be available for prioritizing fish and programs.

D. Twisp Steelhead Program (Mike Tonseth/Todd Seamons)

Mike Tonseth said Todd Seamons wrote a memo "Re: discovery of potential Ryman-Laikre issues in the Twisp River steelhead using Twisp origin broodstock," which Sarah Montgomery distributed to the Hatchery Committees on March 30, 2017 (Attachment C). Tonseth asked Seamons to discuss his memo and the Twisp steelhead program with the Hatchery Committees.

Seamons provided background for the memo and summarized that the relative reproductive success study in the Twisp River included adult to adult-offspring genetic parentage assignments, which provided the data for these analyses. Seamons said the Twisp steelhead program is seeing amplification of a small portion of the steelhead population by the hatchery (see Attachment C for detailed results). Craig Busack (NMFS) said inbreeding depression is occurring in the Twisp steelhead population. He said a Ryman-Laikre effect is to be expected in this situation, because you can expect hatchery fish to be more productive than wild fish. He said a small number of parents depresses the effective population size of the next generation. Busack said to understand how concerning these effects are, one must understand the extent to which the program is closed. Seamons agreed and clarified that his memo is just an explanation of his analysis and another piece to consider is that life history diversity also reduces the genetic diversity of the population. He said the rate of reduction of diversity increases under a Ryman-Laikre effect.

Busack said from the NMFS perspective, the main issue is the effective size of the Methow steelhead population and although the Twisp is an independent subpopulation, the implications for gene flow with the Methow population need to be considered. Seamons agreed and said for recovery purposes, the Methow population is an important unit. He said WDFW proposes purposefully mixing Twisp hatchery fish with Winthrop NFH steelhead to reduce the rate of diversity reduction. Seamons said there is a tradeoff with allowing local adaption to occur or not and purposefully mixing fish reduces local adaptation (which may not matter for recovery purposes). Seamons said the Yakima River has population structure within small creeks with genetic distinction. He said it is plausible that more genetic structure has previously existed in the Methow basin and could exist again if hatchery populations were intermixed. Busack agreed and said the population itself has to prosper, but genetic diversity within the population should also be considered. Busack suggested increasing the size of the Twisp program as a way to foster diversity in the Twisp River and also guard against Ryman-Laikre effects. Seamons responded that there is risk to mining the wild population if the program is expanded and said WDFW's preferred alternative is mixing the hatchery programs (with the tradeoff being the Twisp subpopulation has less of a chance to locally adapt).

Seamons said another consideration is that hatcheries tend to reduce life-history diversity, so incorporating other age classes and life histories in hatchery production could also be considered. For example, rainbow trout, mixed cohorts, coastal parr, or other ideas could be considered. Greg Mackey said there are a lot of rainbow trout in the Twisp River in upstream reaches and in the headwaters. He said he assumes resident and anadromous fish mix to some degree in the Twisp River and bringing resident fish into the hatchery could influence the life histories of hatchery fish. Gale said a USFWS experimental steelhead program at Abernathy Fish Technology Center was sourced from steelhead and resident juveniles that were forced to mature in freshwater. Busack said it would be interesting to examine the genetic profile of rainbow trout in the Twisp River in comparison to steelhead. Todd Seamons said for comparison, there is a lot of genetic diversity between resident and anadromous steelhead.

Tonseth said the current problems with the Twisp steelhead program are low overall abundance and also single age classes, which is why WDFW proposes compositing programs, and incorporating S2s in the release plan in the Twisp River. Mackey said even though the Winthrop contribution in the Twisp River is low (there are few PIT-tag detections), if Winthrop fish return to the Twisp Weir, they should be allowed upstream of the weir to increase gene flow. Regarding gene flow management, Mackey suggested using a smaller brood and removing fewer fish to decrease the representation of hatchery fish in the run at large and also decreasing sampling removal effects.

Busack emphasized that the Twisp steelhead are a subpopulation of the Methow population and there really is not distinction for any tributaries in the upper Columbia River for steelhead. Gale said the genetic focus should be on creating diversity between Methow and Okanogan steelhead first and within the Methow or Okanogan second. Truscott agreed and said fostering local adaptation within the populations will allow them to slowly diverge.

Tonseth said the JFP will be drafting a Methow basin steelhead management plan and Douglas PUD also needs to define the direction of their Twisp hatchery program as part of the consultation process. He said he will organize a workgroup to better define Douglas PUD's program and the role of the USFWS program to give Hurst a more defined action for consultation. Hurst asked for a defined action by the end of June 2017. Murdoch said when the JFP created the Wenatchee spring Chinook salmon management plan, the comanagers initially drafted it, then brought in CCT, NMFS, and the USFWS. She said she envisions the Methow plan also being the purview of the JFP and not necessarily the PUDs. Tonseth said he agrees with Murdoch, but for defining the Twisp program, Douglas PUD needs to be involved, then the JFP can write the plan. Mackey said he would like for

Busack and Seamons to help define the genetic aspects of the Twisp program and added Douglas PUD does have a stake in the management of Methow spring Chinook salmon and will have to agree to the JFP's plan through the HCP processes.

E. Brood Year Stray Rate Targets (Tracy Hillman)

Tracy Hillman said he was asked to analyze brood year stray rates for Chiwawa spring Chinook salmon. He said the Hatchery Committees expected that recipient populations would have high stray rates in years for which brood year stray rates are high and his analysis showed this to be true for Chiwawa spring Chinook salmon. Hillman asked Charlie Snow (WDFW) to perform the same analysis for Twisp spring Chinook salmon and Snow found a different pattern—when the 5% brood year stray rate target was exceeded, the 10% recipient population target was not exceeded. Hillman summarized the patterns in Table 1.

Table 1. Brood Year Stray Rates

Donor Population Size	Brood Year Stray Rate	Small Recipient Population Stray Rate	Large Recipient Population Stray Rate
Large	High	High	?
Small	High	?	Low

Hillman said when the donor population size is large, the recipient population stray rate is more likely to be high if the recipient population is small. In contrast, strays from a small donor population are unlikely to affect large recipient population stray rates. Thus, high brood year stray rates do not necessarily result in high recipient population stray rates. He suggested the Hatchery Committees consider these patterns and discuss brood year stray rates further while discussing M&E objectives during the May 17, 2017, meeting.

Kirk Truscott said the discussion about brood year stray rates also should consider the purpose of the program. If a large portion of the program is straying, the management target is not being met. Mike Tonseth said some straying has management implications, while other straying can have genetic implications. Truscott asked if there is any information on naturalized populations in the Wenatchee basin that should be considered in these discussions about appropriate brood year stray rates. Todd Pearsons said no other hatchery programs in the Columbia River basin have a brood year stray rate target that he is aware of and there is no obvious justification for a 5% brood year stray rate target. Hillman summarized that the Hatchery Committees also considered using stray rates from Ford et al.[1] as targets and are currently discussing whether the brood year stray rate target should be eliminated entirely, or if not, what the target should be. Hillman said representatives might consider reading a recent paper by Bett et al.[2] that focuses on recipient population strays in small populations of Pacific salmon.

III. Chelan PUD

A. Coho Salmon Master Plan and Recalculation Agreements (Keely Murdoch, Cory Kamphaus, Catherine Willard)

Catherine Willard said the Rocky Reach and Rock Island HCP Coordinating Committees approved the Designation of Juvenile Coho Salmon in Phase III (Standard Achieved) at the Rock Island and Rocky Reach Projects Statement of Agreement (SOA) on March 28, 2017, which is an agreement to move juvenile coho salmon at both Projects from Phase III Standard Achieved Interim-Value to designation of Phase III Standard Achieved, with 93% survival at both Projects. She said this agreement is based on a study that adjusted acoustic survival data to PIT-tag data for coho and spring Chinook salmon, and next, survival numbers will inform coho salmon mitigation calculations for agreements. Keely Murdoch said she, Cory Kamphaus (YN), Willard, and Alene Underwood (Chelan PUD) have discussed the next steps for coho salmon mitigation and agree to use the same methods for calculating mitigation numbers as previously used for other species. She said she and Willard will provide the mitigation calculation numbers for review at the May 17, 2017, Hatchery Committees meeting, then Chelan PUD and YN will discuss how Chelan PUD will meet the mitigation requirements.

Murdoch said she is presenting an update on YN's Coho Salmon Master Plan and Kamphaus will discuss the natural production phases and site development parts of the Master Plan. Murdoch shared a presentation titled, "Upper Columbia Coho Restoration Master Plan – 2017 Update" (Attachment D), which Sarah Montgomery distributed to the Hatchery Committees following the meeting on April 19, 2017. A summary of the presentation and questions and comments are included in the following sections.

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[1] Ford, M.J., A. Murdoch, and M. Hughes, 2015. Using parentage analysis to estimate rates of straying and homing in Chinook salmon (*Oncorhynchus tshawytscha*). *Molecular Ecology* 24, 1109-1121. Doi: 10.1111/mec.13091

[2] Bett N.N., S.G. Hinch, N.J. Burnett, M.R. Donaldson, and S.M. Naman, 2017. Causes and Consequences of Straying into Small Populations of Pacific Salmon. *Fisheries* 42 (4), 220-230. Doi: 10.1080/03632415.2017.1276356

Background (Slides 1-3)

The goal of the Coho Master Plan is to re-establish naturally spawning coho salmon populations in upper-Columbia tributaries (Methow and Wenatchee basins) to biologically sustainable levels, which provide significant harvest in most years. Metrics include escapement and harvest rates.

Phased Approaches: Broodstock Development and Natural Production (Slides 4-11)

Broodstock Development Phase I (BDPI) is complete in both the Wenatchee and Methow basins. Phase II is complete in the Methow basin. In the Wenatchee basin, YN found that there were very few coho redds in Nason Creek, and many more males than females were found at Tumwater Dam.
BDP II is ongoing in the Wenatchee basin, and the emphasis is on getting more coho salmon to upstream sites. Murdoch said YN is attempting to trap 50% of the female broodstock at Tumwater Dam for three generations and if reintroduced stock do not sufficiently reach upstream habitat areas, the contingency plan will be implemented. Murdoch said so far, studies indicate coho salmon that come into the system early and green are more likely to ascend Tumwater Dam; however, patterns are not consistent between years, especially drought years.

The Natural Production Phases include decreasing domestication and increasing fitness in the natural environment. YN used EDT and AHA models, to reduce domestication, and phased PNI targets.

In the Methow River, Murdoch said YN may default some of the release numbers to adult outplants instead of juvenile releases due to acclimation space. Murdoch said they have outplanted adults in Nason Creek and subsequently sampled juveniles throughout Nason Creek. Kamphaus said 30% of the juveniles found were related to outplanted adults and in the year YN outplanted adults, there were 95 redds in Nason Creek, which is exceptionally high for that system. Kamphaus said the adults were PIT-tagged and outplanted at a 1:1 ratio; some males moved out of the system and all but one female stayed in the system, likely contributing to the high number of redds for that year.
Mike Tonseth asked when the outplanted adults were collected in relation to peak spawning in Nason Creek. Kamphaus said the adults were collected as natural fish were being detected at the Nason Creek PIT-tag array.

Willard asked how the hatchery release numbers were calculated. Murdoch said models were used to determine capacity estimates, then release numbers were calculated for achieving that capacity estimate. The goal is to create a spawning aggregate based on the capacity estimate.

Monitoring and Evaluation (Slides 12-16)

Monitoring and evaluation for the Coho Master Plan includes Project Performance Indicators, Species Interactions, and Genetic Adaptability.

Regarding Project Performance Indicators, Murdoch noted that the volitional release and tributary residence timing Project Performance Indicators overlap with the species interactions sections that YN reports to NMFS, so these indicators inform more than project performance.

Regarding Species Interactions, Murdoch said YN checks for the status of Non-Target Taxa Of Concern species in response to reintroduction of coho salmon.

Regarding Genetic Adaptability, Murdoch said there are phenotypic differences between Tumwater Dam and Dryden coho salmon. She said YN is bringing up a side-by-side release of coho salmon from Leavenworth NFH to study survival rate advantages that could be repeated in future years. Kamphaus said YN is also doing genetic monitoring and looking for genetic and phenotypic changes. He said the Columbia River Inter-Tribal Fish Commission is working on a manuscript on assigning coho salmon genetic divergence to adaptive or neutral markers.

Site Development (Slides 17-20)

Kamphaus said the Coho Salmon Master Plan includes some existing sites (e.g., natural earthen ponds, constructed ponds, tanks), some proposed sites, plus Natapoc FH, which is being designed to provide adult holding, early incubation, and full-term rearing for juveniles. Kamphaus reviewed the status of sites in both the Methow and Wenatchee basins and the implementation timelines for both basins. He summarized that all sites are expected to be complete and operational by September 2019. There were no further questions or comments.

IV. HCP Administration

A. HCP Representative Changes

Tracy Hillman said Chelan PUD designated Catherine Willard as the Hatchery Committees representative and the alternate position is currently unfilled, effective April 12, 2017.

Mike Tonseth mentioned that he asked the Coordinating Committees to approve email distribution access for Alf Haukenes, who is the hatchery/wild interactions unit lead for WDFW.

B. Next Meetings

Matt Cooper asked the Hatchery Committees if they would be interested in a presentation about epigenetics by Penny Swanson. Representatives present said they would be and Cooper said he would invite Swanson to present at the May 17, 2017, Hatchery Committees meeting.

The next Hatchery Committees meetings are on May 17, 2017 (Grant PUD), June 21, 2017 (Grant PUD), and July 19, 2017 (Grant PUD).

V. List of Attachments

Attachment A	List of Attendees
Attachment B	Outplanting Adults Plan
Attachment C	Ryman-Laikre Issues in the Twisp River Steelhead Program Memo
Attachment D	Upper Columbia Coho Salmon Restoration Master Plan – 2017 Update

Attachment A
List of Attendees

Name	Organization
Tracy Hillman	BioAnalysts, Inc.
Sarah Montgomery	Anchor QEA, LLC
Catherine Willard*	Chelan PUD
Greg Mackey*	Douglas PUD
Tom Kahler*	Douglas PUD
Todd Pearsons‡	Grant PUD
Peter Graf‡	Grant PUD
Deanne Pavlik-Kunkel†‡	Grant PUD
Bill Gale*	U.S. Fish and Wildlife Service
Matt Cooper*	U.S. Fish and Wildlife Service
Brett Farman*†	National Marine Fisheries Service
Charlene Hurst*†	National Marine Fisheries Service
Craig Busack	National Marine Fisheries Service
Mike Tonseth*	Washington Department of Fish and Wildlife
Todd Seamons†	Washington Department of Fish and Wildlife
Keely Murdoch*	Yakama Nation
Cory Kamphaus	Yakama Nation
Kirk Truscott*	Colville Confederated Tribes

Notes:
* Denotes Hatchery Committees member or alternate
† Joined by phone
‡ Joined for the joint HCP-HC/PRCC HSC discussion

Out-planting Surplus Methow Composite Spring Chinook Salmon Adults

Final approved by the HCP-HC 4-19-2017

Background

The Hatchery Committees (HCs) recently reviewed the "Evaluation of Hatchery Programs Funded by Douglas County PUD 5-year Report 2006-2010". As a result, Objective 6 monitoring question Q6.1.1: "Is the stray rate of hatchery fish less than 5% for the total brood year return?" was identified as not meeting the target for the Chewuch River final acclimated fish. The HCs determined that methods to improve homing would have uncertain success, be difficult to implement, and challenging to statistically evaluate. In an effort to achieve the goal of increased hatchery-origin spawner abundance in identified reaches that a higher rate of homing would convey, the HCs agreed to pilot adult out-planting of surplused Methow Composite spring Chinook into the Chewuch River.

The goal of this pilot evaluation is to determine if surplused Methow Composite spring Chinook adults collected and held at the Methow Hatchery, and subsequently out-planted into the Chewuch River, remain in the Chewuch River and subsequently spawn. This pilot evaluation will be conducted in an effort to determine if adult-outplanting can be an effective tool to increase spawner abundance, spawner distribution, and natural production in the Chewuch River in years of low abundance. It is a low-risk management tool that has been used in many locations such as the Wenatchee and Willamette watersheds.

2017 Out-planting of Surplus Methow Composite Spring Chinook Salmon Adults Objectives:

- During spawning surveys, estimate the number of females trapped and out-planted to the Chewuch River that exhibit spawning behavior, construct a redd, and/or spawned (determined by egg voidance).
- Assess the ability of transporting adult spring Chinook to the Chewuch River to provide the overall number of hatchery spawners allowable under ESA permit conditions.
- Assess how many days fish were held from trapping to out-planting and from out-planting to spawner success.
- Estimate spawner distribution of males and females within the Chewuch River post release and compare results to retention time in the Chewuch River and spawner success.
- Assess the proportion of out-planted males and females that remain in the Chewuch River compared to out-planted males and females determined to have left the Chewuch River.

Methods

Up to 200 hatchery-origin spring Chinook salmon adults (jacks will be excluded) returning to the Methow Hatchery, in excess of broodstock needs for the Methow Hatchery and Winthrop National Fish Hatchery (NFH), will be collected, held and out-planted to targeted spawning reaches of the Chewuch River. The specific number of fish to be held and out-planted will be based upon permit limitations, availability of fish, and pHOS level as agreed to by the HC. A female to male ratio of 1.0:0.2 will be implemented unless run composition assessment for the run at large suggests a deviation from this level.

- Out-plant a maximum of 200 hatchery-origin spring Chinook adults (jacks will be excluded) at a female to male ratio of 1.0:0.2 will be implemented unless run composition assessment for the run at large suggests a deviation from this level.

- The number of adults shall be consistent with the terms and conditions of the ESA incidental take permits for the Methow Hatchery (#18925; #18927; #20533) according to the decision tree below:

1. If the natural origin run to the Methow basin is estimated to be <100, then pHOS in the Chewuch will be =-0.002x+0.8 (where x=estimate of the natural origin run size in the Chewuch River), else,
2. If the natural origin run to the Methow sub-basin is estimated to be ≥100 and <300, then pHOS in the Chewuch River will be =-0.0013x+0.8 (where x=estimate of the natural origin run size in the Chewuch), else,
3. If the natural origin run to the Methow sub-basin is estimated to be ≥300, then pHOS in the Chewuch River will be =0.8(1-e^(-0.006x) (where x=estimate natural origin run size in the Chewuch).
4. In each case, the number of hatchery origin fish to be released in the Chewuch will be calculated as
    a. Find the allowable basin pHOS based on estimated natural-origin spawning escapement to the Methow sub-basin and the estimated pHOS for the Methow Hatchery program (Twisp + MetComp).
    b. Use this pHOS to estimate how many hatchery-origin fish can be allowed in the Chewuch River based on the expected natural-origin spawning escapement to the Chewuch River.
    c. Calculate how many additional, surplus hatchery-origin fish shall be transported and released to the Chewuch River to remain within permit limits.
    d. A spreadsheet "Adult Outplanting Calculator.xls" is available to perform these calculations (Attachment A).

Holding and Out-planting

Surplus hatchery-origin adults returning to the Methow Hatchery will be held (duration of holding period will be variable based upon when the individual was collected) and out-planted approximately one week before estimated peak spawning (i.e., during the latter part of August/early September). If the fish being held for subsequent out-planting exhibit disease concerns as identified by fish health personnel, the fish will not be out-planted. All out-planted adults will be PIT-tagged and marked with a visible mark. Depending on availability of fish for out-planting, up to 100 adults will be released into each of one of two sites; if fish availability is limited, all fish will be out-planted into the upper release site. One site will be above the upper Chewuch River PIT tag instream PIT tag antenna array (CRU) and the other below CRU and above the Winthrop (CRW) PIT tag antenna array (Figure 1). Release locations will be determined based on accessibility, suitable spawning habitat, distance from the hatchery, distance from PIT tag arrays, and areas that are not being utilized by spawners already in the system.

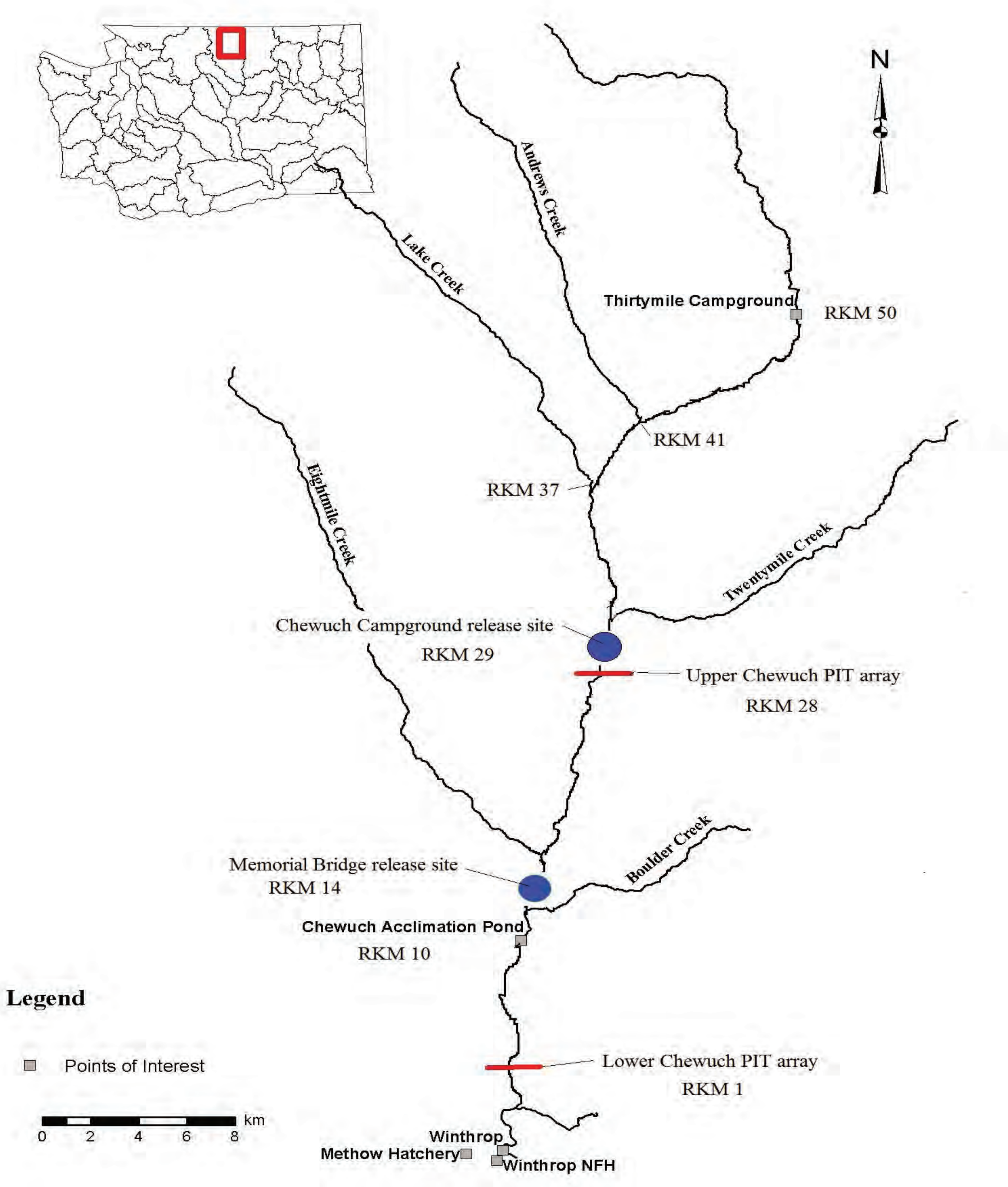
Evaluation

The association of the out-planted adults with redds will be documented during spawner surveys (e.g., identification of out-planted adults on redds). Potential spawning success of females will be documented by estimating the proportion of eggs that are retained within female carcasses sampled during carcass recovery surveys. Carcass location and redds determined to be constructed by out-planted adults will be documented using a GPS device.

Post release PIT detections at the CRW PIT tag antenna array, non-Chewuch River PIT detections, and out-planted adults returning to the Methow Hatchery and Winthrop NFH will be used to estimate the proportion of out-planted spring Chinook salmon that left the Chewuch River.

The results of this pilot evaluation will be summarized and presented to the HCs no later than the January 2018 meeting. The results of the 2017 out-planting effort may be used to inform potential future decisions and/or actions regarding out-planting methodology.

Figure 1. Release site locations for out-planting surplus Methow spring Chinook, 1) Chewuch Campground release site and, 2) Memorial Bridge release site.



Memorandum

Todd R. Seamons, Ph.D.
Director, Molecular Genetics Laboratory
Washington Dept. of Fish and Wildlife

RE: discovery of potential Ryman-Laikre issues in the Twisp River steelhead using Twisp origin broodstock

Summary: Adult to adult-offspring genetic parentage assignments were performed as part of an ongoing hatchery-wild relative reproductive success study. Returning adult hatchery-produced steelhead were spawned from very few adults, a result of natural variability in reproductive success among the small numbers of Twisp steelhead spawned in the hatchery each year. However, those hatchery fish comprised a quarter and half of naturally spawning adults in 2014 and 2015 (respectively) setting the stage for a reduction in genetic diversity and effective population size (N_e) to occur (i.e., Ryman-Laikre effects, Ryman and Laikre 1991).

Background – A steelhead hatchery/wild relative reproductive success project has been ongoing in the Twisp River since 2009. Relative reproductive success is evaluated by counting offspring of parents of hatchery and natural origin. Returning adult offspring are identified through genetic parentage analysis. For the first two years of the project, hatchery fish released in the Twisp were Wells stock – a hatchery program with relatively large numbers of broodstock each year, ~82 mated pairs. In 2011, the Twisp program was started, which uses as broodstock only natural origin adults captured at the Twisp weir and has a much lower broodstock goal of 26 individuals or 13 mated pairs. The project has now been ongoing long enough for a full cohort of adult offspring from the Twisp program to have returned. The potential for Ryman-Laikre effects to occur was evaluated by quantifying the number of families represented in the hatchery and natural origin spawners and the proportion of hatchery origin spawners.

Methods – Adult hatchery and natural origin steelhead on their spawning migration are trapped and sampled at the Twisp River weir. A small number (~26, roughly half are female) of unmarked (i.e., natural origin) steelhead were taken and used as broodstock for the Twisp River steelhead hatchery program. The remaining natural origin fish were sampled and released upstream to spawn naturally. A fraction of hatchery origin adults were released upstream to spawn; the number released was limited in an attempt to maintain a specific proportion of hatchery fish on the spawning grounds relative to natural origin fish (~0.50). Remaining hatchery origin fish were euthanized.

Fin clips were taken from all adults trapped at the weir and shipped to WDFW MGL for genetic analysis. Fish were genotyped at the panel of 192 SNP loci used for *Oncorhynchus mykiss* studies statewide. Genotypes were used to match parents to offspring using an algorithm that also infers unsampled parents (COLONY).

Results/Discussion – Ryman-Laikre effects are expected to occur when the number of fish taken into the hatchery for spawning is small resulting in the “amplification” of a small segment of the population

(Ryman and Laikre 1991). The number of fish spawned in the hatchery and the number of families produced was very low for the two years for which I have data. Twenty five adults (12 F, 13 M) were spawned in 2011 and 28 (14 F, 14 M) were spawned in 2012. **These natural origin fish taken for broodstock represented ~10% of the fish returning to the weir in those years.**

Effective size can also be affected by the mating design. Mating was performed as 1:1 pairings followed by a secondary "backup" male. Parental pairings were recorded in 2011, but not in 2012. In 2011, only 12 different primary pairings were made, resulting in a possible 24 different full-sib families, if eggs were fertilized by both the backup male and the primary male. Of the 24 possible full-sib families, members from only 18 families were detected among returning hatchery-origin adults. Most (77%) were offspring of the primary pairings. Although pairings were not recorded in 2012, based on spawn date and the parentage results, many pairings were detected, which, based on 2011 results, I assume mainly represent primary pairings. Of 14 known possible pairings, 12 families were detected. (No half-siblings were detected, which I interpret as failure of the backup male to produce adult offspring.) About 50% of the steelhead redds found in the Twisp basin in 2014 and 2015 were downstream of the weir, so it is likely some families were not sampled.

In order to evaluate the possibility of Ryman-Laikre effects, hatchery produced fish data need to be compared to natural origin fish data. Because hatchery produced fish mature at total age 3, 4, and possibly 5, hatchery fish spawned in 2011 and 2012 produced offspring returning in 2014 and 2015. In order to compare hatchery fish to wild fish, results reported from this point forward were summarized by spawn year, 2014 and 2015. It is important to note that in order to control the proportion of hatchery fish on the spawning grounds not all of the adult hatchery offspring that returned to the weir were released upstream. Thus, the actual number of representatives of hatchery families allowed upstream to spawn was less than what was detected in all returning hatchery fish.

In 2014, 181 fish were captured at the weir consisting of Twisp program hatchery fish (51), other hatchery stocks (52), and natural origin fish (79). Of the 51 Twisp program hatchery fish captured at the weir, 29 were allowed upstream to spawn. Twenty-eight of 29 fish were produced in 2011, and just one was produced in 2012. These 29 fish represented just 12 full-sib families and just 20 different hatchery parents. In contrast, the other hatchery stocks and natural origin steelhead that were released upstream the same year represented 85 full-sib families and 144 different naturally spawning parents. **In 2014, 23% of the naturally spawning adults in 2014 were produced by just 20 (12%) of the assigned and inferred parents.**

In 2015, of 154 Twisp program hatchery fish captured at the weir, at least 47 were allowed upstream to spawn and parentage was completed for 45. Nearly half (24) were produced in 2011 and in 2012 (21). These 45 fish represented just 20 full-sib families and just 33 different hatchery parents. In contrast, 48 natural origin steelhead returned in 2015 and were allowed upstream. These fish represented 48 full-sib families and 87 different parents. **In 2015, nearly half (48%) of the naturally spawning adults were produced by just 33 (26%) of the assigned and inferred parents.**

The potential for Ryman-Laikre effects appeared quite high for the Twisp steelhead hatchery program in two recent spawn years. Of the two spawn years, 2015 is more representative of what would happen in future years because two hatchery cohorts are present (BY 2011 and 2012) and all but two hatchery fish were Twisp program fish. The conditions in 2015 were comparable to those modeled in the original Ryman-Laikre paper reproduced below (Figure 1; figure 1b of Ryman and Laikre 1991). They predicted that with 20 of 200 adults used as hatchery broodstock and half of the spawning population composed of hatchery produced individuals, the expected drop in effective population size would be dramatic – roughly half of what it would be if there was no hatchery program. Their model assumed discrete generations, so half is probably an overestimate of the effects that might occur in Twisp steelhead because overlapping generations support higher diversity by reducing drift. However, the data show that roughly 25% of the parents are amplified to be roughly 50% of the spawners in the next generation, so significant reductions in N_e would be expected if this practice continues. This effect will likely be exacerbated in the 2017 brood year because the run is comprised almost entirely of 2-salt fish, suggesting poor survival of the 2014 brood; 1-salt returns represented only ~6% of the run-at-large sample at Wells Dam in 2016.

References

Ryman, N., and Laikre, L. 1991. Effects of supportive breeding on the genetically effective population size. Conserv. Biol. **5**(4): 325-329.

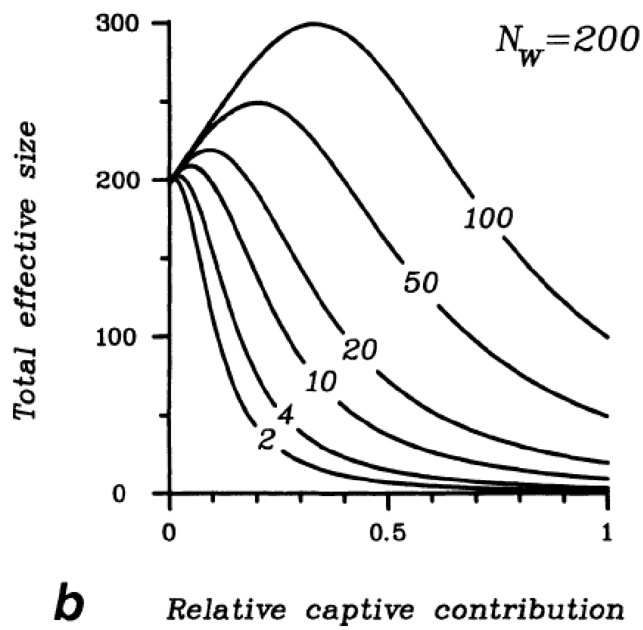


Figure 1. Figure 1b of Ryman and Laikre (1991), which shows the modeled effects on effective population size (N_e) of taking a small number (the different curves) of a small population (in this case 200 individuals) and "amplifying" their genetic representation through artificial propagation. This population size and broodstock size (focus on line = 20) is very similar to the conditions for Twisp steelhead and the Twisp steelhead hatchery program.

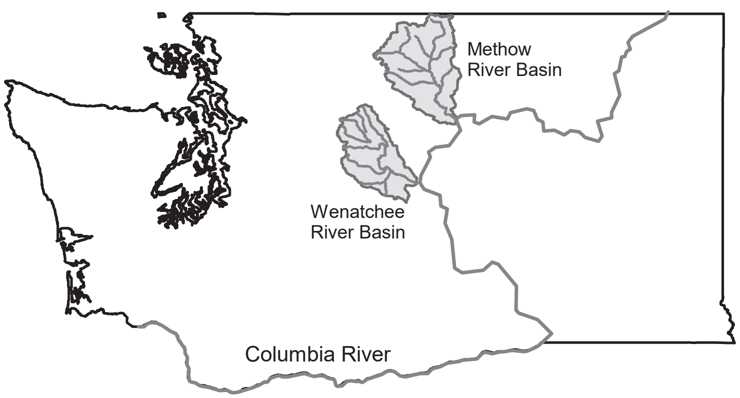
Attachment D

UC Coho Restoration Master Plan – 2017 Update

Keely Murdoch
& Cory Kamphaus

Vision

To re-establish naturally spawning coho populations in mid-Columbia tributaries to biologically sustainable levels which provide significant harvest in most years



Yakama Nation Fisheries

Biological Objectives & Numerical Goals

- Develop a locally adapted, naturally spawning coho stock in the Wenatchee and Methow river basins capable of supporting harvest
  - Metric 1: Mean escapement of NOR returns in the Wenatchee and Methow Rivers of 1500 fish
  - Achieve total harvest rate of 23% which includes a 10% mixed stock harvest, 10% Mainstem harvest, and 5% terminal harvest in most years.

Yakama Nation Fisheries

A Phased Approach

- Broodstock Development Phases
  - Eliminate transfers of lower Columbia broodstock
  - Ensure that coho can reach key habitat
- Natural Production Phases
  - Increase geographical scope
  - Emphasize local adaptation to the natural environment

Broodstock Development Phases

- Broodstock Development Phase I
  - BDPI focused on eliminating reliance on lower Columbia River stocks an transitioning to a local broodstock.
  - Completed in both basins
- Broodstock Development Phase II
  - Encourage continued adaptation of the stock by moving capture sites further upstream
  - Ensure that reintroduced stock is able to reach key habitat areas prior to starting the Natural Production Phases.
  - Completed in the Methow Basin

BDPII Goals

- Wenatchee
  - 50% of female broodstock must be trapped from TWD for one generation (3 years)
  - Implement contingency plan if not achieved in 3 generations
    - Evaluate cause of failure
    - Determine if phenotypic differences between TWD and Dryden
    - Selective broodstock collection
- Methow
  - 100% of broodstock trapped as swim-in to WNFH or MFH (for one generation) with sufficient ‘trappable’ numbers at Wells Dam to expand the program

Natural Production Phases

- Introduce coho to new habitats
- Decrease domestication selection
- Increase fitness in the natural environment
- Modeling
  - EDT to help predict coho habitat and capacity
  - AHA model to reduce domestication selection
  - Phased PNI targets

Natural Production Phases

- Natural Production Implementation Phase (NPIP)
  - Initial introduction into new habitats
  - Create spawning aggregate
  - One generation
  - After three years of release, reduce numbers
- Natural Production Support Phases (NPS 1 & 2)
  - Systematic reduction in releases sizes
  - Increase PNI

Yakama Nation Fisheries

Example

Phase	Prod.*	Adult Capacity	NPIP Smolt Release Number	pNOB Goal	pHOS Goal	pNOB Realized	pHOS Realized	PNI	Avg. Predicted HOR	Avg. Predicted NOR	Avg. NOR Escape-ment	Avg. Total Escape-ment
NPIP	1.10	1415	300,000	10%	90%	10%	84%	0.11	1367	209	173	1061
NPS 1	1.10	1415	211,000	35%	80%	35%	80%	0.30	981	244	155	1092
NPS 2	1.45	1415	105,000	80%	65%	80%	57%	0.58	491	421	289	746
Recovered (PFC)	1.79	2000	None	N/A	N/A	N/A	N/A	1.0	0	456	456	456

Yakama Nation Fisheries

Natural Production Phases
Methow River

Location	NPIP (3 years)	NPS I (approx. 2 gen)	NPS 2 (est 2 gen)
Mainstem Methow*	350,000	245,000	122,500
Chewuch	300,000	210,000	105,000
Twisp R*	250,000	175,000	87,500
Beaver Cr	50,000	35,000	17,500
Gold Cr	50,000	35,000	17,500
Total	1,000,000	700,000	350,000

Yakama Nation Fisheries

Natural Production Phases Wenatchee Basin

Location	NPIP (3 years)	NPS I (approx. 2 gen)	NPS 2 (est 2 gen)
Chiwawa River	350,000	245,000	122,500
White R *	150,000	112,000	56,000
Little Wen *	210,000	175,000	87,500
Upper Wen	50,000	35,000	17,500
Chumstick*	50,000	35,000	17,500
Brender/Mission*	50,000	35,000	17,500
Icicle Cr	100,000	70,000	35,000
Total	1,155,000	808,500	404,250

Monitoring and Evaluation

- Project Performance Indicators
- Species Interactions
- Genetic Adaptability

Project Performance Indicators

- Release-to-McNary Survival (PIT tags)
- In-Pond Survival
- Pre-Release Fish Condition
- Volitional Release and Tributary Residence
- Spawning Escapement and Distribution
- Natural Smolt Production
- Egg-to-Emigrant Survival Rates
- Smolt-to-Adult Survival Rate
- Adult-to-Adult Productivity

Yakama Nation Fisheries

Species Interactions

- Status of NTTOC
  - Changes in size, abundance or distribution with reintroduction of coho
  - Natural Production Phases
- NTTOC Risk Assessment
- Mechanisms of Interaction
  - Competition
    - Surrogate Variables
    - Additional Studies
  - Predation
    - Surrogate Variables
    - Additional predation studies

Genetic Adaptability

- Is divergence at neutral and adaptive SNP loci a useful measure of reproductive isolation and phenotypic plasticity?
- Is phenotypic divergence (if observed) a useful proxy for local adaptation?
- Biological significance to perceived local adaptation/naturalization
- Mechanisms leading to adaptation and how quickly can stocks react to alternative natural selection regimes

Genetic Adaptability

- Morphometrics and life history traits.
- Phenotypic traits and Tumwater and Dryden Dams
- Contemporaneous Life-History Traits

Site Development-Overview

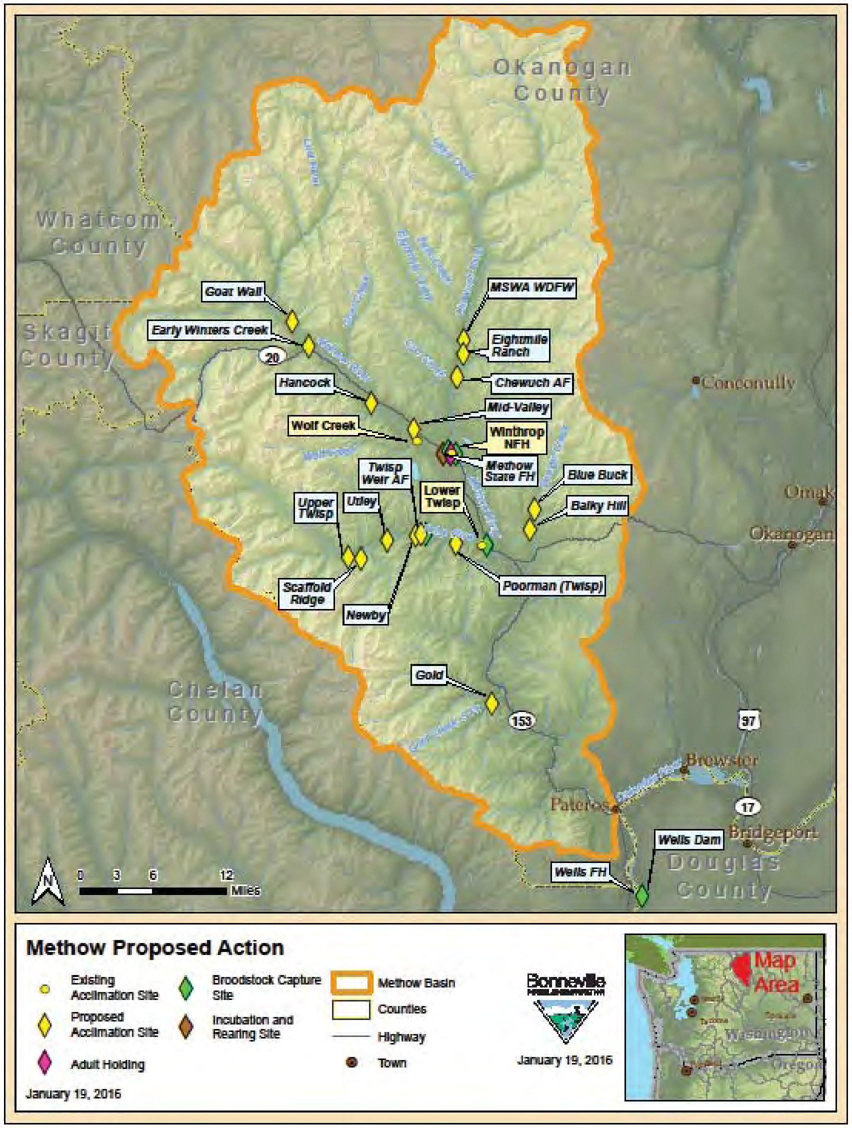
- Proposed Sites-Existing
  - <u>Wenatchee Sites</u>
    - Little Wenatchee River: *Two Rivers*
    - White River: *White River Springs, White River Bridge*
    - Chiwawa River: *Clear Creek Pond*
    - Lower Wenatchee: *Brender Creek*
  - <u>Methow Sites</u>
    - Twisp River: *Twisp Weir Site, Upper Twisp Pond*
    - Chewuch River: *Chewuch Acclimation Facility*
    - Upper Methow River: *Mid-Valley, Goat Wall*
    - Beaver Creek: *Blue Buck*

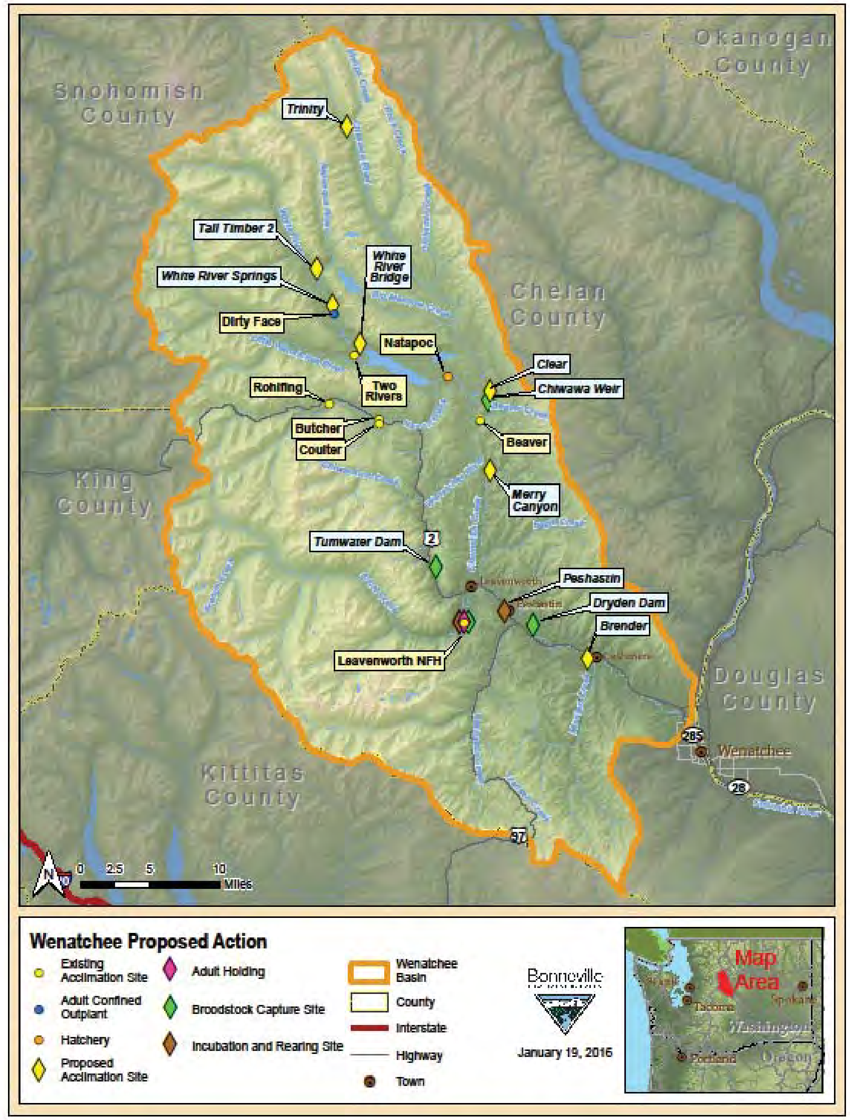
Site Development-Overview

- Proposed Sites: Constructed
- Natapoc FH
  - Being designed to provide adult holding, early incubation for entire WEN program as well as full-term rearing for up to 250,000 juveniles
    - *Transferred as pre-smolts to various acclimation sites*
- Acclimation sites
  - Mostly spring (S) w/ one overwinter (O) location
    - Upper Methow River: *Early Winters (S)*
    - Chewuch River: *Eightmile Ranch (S)*
    - Chiwawa River: *Trinity (O)*
    - White River: *Tall Timber 2 (S)*
    - Chumstick Creek: *Merry Canyon (S)*

Site Development-Overview

Yakama Nation Fisheries





Yakama Nation Fisheries

Site Development-Overview

- Implementation timelines:
  - Varies by project/site but generally:
  - Methow sites
    - Targeted construction of summer/fall 2017 with implementation in spring 2019.
  - Wenatchee acclimation sites
    - Targeted construction most likely summer 2018 & 2019 with implementation once BDP II is completed
  - Wenatchee-Natapoc
    - Bidding process to begin summer/fall 2017 with target of substantial completion of end of August 2019
    - Operational by September 2019

FINAL

720 Olive Way, Suite 1900
Seattle, Washington 98101
206.287.9130

ANCHOR QEA

Memorandum

To: Wells, Rocky Reach, and Rock Island HCP Hatchery Committees

Date: June 21, 2017

From: Tracy Hillman, HCP Hatchery Committees Chairman

cc: Sarah Montgomery, Anchor QEA, LLC

Re: Final Minutes of the May 17, 2017, HCP Hatchery Committees Meeting

The Wells, Rocky Reach, and Rock Island Hydroelectric Projects Habitat Conservation Plan (HCP) Hatchery Committees meeting was held at the Grant PUD office in Wenatchee, Washington, on Wednesday, May 17, 2017, from 10:30 a.m. to 3:15 p.m. Attendees are listed in Attachment A to these meeting minutes.

Action Item Summary

- Andrew Murdoch (Washington Department of Fish and Wildlife [WDFW]) will write an overview of proposed expanded sampling at the off-ladder fish trap (OLAFT) at Priest Rapids Dam (Item I-A). *(Note: this item is ongoing.)*
- Hatchery Committees representatives will review McLain Johnson's (WDFW) Genetic Monitoring Update for discussion at the Hatchery Committees June 21, 2017, meeting (Item I-A). *(Note: Sarah Montgomery distributed the update on April 6, 2017; Mike Tonseth postponed the update via email on June 13, 2017.)*
- Tracy Hillman will draft footnotes for Table 1 of the Monitoring and Evaluation (M&E) Plan for PUD Hatchery Programs (2013 Update) regarding run timing, redd distribution, and spawn timing (Item II-F).
- Sarah Montgomery will distribute Craig Busack's (National Marine Fisherie Service [NMFS]) 2013 document "Methow Basin Management Frameworks for Spring Chinook and Steelhead" to the Hatchery Committees (Item II-G). *(Note: Montgomery distributed the document following the meeting on May 17, 2017.)*

Decision Summary

- There were no decisions discussed during today's meeting.

Agreements

- There were no agreements discussed during today's meeting.

Review Items

- Sarah Montgomery sent an email to the Hatchery Committees on June 15, 2017, notifying them the Draft 2016 Chelan PUD and Grant PUD Hatchery M&E Annual Report is available for a 30-day review, with comments due to Tracy Hillman by July 15, 2017.

Finalized Documents

- There are no documents that have been recently finalized.

I. Welcome

A. Review Agenda, Review Last Meeting Action Items, and Approve the April 19, 2017, Meeting Minutes (Tracy Hillman)

Tracy Hillman welcomed the Hatchery Committees and asked for any additions or changes to the agenda. Mike Tonseth postponed the Genetic Monitoring Update to the June 21, 2017, Hatchery Committees meeting. Later in the meeting, Hillman postponed the Brood Year Stray Rate Targets discussion to the June 21, 2017, Hatchery Committees meeting.

The Hatchery Committees reviewed the revised draft April 19, 2017, meeting minutes. Sarah Montgomery said there are no outstanding comments to be discussed. Hatchery Committees representatives present approved the draft April 19, 2017, meeting minutes, as revised.

Action items from the Hatchery Committees meeting on April 19, 2017, and follow-up discussions were addressed *(note: italicized text below corresponds to agenda items from the meeting on April 19, 2017)*:

- *Andrew Murdoch (Washington Department of Fish and Wildlife [WDFW]) will write an overview of proposed expanded sampling at the off-ladder fish trap (OLAFT) at Priest Rapids Dam (Item I-A).*
  This item is ongoing.
- *Hatchery Committees representatives will review the Hatchery Monitoring and Evaluation (M&E) Plan Objectives before the Hatchery Committees May 17, 2017, meeting (Item I-A).*
  This item will be discussed today.
- *Hatchery Committees representatives will review McLain Johnson's (WDFW) Genetic Monitoring Update for discussion at the Hatchery Committees May 17, 2017, meeting (Item I-A).*
  This item is ongoing and will be discussed during the June 21, 2017 Hatchery Committees meeting.

- *Brett Farman and Charlene Hurst will provide an update to the Hatchery Committees on the differences between Endangered Species Act (ESA) Section 7, Section 10, and Section 4(d) coverage in regard to permitting for some HCP programs (Item II-B).*
  Bill Gale said Farman and Hurst provided information about coverage during a Methow basin workgroup meeting.
- *Mike Tonseth will organize a workgroup to discuss the future of the Twisp Steelhead Program and define its proposed actions for consultation (Item II-D).*
  Tonseth said this item is related to the gene flow discussion occurring today.
- *Catherine Willard and Keely Murdoch will provide coho salmon recalculation numbers to the Hatchery Committees for discussion at the Hatchery Committees May 17, 2017, meeting (Item III-A).*
  This item will be discussed today.
- *Keely Murdoch will provide the latest Yakama Nation (YN) Coho Salmon Master Plan to Sarah Montgomery for distribution to the Hatchery Committees (Item III-A).*
  This item is complete. Murdoch sent the master plan to Montgomery on May 17, 2017, which Montgomery forwarded to the Hatchery Committees on May 19, 2017.
- *Hatchery Committees representatives will discuss internally the brood year stray rate target and prepare for further discussion at the Hatchery Committees May 17, 2017, meeting (Item II-E).*
  This item will be discussed today.
- *Matt Cooper will invite Penny Swanson (National Oceanic and Atmospheric Administration [NOAA]) to give a presentation about epigenetics at the Hatchery Committees May 17, 2017, meeting (Item IV-B).*
  Mackenzie Gavery (*NOAA)* will give a presentation about epigenetics today.

II. Joint HCP-HC/PRCC HSC

A. Epigenetics Presentation (Mackenzie Gavery)

Tracy Hillman welcomed Mackenzie Gavery to the Hatchery Committees meeting. Gavery said she is working on postdoctoral research with Penny Swanson (NOAA) and Krista Nichols (NOAA) and coordinating with Winthrop National Fish Hatchery (NFH) staff to study the influences of hatcheries on DNA methylation in Methow River steelhead. Gavery said her presentation, "Epigenetics: what is it and why is it relevant to hatchery practices?" (Attachment B), will include an overview of epigenetics, discussion of a specific genetic mark called DNA methylation, and its functions and relation to the environment, and then she will present results for the Methow River steelhead DNA methylation study. A summary and questions and comments are included in the following sections.

<u>Background (Slides 1-10)</u>

Epigenetics refers to heritable changes in trait or phenotype caused by a mechanism other than mutation to the DNA sequence. The epigenome of an organism provides the instruction for which genes should be expressed; it regulates the functional aspects of the genome.

An organism's phenotype is influenced by its genes (DNA), its environment, and its epigenome. Unlike DNA, the epigenome can be changed by signals from the environment. In certain cases, epigenetic changes can persist in an organism or be passed to subsequent generations even after the environmental signal is removed.

Of the multiple epigenetic pathways, DNA methylation is the most studied and the focus of Gavery's research.

<u>DNA Methylation (Slides 11-42)</u>

Gavery reviewed the function of DNA methylation, how environmental factors (e.g. toxins, temperature, behavior) have been shown to affect DNA methylation and how DNA methylation state can be inherited. Gavery emphasized environmentally induced epigenetic changes are more likely to be persistent/heritable when exposure occurs during early development.

Todd Pearsons asked what controls which parts of a gene are methylated. Gavery said during mitotic cell division, methylation is on each strand of a Cytosine-Guanine (C-G) base pair, so when the double-helix separates, an enzyme replaces the methyl group on each side of the strand. She said the process for controlling methylation during meiotic cell division is less clear. She said it could be a combination of noncoding RNAs attending certain portions of the genome, but factors determining methylation during meiosis are still being researched. She said there is a clear association between genetics and epigenetics and multiple epigenetic markers work in concert to control gene expression.

Tracy Hillman asked if methylated C-G base pairs anywhere in the codon influence the reading of DNA strands. Gavery said yes, promoter gene sequences play an important regulatory role and methylation in a gene can influence splicing.

Gavery summarized that DNA methylation can be adaptive if the embryonic environment and adult environment match, but can also be maladaptive if they do not match.

<u>Epigenetics: Relevance to Hatchery Programs (Slides 43-68)</u>

Salmon and steelhead reared in a hatchery are phenotypically different than wild fish. Some of the phenotypes, including reduced reproductive success of hatchery fish, are associated with a loss of fitness. Hatchery-induced selection (domestication) or environmentally induced, heritable, epigenetic change could be mechanisms for these fitness losses. Some differences in the environment of wild and hatchery fish that could influence the epigenome include light, temperature, water chemistry, olfactory clues, and available nutrients. Gavery is studying whether there are discernable epigenetic differences between hatchery- and natural-origin steelhead at Winthrop NFH. The project collected returning hatchery- and natural-origin adult steelhead in 2014 and took blood and sperm samples. This research found that hatchery- and natural-origin fish in this system are differentiated by epigenetics. Previous research found that hatchery- and natural-origin fish in this system are not genetically distinct. Larissa Rohrbach (Anchor QEA, guest) asked how other populations of steelhead would compare on the PCA. Gavery said she expects different populations would be distinguishable on the PCA. This project's DNA methylation analysis was performed on red blood cells and sperm cells in order to look at both somatic and germ-line cells (which are passed on to the next generation). Results show steelhead have a heavily methylated genome compared to other species. Comparisons of differentially methylated regions (DMRs) between red blood cells and sperm cells show sperm carry important epigenetic information regarding which genes are going to be turned on in the early embryo. Results also show there are differences in DNA methylation between hatchery- and natural-origin steelhead in both somatic and germline-derived cell types. This research is an important first step in understanding the role of epigenetics in the observed fitness loss of steelhead after a single generation of rearing.

Gavery emphasized that epigenetics can help organisms retain and pass on information about their environment and epigenetics is an emerging field that will help understand how the environment affects phenotype in hatchery fish. Genetic and epigenetic variation can be assessed when considering fitness loss in populations.

Gavery said a second study is underway at the NMFS Manchester facility wherein offspring from natural-origin Methow steelhead families are divided into two groups and reared in a hatchery tank and an artificial stream. Because the fish are siblings and will have similar genomes, differences in epigenetics between the rearing environments will be assessed.

<u>Questions and Comments</u>

Tom Kahler asked if specific genes were identified that were differentially methylated for hatchery- and natural-origin steelhead. Gavery said the research focused on the function of the genes and there are multiple functional classes associated with methylated areas.

Kahler said other research has found differences in wound healing, immunity, and metabolism between groups of study fish. He asked if that persists to a second or further generation. Gavery said her research focuses on a specific cell type, which does not functionally overlap with genes regulating wound healing so it is unclear whether that change would persist.

Greg Mackey asked about the timing and intensity of exposure needed to elicit epigenetic change. Gavery said the timing of exposure appears to be more important than the intensity or length of exposure and early gestational periods are very sensitive to environmental conditions. Rohrbach asked if the most sensitive timeframe is known for fish. Gavery said epigenomes are especially sensitive to change when germlines develop. Rohrbach said when thinking about hatchery rearing affecting phenotypes, this sensitive period could be as short as one day during incubation. Gavery agreed and said epigenetics could be used as a tool, in aquaculture for instance, to effect positive phenotypic changes in a short period without expending as much energy throughout the entire rearing process. Kahler asked if Gavery is familiar with anyone using epigenetics for those kinds of applications. Gavery said she expects epigenetics research is being applied in sole aquaculture and provided an example of an application in plants where high-producing phenotypes are selected for cloning (oil palms).

Bill Gale asked if research so far has shown that reductions in relative reproductive success in hatchery fish carry through more than one generation, and if so, what is the timeline for reversing those epigenetic effects. Gavery said that is currently unknown, but in plants phenotypic changes can persist for 20 generations before reversing; but since the next generation of hatchery fish is being reared in the wild, the impact may or may not erase after just one generation. Kahler said some studies in humans and mouse-models show three to four generations are common, but others have found the persistence of epigenetically induced phenotype persisting for 84 generations. Gavery added teleosts have a high rate of methylation and some fish populations seem to have more environmentally sensitive genotypes than other groups of fish or species. Gale said persistence to a second or further generation in hatchery-origin fish could be a combination of domestication and epigenetic effects, and domestication effects could be longer lived than epigenetic effects. Gale said it would be interesting to see the evolutionary difference in epigenetic effects between different groups of fishes, such as sharks, which are commonly used for biomedical research. Gavery said invertebrates, for example, have much less methylation than teleosts. She said methylation is a tool and different organisms adopt it for different purposes in different evolutionary lines. Kahler added that some species use acetylation and other molecules instead of methylation as tools for epigenetic change.

Catherine Willard asked if methylation in fish species can be reversed by diet, such as high-soy diets. Gavery said in trout, high-methyl diets have been shown to help reverse methylation. She said humans, in contrast to fish, reset methylation regularly although certain regions do not change (imprinted genes are probably more sensitive to transgenerational signals) and diet does appear to affect methylation reversal. She said fish do not reset their methylation in the same way, so they are perhaps more susceptible to transgenerational effects. Gavery emphasized that epigenetic research in fish, especially non-model species, is a really new field and while so much is still unknown, researchers need to be careful when extrapolating results for species in different evolutionary lines.

Hatchery Committees representatives present thanked Gavery for her presentation.

B. USFWS Bull Trout Consultation Update (Matt Cooper)

Matt Cooper said Karl Halupka (U.S. Fish and Wildlife Service [USFWS]) sent him an update on USFWS consultations, which he summarized as follows:

- Halupka said he is still revising the draft Biological Opinion (BiOp) for the batch of Wenatchee subbasin programs and expects it will be finalized in mid-June 2017.
- Halupka has no other progress to report on consultations in the upper Columbia River.

C. NMFS Consultation Update (Brett Farman)

Brett Farman said Emi Kondo (NMFS) has been working on consultation for the unlisted programs in the upper Columbia River. He said the proposed actions will likely be finished in June and any questions regarding that consultation should be directed to Kondo.

Farman said Charlene Hurst is working on the Methow steelhead consultation and coordinating with various people on data requests. He said there is a consultation update meeting schedule for June 1, 2017, and if any additional parties would like to attend, please alert Hurst. He said the Twisp steelhead discussion should be finalized soon, which will also inform this consultation.

D. Wells Hatchery Power/Water Outage (Mike Tonseth/Tom Kahler)

Mike Tonseth said Wells Fish Hatchery experienced a power and water outage on May 2, 2017. He said the power disruption shut down the main well field for the hatchery and even though staff turned on the pumps to the main raceways, there were issues getting enough water to the main incubation building, perhaps due to an airlock that occurred when the well field back up was restarted, preventing the well water from reaching the incubation area.

Tonseth said approximately 20,000-25,000 steelhead fry (of unknown origin) were lost, and a few hundred Chinook fry, but he does not expect this to impact the overall production obligation. Greg Mackey clarified that the fry were sucked into pipe headers and then came out of headers into other tanks (e.g., the sturgeon tank) where hatchery staff attempted to retrieve them but were not entirely successful.

Mackey said the source of the outage was a blown fuse in the dam after power was reestablished after a planned shutdown. The blown fuse knocked out the three-phase power (which the hatchery pumps run on), so dam operators, electricians, and hatchery staff worked to turn on the backup generators, then switch to surface water. Mackey said the surface water was shut off quickly after it was turned on because the water had become stagnant and foul while in the pipe. Mackey said it is not clear whether the well water was prevented from reaching the incubation area by an airlock or not, but there are multiple high points in the pipes of this system where Douglas PUD will be placing air-relief valves. He said this facility will be used for sturgeon, trout, and other species in the future, rather than steelhead or Chinook.

Kirk Truscott asked if the backup plan of switching to surface water worked. Tonseth said it did work; however, the water was determined not to be suitable for fish, so staff switched back to groundwater. Truscott asked which stocks were affected by the fish loss and said the Okanogan program is relatively limited on natural-origin fish. Mackey said he does not think that natural-origin fish were part of the loss, because they would have been in trays instead of start tanks. Tonseth said most of the fish loss was from start tanks and one tray was lost. Kahler said the earliest spawned fish (Wells stock) were more likely killed than other stocks. Tonseth summarized that the fish loss will likely not be detrimental to production obligations; however, it is a fish kill and Douglas PUD has implemented facility improvements to address this.

E. Wells West-ladder Trapping Contingencies (Greg Mackey)

Greg Mackey said the West-ladder Trap at Wells Dam traps fish, which are then transported through an underground pipe to a new adult holding pond. He said Douglas PUD has found that the extension from the old pipe to the new pipe is not designed in a satisfactory way and is being updated. He said a lot of water flows through this 30-inch diameter pipe and there is no dewatering screen before the water enters the pond. He said decreasing the water flow in the pipe could result in fish being trapped and using the desired amount of flow results in too much water in the pond. He said Douglas PUD is working with fabricators to increase the pipe diameter (from 18" to 30" for almost the enire length) and install a dewatering screen. Currently, WDFW is trapping spring Chinook salmon manually at the West-ladder and trapping as usual at the East-ladder. Manual trapping at the West-ladder includes catching fish with a net in a method approved by the Wells HCP Coordinating Committee in 2016. Tom Kahler said so far 12 spring Chinook salmon have passed Wells Dam and the run is later than usual this year. Mackey said that when the West ladder is trapping, the West-ladder is blocked by grating, so fish continue left into a Denil fishway, then into a holding box. He said the operator can use a diverter to pass fish to the holding pond or through the system. He said the improvements to the pipe should be complete very soon.

F. Review Hatchery M&E Plan Objectives (All)

Tracy Hillman said the Hatchery Committees are beginning to review the objectives in the Hatchery M&E Plan[1] in order to update the Plan. He suggested the review of objectives start with Table 1, which includes program objectives, indicators, and goals for conservation hatchery programs including productivity and monitoring indicators.

Hillman said the first objective is to "determine if the program has increased the number of naturally spawning adults" and its indicators are abundance of natural spawners and adult productivity (i.e. natural return rates [NRRs]. There were no issues raised with this objective or its indicators.

Hillman said the second objective is to "determine if the proportion of hatchery fish affects freshwater productivity" and its indicators are residuals vs. proportion of hatchery-origin spawners (pHOS) and juveniles per redd vs. pHOS. Greg Mackey said there are two issues with this objective. He said getting a good estimate of freshwater production is hard, especially in the Methow basin. He said there are also limiting life stages or factors that could influence hatchery operation, which is not considered in this objective and is not captured by using rotary screw smolt traps. He said, for example, if there was no limiting factor in freshwater, programs could confidently boost the hatchery production of smolts. Alternatively, he said if habitat was a limiting factor in freshwater, programs would not want to boost production of smolts because that would result in no increase or possibly decreased natural origin production—the habitat would have to be fixed first. Hillman said for Chiwawa spring Chinook salmon, freshwater production can be estimated. He said there are estimates of total number of migrants, summer parr, and smolts produced within the Chiwawa River basin. No density dependence has been observed with total migrants; however, there is evidence of strong density dependence in parr and smolt production. Comparing the residuals from the stock-recruitment relationships with pHOS indicated no relationship, suggesting that the proportion of hatchery orirgin spawners has not negatively affected productivity of Chiwawa spring Chinook salmon. He said the Nason Creek program could be analyzed in the same way, because total migrants and smolt production within Nason Creek is known. Hillman asked if this objective should be reevaluated, considering the Methow basin data are questionable. Mackey said the key step is to develop a better estimate of freshwater productivity and while the methodology for doing this is being improved in the Methow basin, this objective is okay as it is written. He cautioned that precise estimates do not equate to accurate estimates (using an example where increasing the number of sites reduced confidence intervals, but caused the true number not to be captured within the confidence interval) and emphasized that the methodology for estimating freshwater productivity

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[1] Hillman, T., T. Kahler, G. Mackey, J. Murauskas, A. Murdoch, K. Murdoch, T. Pearsons, and M. Tonseth, 2013. Monitoring and Evaluation Plan for PUD Hatchery Programs: 2013 Update. Report to the HCP and PRCC Hatchery Committees, Wenatchee, Washington.

can be improved. No changes were requested to this objective because improvements to methodologies are underway.

Hillman said the third objective is to “determine if run timing and distribution meets objectives” and has the indicators of migration timing, spawn timing, and redd distribution. Hillman said in general wild and hatchery fish should have the same migration timing, spawn timing, and redd distribution; however, there are exceptions, e.g., Wenatchee summer Chinook salmon, which the Committees indicated should be segregated. Hillman said the exceptions are outlined in the Appendix to the Plan. Todd Pearsons suggested adding a footnote to this objective and citing the appropriate appendix to review for deviations from the indicator targets. Bill Gale asked how migration timing is quantified. Hillman said it depends on the stock, but usually includes counts at mainstem dams and other locations (such as Bonneville Dam, Priest Rapids Dam, Rock Island Dam, Dryden Dam, Tumwater Dam, and wiers, or for Methow and Okanogan programs, Wells Dam). Tom Kahler said the metric for comparing migration timing is mean Julian date. Hillman said wild and hatchery stocks are compared using cumulative frequency plots and differences in 10%, 50%, 90%, and mean timing.

Regarding all objectives, Pearsons asked if there is a time at which sufficient data could be collected that the committees could say an objective is addressed, and although data could continue to be collected, a difference in result would not be expected (unless the program is changed). In such a case, pehaps the variable no longer merits annual assessment. He suggested considering variables where there is a high degree of correlation year to year, such as spawning distribution. Mackey said he thinks it would not be removed from the list of objectives, but monitoring frequency could be changed. Gale said most of the monitoring pieces are used to make management decisions for hatchery programs anyway, so he does not see how frequency would be changed. Pearsons said some of the variables like spawn timing or spawn distribution answer multiple objectives anyway and emphasized that the M&E Plan is supposed to assess the performance of the hatchery and its effect on natural populations.

Pearsons said the target for spawn timing is “no difference;” however, there should be a difference in spawn timing depending on elevation. He said if hatchery fish are spawning lower in a river, they may spawn later than upper river fish. Kirk Truscott said this indicator could be assessed for fish in the same location at the same time. Gale said the differences in distribution may be subtle enough to not appear in this analysis, because the surveys are weekly. Mike Tonseth said steelhead have protracted spawn timing, which appears to be more related to temperature gradients than elevation. Hillman said his opinion is that differences in spawn timing should focus on biological significance rather than statistical significance. He said he will also add a footnote to this objective for spawn timing.

Hillman said the fourth objective addresses genetic diversity and population structure and suggested the Hatchery Committees review McLain Johnson's genetic monitoring update at the June 21, 2017, Hatchery Committees meeting before discussing this objective. Members present agreed.

Hillman said the fifth objective is to "determine if hatchery survival meets expectations," and its indicators include hatchery return rates (HRRs) being greater than NRRs and greater than goals set for each program. Hillman said the updated appendix includes HRR targets and he will make sure the Plan is consistent with the appendix. No other issues were raised with this objective.

Hillman said the sixth objective is to "determine if stray rates of hatchery fish are acceptable," and its indicators include out-of-basin and in-basin stray rates. Gale suggested editing this to say, "recipient stray rates," and Hillman made that change. Hillman pointed out that the table does not include brood year stray rates. He said this discussion can continue at the June 21, 2017, Hatchery Committees meeting. The seventh and eighth objectives can also be discussed at that time.

G. Methow Steelhead Gene Flow Plan (Greg Mackey)

Greg Mackey shared a spreadsheet titled "Methow Steelhead Gene Flow Analysis," which Sarah Montgomery distributed to the Hatchery Committees on May 16, 2017 (Attachment C). Mackey said Michael Humling (USFWS) and Charlene Hurst also contributed todevelopment of the gene flow management sliding scale.Hurst said she will use whichever plan the Hatchery Committees agree to while writing the Methow steelhead BiOp. Hurst said this plan includes achieving a pHOS of 0.3 for most run sizes. Mackey said that the original plan was to adapt the spring chinook Methow sliding scale to steelhead, but found that this approach did not work very well because of the compressed zone between low run size (300) and recovery target (1,000). He said instead of a sliding scale, this plan is a two-part scale. The plan operates by achieving 500 total spawners at all time at runs below 300 wild fish, regardless of pHOS. Once wild fish number 300 or more, the plan targets pHOS of 0.30. Mackey said he estimates based on the assumption of program performance that a proportion of natural-origin broodstock (pNOB) of 0.9 and a proportionate natural influence (PNI) of 0.75 could be reached.

Keely Murdoch said she is uncomfortable with this gene flow plan. She said in 2013, the Hatchery Committees came to an agreement about pHOS, PNI, and gene flow for the purposes of permitting, which Craig Busack described in a document. (Note: Busack distributed the document, Methow Basin Management Frameworks for Spring Chinook and Steelhead, via email to Hatchery Committees representatives on June 10, 2013, and Montgomery sent it again to the Hatchery Committees distribution list on May 17, 2017, following the meeting). Murdoch said the 0.3 pHOS in the current gene flow plan proposal stems from the Hatchery Scientific Review Group (HSRG) guidelines, which are recommendations, not laws. Hurst said NMFS intends to permit the most scientifically defensible gene flow plan possible, and the one presented today is a proposal for discussion. Hillman asked Murdoch to describe Busack's 2013 gene flow document. Murdoch said the document included a phased approach to reaching a pHOS of 0.5 over the entire basin from October 2013 to October 2020 (phase 1), and to a maximum pHOS of 0.25 in spawning habitat upstream of hatcheries and unrestricted pHOS below hatcheries from October 2020 to October 2023 (phase 2). She said the document also includes a maximum for total steelhead releases, specific information for the Twisp River, and a phased approach to reaching different levels of pHOS in different areas. Hurst asked how that plan would be implemented, because there is no weir in the upper Methow basin. Murdoch guessed that it would be implemented through fisheries and specific release locations for fish with upper basin releases limited. Mike Tonseth recalled that there was uncertainty at the time as to how effective the hatchery can be in attracting hatchery adults back to the facilities. He said there are limited data available now to inform this, and it is still in development. Bill Gale said the other intent of the 2013 plan was to provide a transition period from the old production scheme and levels to the newer production scheme with lower levels, and it would allow for more liberal allowances for pHOS knowing that programs are working through a shift.

Kirk Truscott said the HSRG included qualifications with their pHOS recommendations as well. He said the pHOS level, according to the HSRG, should be based on listing status and populations with low abundance may not be applicable. Mackey said in the Methow, the recommendation at the time was to have a 100,000-steelhead release program. He said Douglas PUD thought at the time that they could achieve a pHOS of 0.25 with some assumptions about adult fish removal at hatchery outfalls. Mackey said the level of scrutiny of the programs has increased and there is the real possibility of a lawsuit concerning the consultation; therefore, Douglas PUD wants to make sure their steelhead program is designed in the most scientifically sound way. He said looking to the future, Douglas PUD is responsible for 8,000 no net impact fish and the 140,000 inundation fish (with 40,000 fish in the Twisp River) that are currently released in the basin, and the steelhead program is further complicated because Winthrop NFH is the driver for the conservation program. Mackey said he did not include the safety-net program in this spreadsheet, but it would need to be included if that program stays in the basin. Mackey emphasized that this spreadsheet is just a first look at the basic shape of the curve for pHOS, pNOB, and PNI and how individual programs contribute to the numbers in this spreadsheet is still to be determined.

Hillman asked Hurst how NMFS would approach an initial pHOS target of 0.5. Hurst said NMFS currently prefers a pHOS target of 0.3, but she understands that it takes time to reach 0.3. Humling said another consideration is that it would take about 85% to 90% removal rates to get to a pHOS of 0.3, which would mean that a PNI of 0.67 would be reached at approximately the same time as a pHOS of 0.3, if not earlier. Tonseth said a phased approach similar to the 2013 approach could be considered. He said since recalculation, steelhead releases in the Methow basin have been capped at

350,000 fish and upper basin releases according to the 2013 approach would be capped at 250,000 fish. He said he likes the idea of a floating pHOS in the lower basin and more stringent pHOS in the upper basin. He said adult removal can also be increased in multiple ways and adult management activities are also being evaluated. Tonseth said capping releases in the upper basin and moving in the direction of trying to reach a pHOS of 0.3 would be a good direction for steelhead in the basin. Hurst agreed that a phased approach might be appropriate to allow for program goals to be realized, but of course it depends on what the phases are and when they start. Hurst asked how many fish the Winthrop program was releasing at the time Busack wrote the 2013 document. Murdoch said Busack's framework document addresses that; it says the Winthrop NFH program will grow during the permit period from 100,000 fish to as high as 200,000 fish as feasible and consistent with a pNOB of 0.5. Gale explained that Winthrop NFH shifted to a 2-year rearing cycle and an increased program and reduced the spring Chinook salmon production on station to save space. He said the Winthrop program maximizes pNOB within the production range of 100,000 to 200,000 fish. Tonseth advocated for combining the 2013 phased approach with the current proposal. Gale said PNI and PNI goals should be calculated using a multi-population model. Murdoch agreed. Hurst said the bulk of the analyses will be completed with the 3- or 4-population model, but the Twisp program will inform these analyses so they are not finished yet.

Mackey said Douglas PUD wishes to release only the fish required to achieve desired purposes in the Methow basin and that might involve changing the proportions of fish in different programs. Tonseth said the ideal program would be appropriately sized so that fewer fish need to be removed as adults. Truscott said the size of the conservation program would ideally maximize recovery efforts, which could be different from the required mitigation level. Hillman summarized that there is more work to be done on the Methow steelhead gene flow plan and the Joint Fishery Parties are also meeting to discuss this. Hurst emphasized that the final gene flow plan should be communicated to her by the end of June so she can write the BiOp.

Truscott asked why the proposed gene flow plan includes meeting a pHOS of 0.3 at 500 fish instead of 750 fish. Mackey said the goal of the plan is to reach 0.3 at the lowest run size possible once 500 total spawners are achieved (and 500 is used because it is a standard, widely-used minimum population size for conservation purposes).

Hurst asked if the future of Twisp broodstock has been decided yet. Gale said 2017 broodstock collection was decided, but parties are still discussing 2018 and future years. Gale said he approves of mixing the smolt age of releases in the conservation program and releasing S2s in the Twisp and S1s in other areas (which would only work if the Twisp and Winthrop programs are composited). He said these elements would maximize diversity of brood years returning and increase the number of age classes and family sizes on spawning grounds. Tonseth said he also advocates using a mainstem collection approach and using the Twisp weir as a back-up collection location. Mackey summarized that the future of the Twisp program will be decided soon and that the gene flow model can be finished by the end of June.

III.Chelan PUD

A. Coho Salmon Recalculation (Catherine Willard/Keely Murdoch)

Catherine Willard said there are two earlier Statements of Agreement (SOAs) relevant to discussions on coho salmon recalculation: the June 20, 2007, Rocky Reach and Rock Island SOA that states the first 10-year check-in on Chelan PUD's coho salmon obligation will occur in 2017, and the August 29, 2007, Rocky Reach and Rock Island SOA that states Chelan PUD enters into agreement with YN to fund 10 years of their coho salmon program in order to meet Chelan PUD's coho salmon obligation. Willard said she and Keely Murdoch have been working together on this item and will jointly discuss the presentation titled "Approach to Determine Chelan PUD Coho Hatchery Mitigation" (Attachment D), which Montgomery will send to the Hatchery Committees once Willard makes a few revisions. (Note: Montgomery distributed the revised presentation on June 9, 2017.)

Willard said Chelan PUD proposes to use the same recalculation methods for coho salmon as were used for other species during the last recalulation. Murdoch said due to variable passive integrated transponder-tag detection efficiencies at Rock Island Dam, SARs were estimated for Wenatchee subbasin program fish from release to Priest Rapids Dam instead of Rock Island Dam. Willard and Murdoch reviewed the approach for determining mitigation, including the Biological Assessment and Management Plan formula outputs for coho salmon returns and smolt-to-adult survival for both Rocky Reach and Rock Island, and the total mitigation (hatchery and natural) for release years 2018 to 2027. Willard said she and Murdoch will finalize the mitigation numbers in an SOA for the Hatchery Committees to review and approve and she anticipates the SOA will also include Chelan PUD and YN's agreement for Chelan PUD to fund YN's coho salmon program for this mitigation.

Mike Tonseth asked if there has been an attempt to align the coho salmon mitigation timeline with other plan species. Willard said that has been discussed; however, Chelan PUD and YN have a contract that ends in October 2017 and a new or extended agreement needs to be in place. Tonseth said it might be efficient to align coho salmon with other plan species, given the uncertainty with plan project releases after 2020. He said the 2021 brood year would be affected by recalculation for release in 2023. Todd Pearsons said he thinks the 2022 brood year would be affected, for release in 2024. Murdoch said YN had a shorter agreement with Douglas PUD to align coho salmon with other plan species. Tom Kahler said YN and Douglas have an agreement for the duration of the HCP, and aligned recalculation for all species, with mitigation for Methow coho natural production beginning in 2023. Willard said there are a few minor errors in the presentation, and she will distribute a revised version.

IV. HCP Administration

A. Update from the Regional Technical Team

Tracy Hillman said the Independent Scientific Advisory Board (ISAB) is working with the Upper Columbia Salmon Recovery Board (UCSRB) to review upper Columbia River spring Chinook salmon recovery analyses and strategies. He said ISAB is visiting the upper Columbia River on July 20-21, 2017, for presentations and site visits. He said ISAB has discussed their review with the UCSRB and may also request information or presentations from the Hatchery Committees.

B. Next Meetings

The next Hatchery Committees meetings are on June 21, 2017 (Grant PUD), July 19, 2017 (Grant PUD), and August 16, 2017 (Grant PUD).

V. List of Attachments

Attachment A	List of Attendees
Attachment B	Epigenetics: what is it and why is it relevant to hatchery practices?
Attachment C	Methow Steelhead Gene Flow Analysis
Attachment D	Approach to Determine Chelan PUD Coho Hatchery Mitigation

Attachment A
List of Attendees

Name	Organization
Tracy Hillman	BioAnalysts, Inc.
Sarah Montgomery	Anchor QEA, LLC
Catherine Willard*	Chelan PUD
Greg Mackey*	Douglas PUD
Tom Kahler*	Douglas PUD
Todd Pearsons‡	Grant PUD
Peter Graf‡	Grant PUD
Deanne Pavlik-Kunkel†‡	Grant PUD
Bill Gale*	U.S. Fish and Wildlife Service
Matt Cooper*	U.S. Fish and Wildlife Service
Michael Humling	U.S. Fish and Wildlife Service
Brett Farman*†	National Marine Fisheries Service
Charlene Hurst*†	National Marine Fisheries Service
Mackenzie Gavery⁰	National Marine Fisheries Service
Mike Tonseth*	Washington Department of Fish and Wildlife
Charlie Snow†	Washington Department of Fish and Wildlife
Keely Murdoch*	Yakama Nation
Kirk Truscott*	Colville Confederated Tribes
Larissa Rorhbach⁰	Anchor QEA

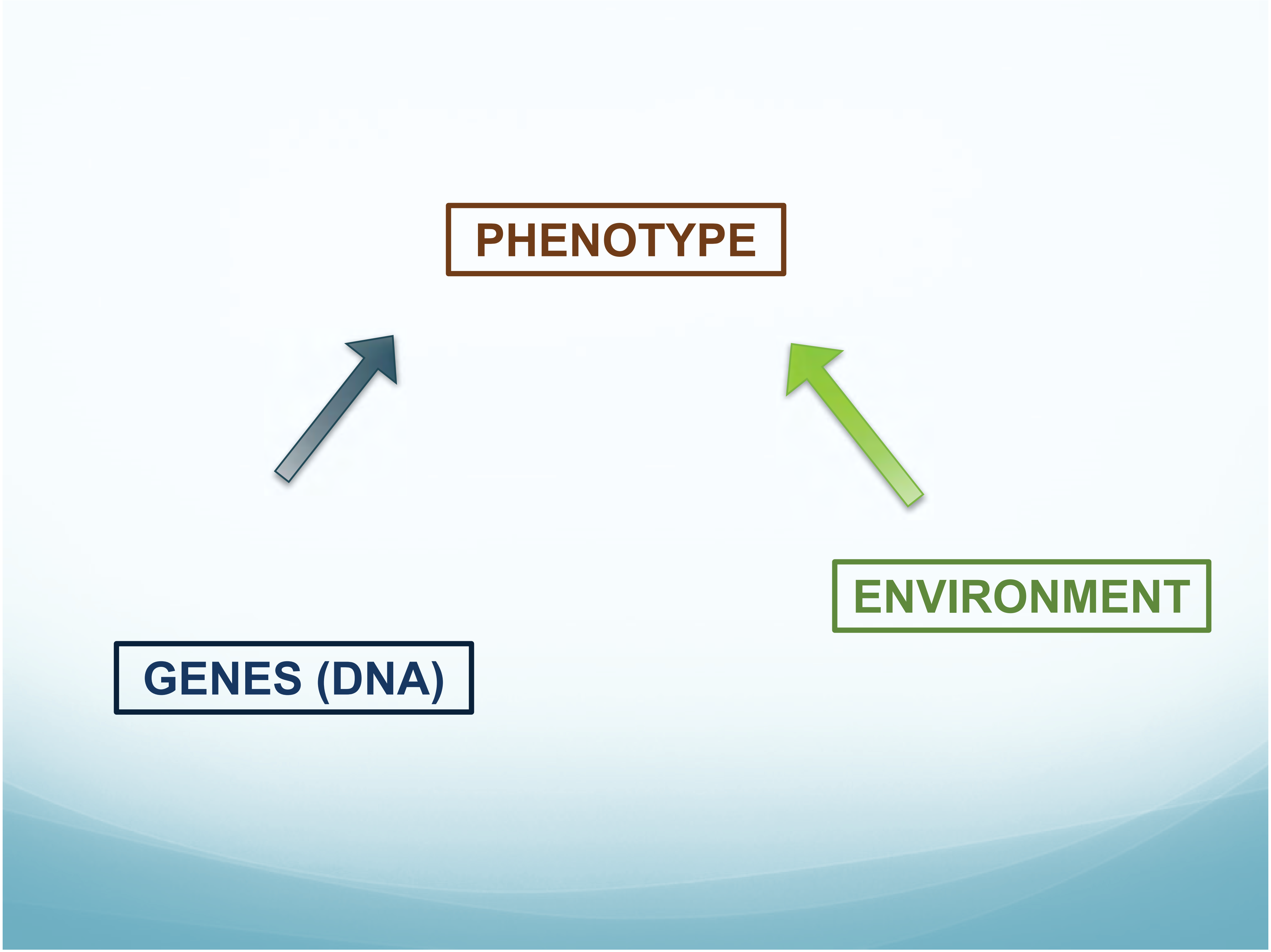
Notes:
* Denotes Hatchery Committees member or alternate
† Joined by phone
‡ Joined for the joint HCP-HC/PRCC HSC discussion
⁰ Joined for the Epigenetics Presentation (Item II-A)

Epigenetics: what is it and why is it relevant to hatchery practices?

Mackenzie Gavery[1], Krista M. Nichols[2], Giles Goetz[1], Mollie A. Middleton[1], Penny Swanson[2]

[1] University of Washington, SAFS

[2] NOAA Fisheries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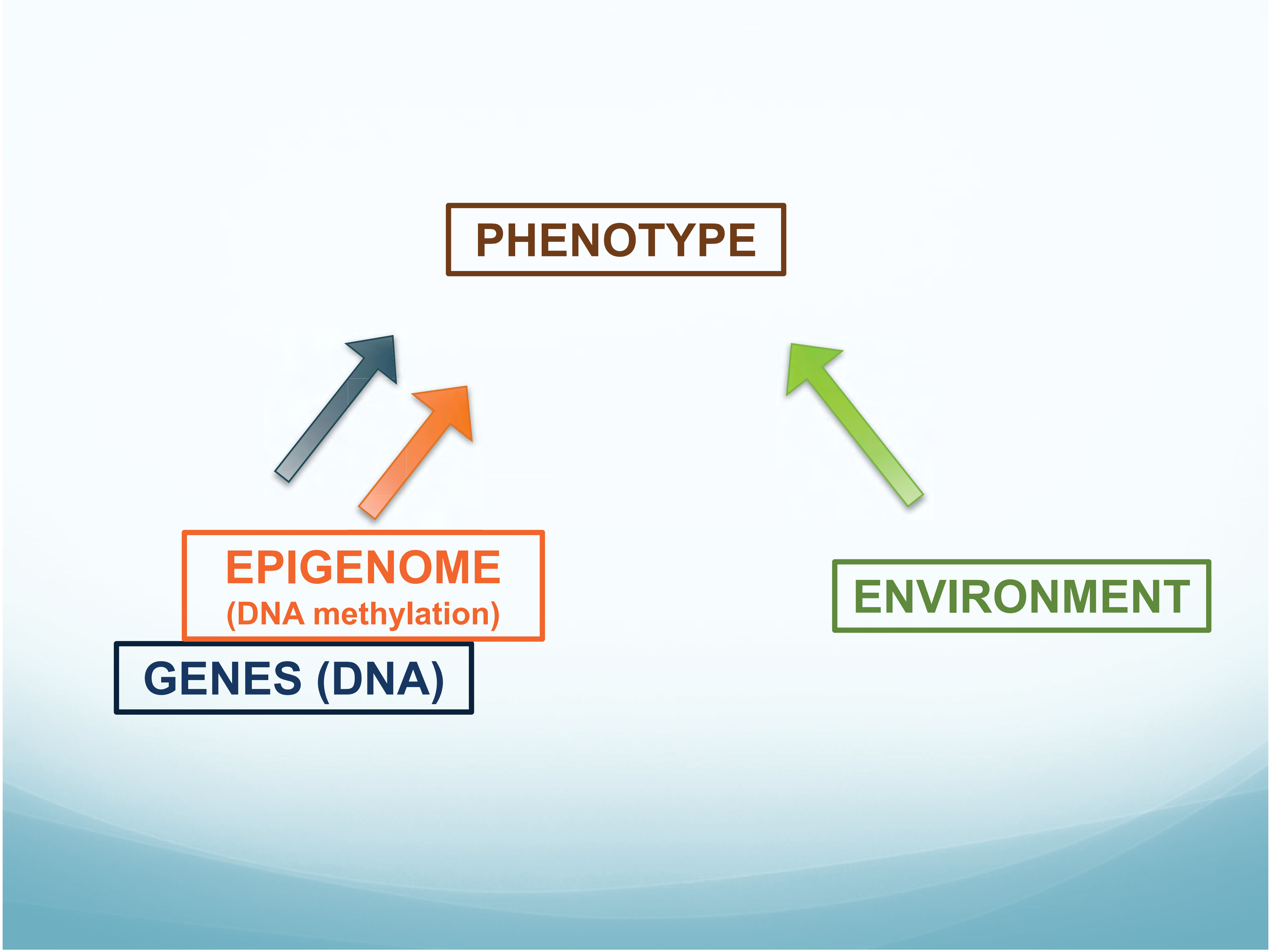
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(DNA methylation)
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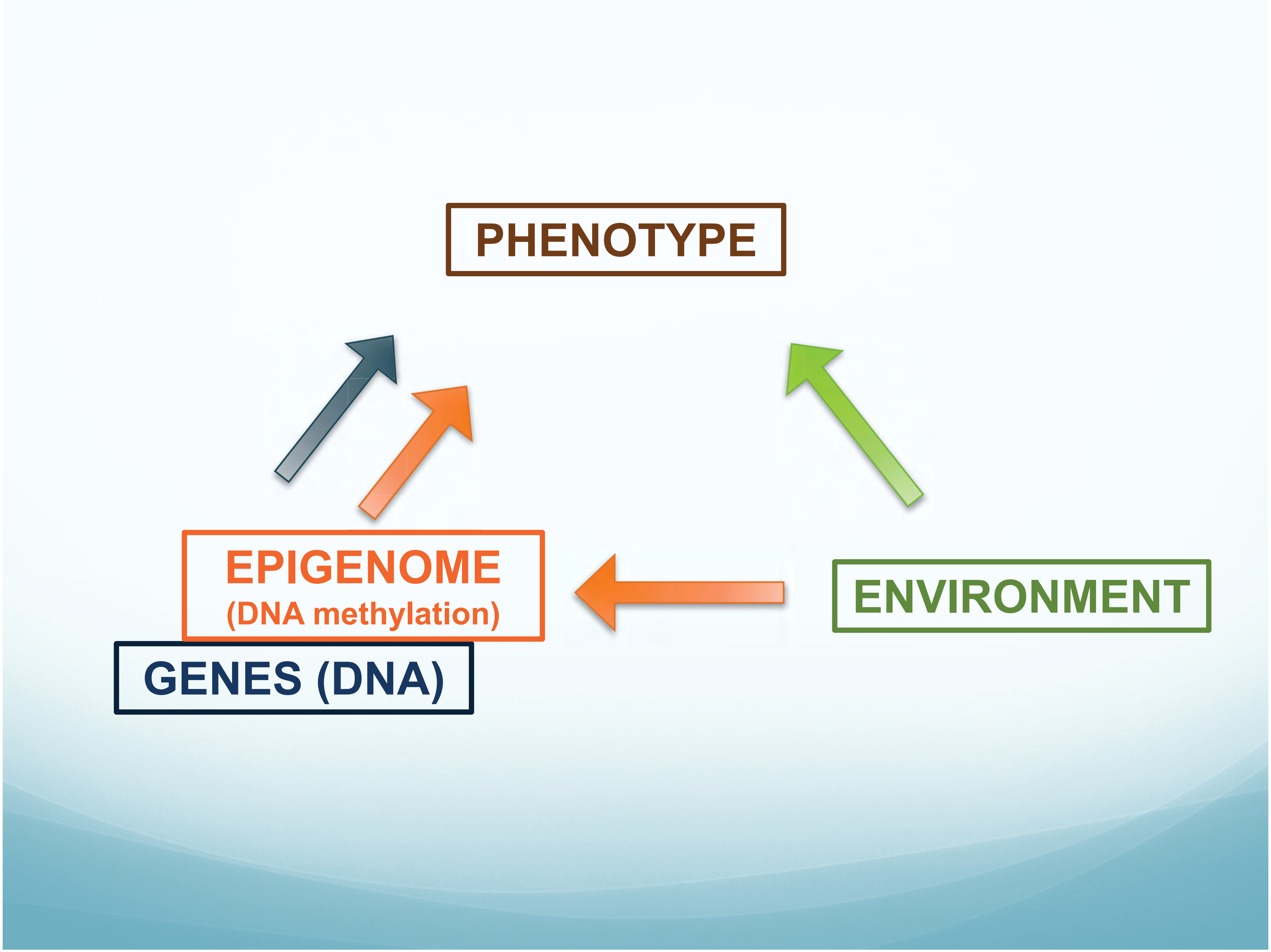
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(DNA methylation)
ENVIRONMENT
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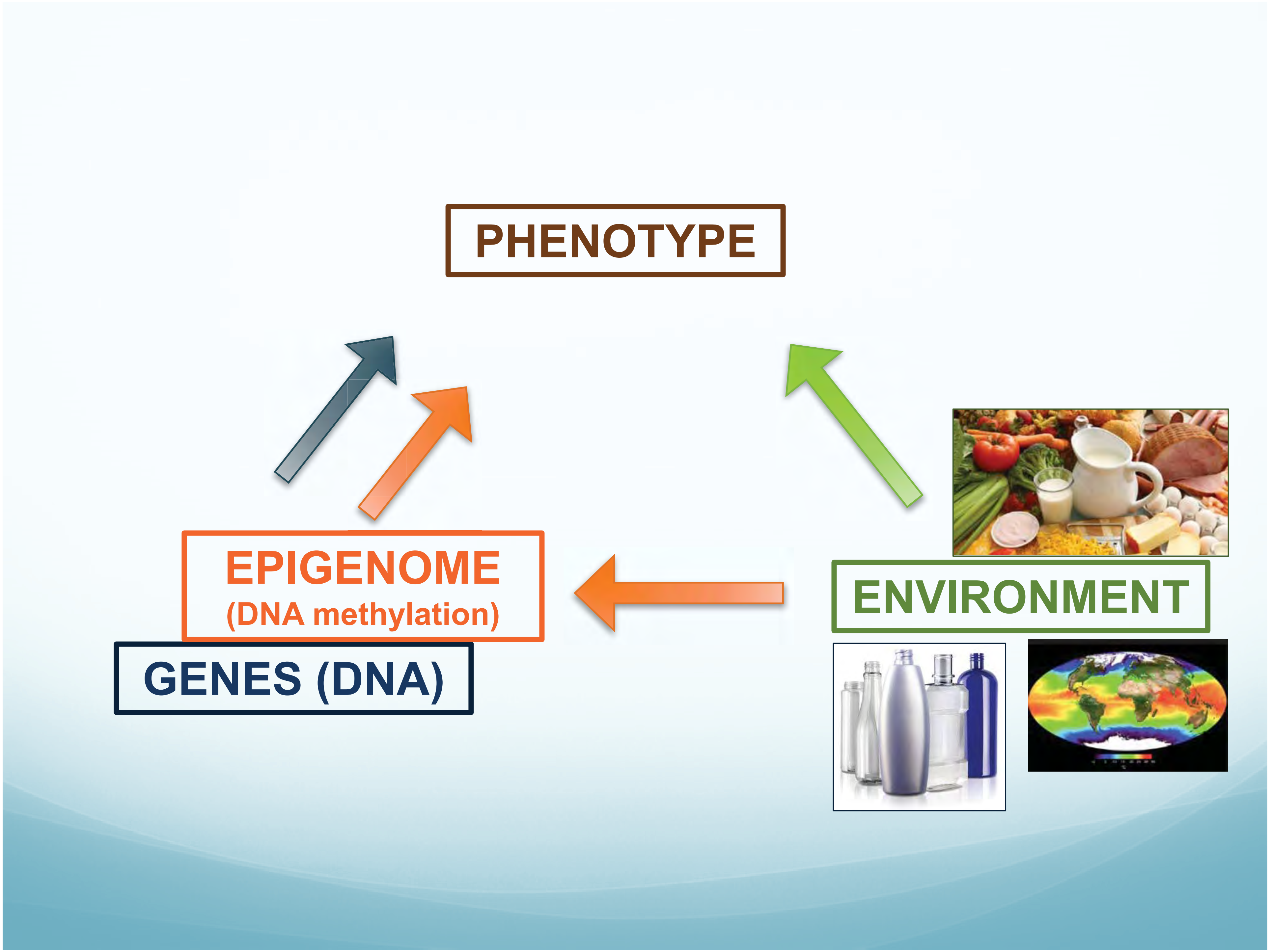
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(DNA methylation)
GENES (DNA)
ENVIRONMENT

Outline

- Epigenetics Basics
  - Definitions
  - DNA methylation
    - Functions
    - Environment
    - Epigenetic inheritance
- Why is epigenetics relevant to hatchery practices?
  - DNA methylation data from Methow River steelhead

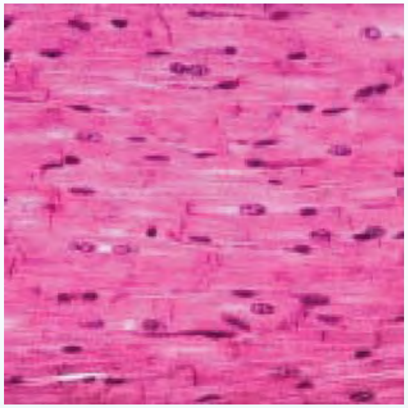
Epigenetics

- Heritable changes in trait or phenotype, caused by a mechanism other than mutation to the DNA sequence

Epigenetics

- Heritable changes in trait or phenotype, caused by a mechanism other than mutation to the DNA sequence

All of these cell types contain the same DNA.. so why do they look so different?



Epigenetics

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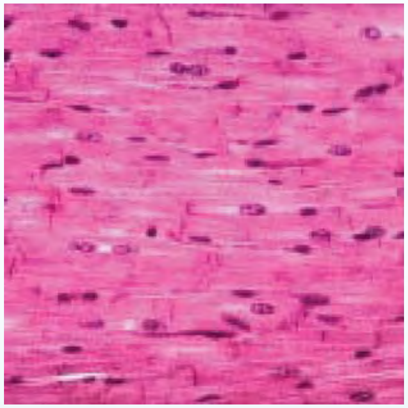
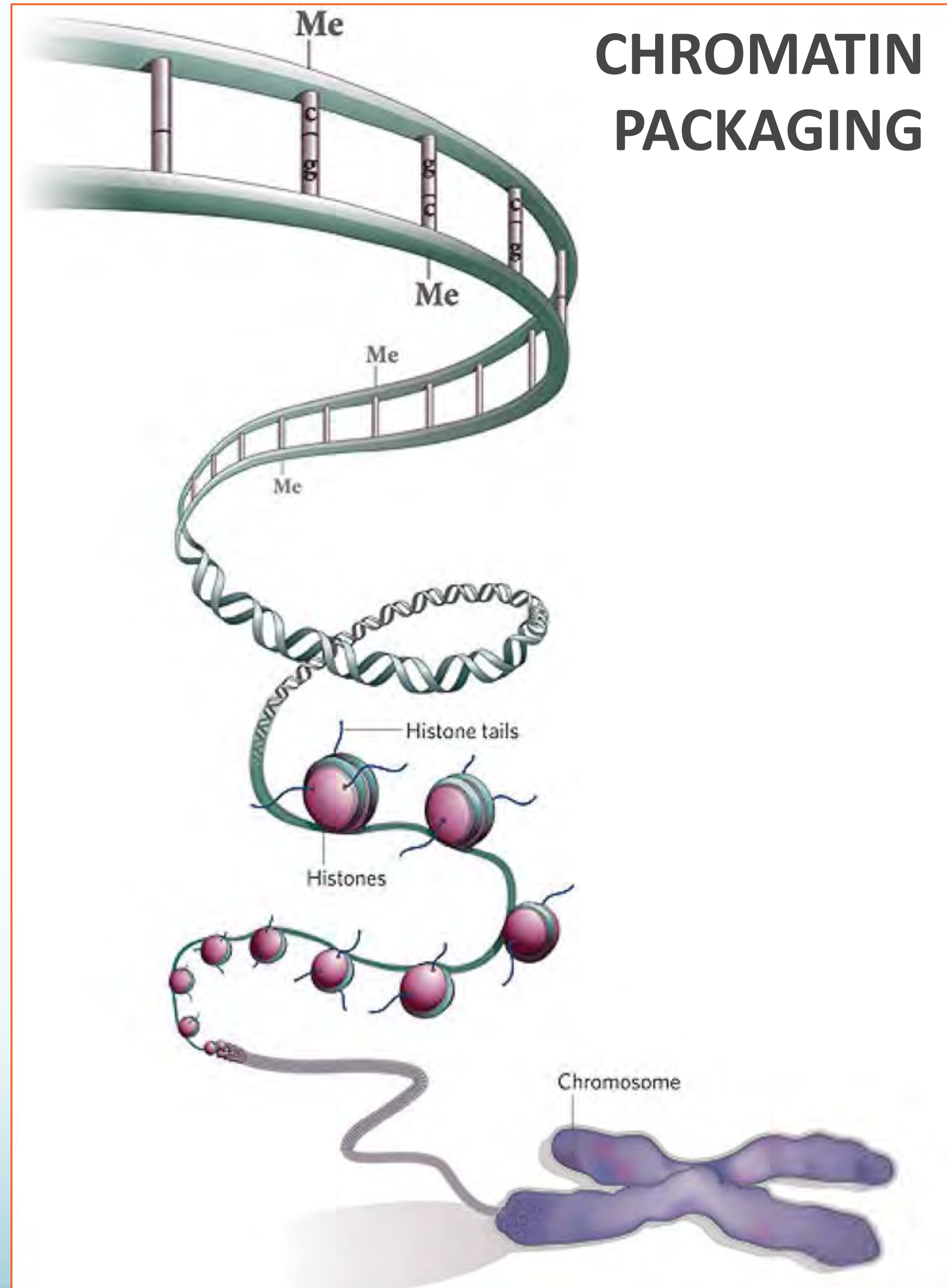


If DNA is the ‘hardware’, the epigenome is the ‘software’. It provides the instructions to regulate the genome

Epigenetic Marks

- Histone modifications
  - Acetylation
  - Methylation
- DNA methylation
- Non-coding RNAs
  - micro RNA (miRNA)

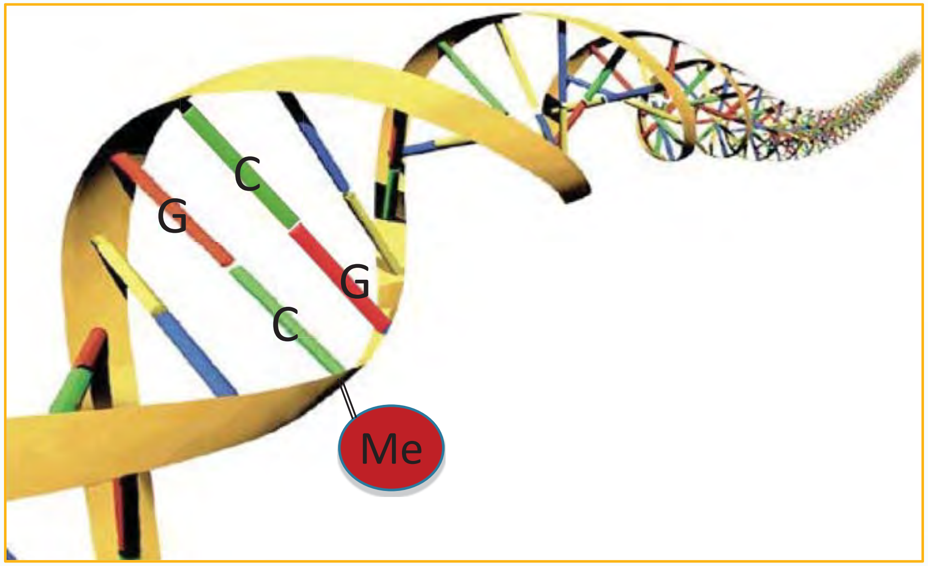


DNA Methylation

- Functions
- DNA methylation & the environment
- Epigenetic inheritance

DNA Methylation

- **Functions**
- DNA methylation & the environment
- Epigenetic inheritance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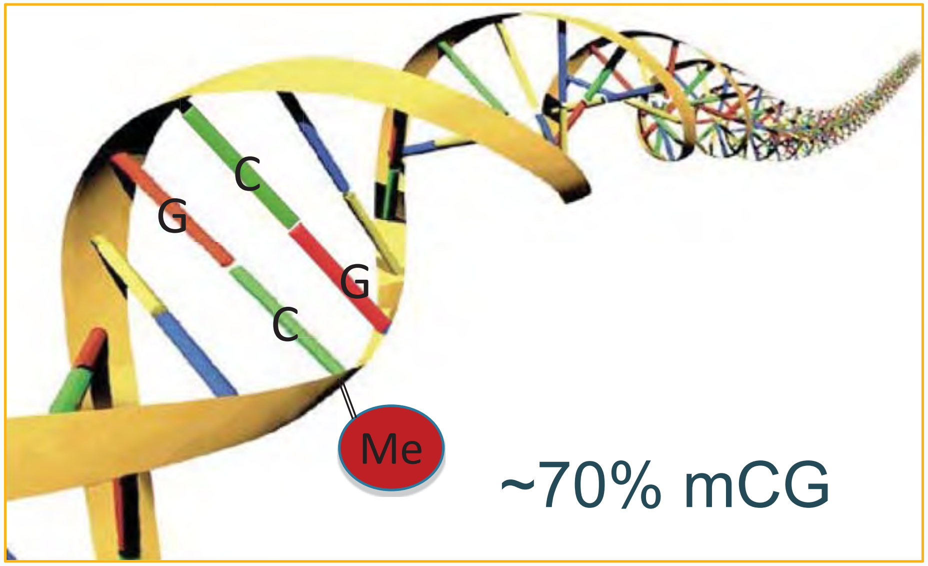
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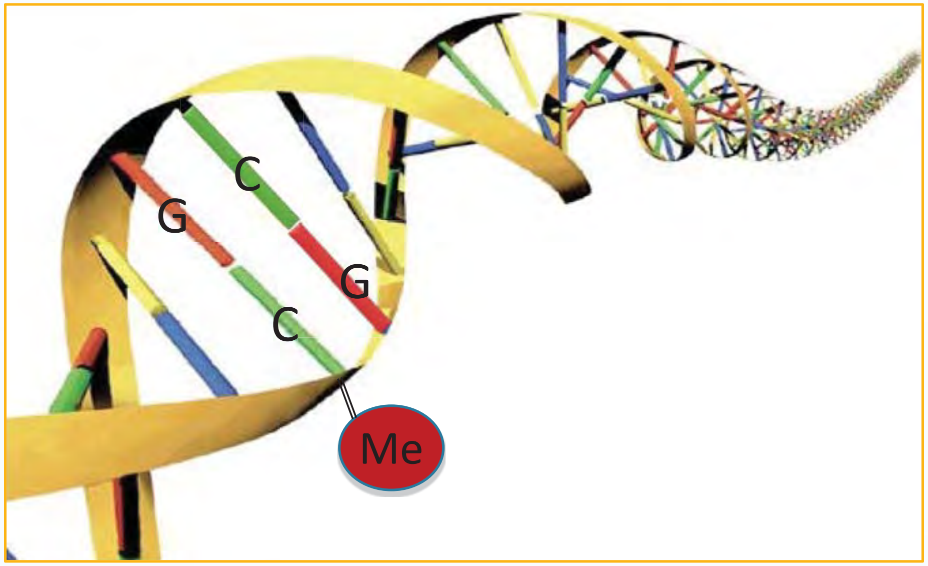
~70% mCG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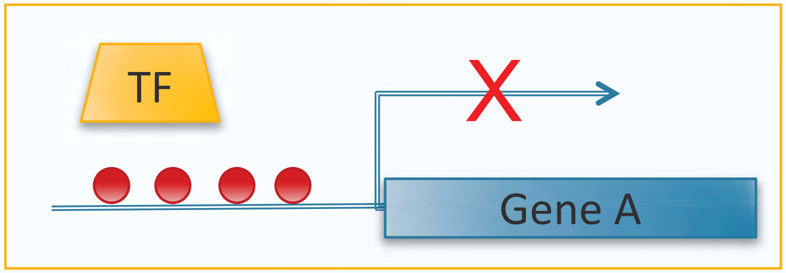
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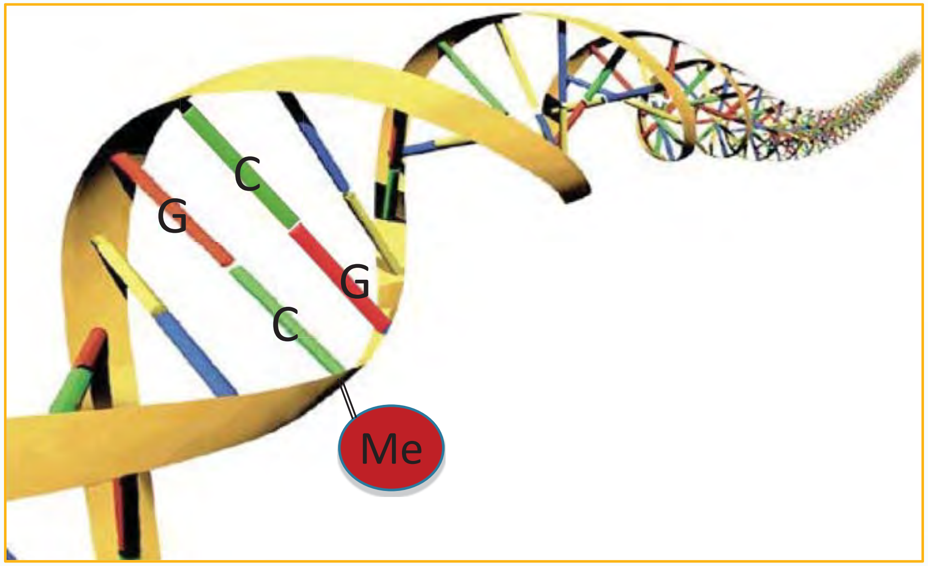
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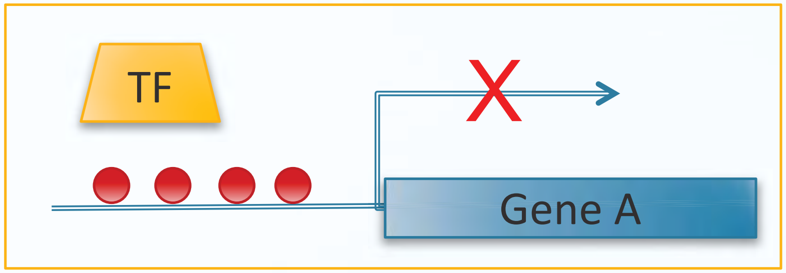
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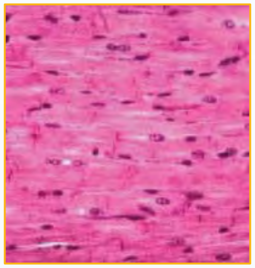

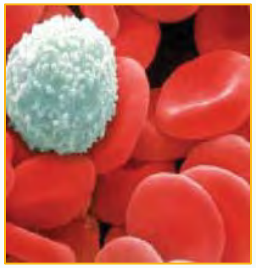

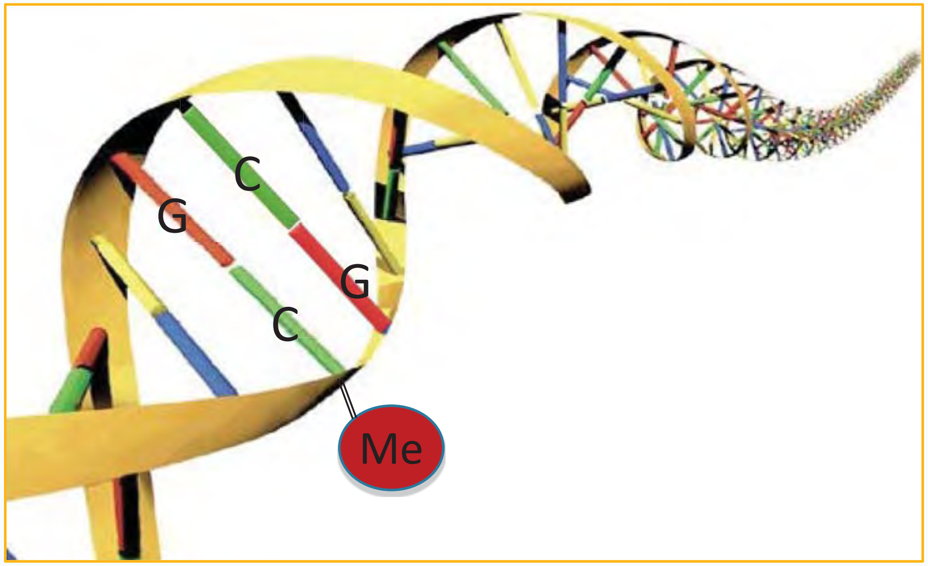
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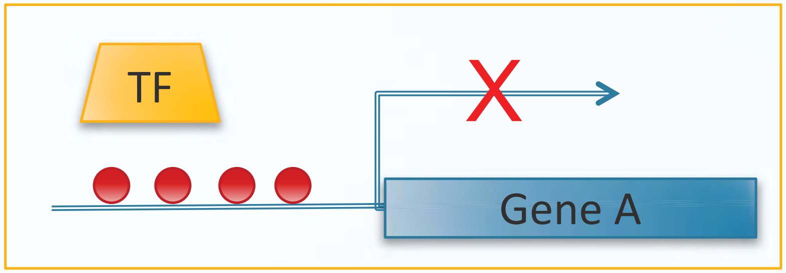
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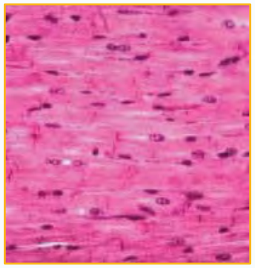

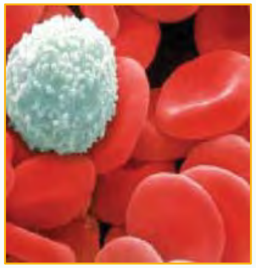


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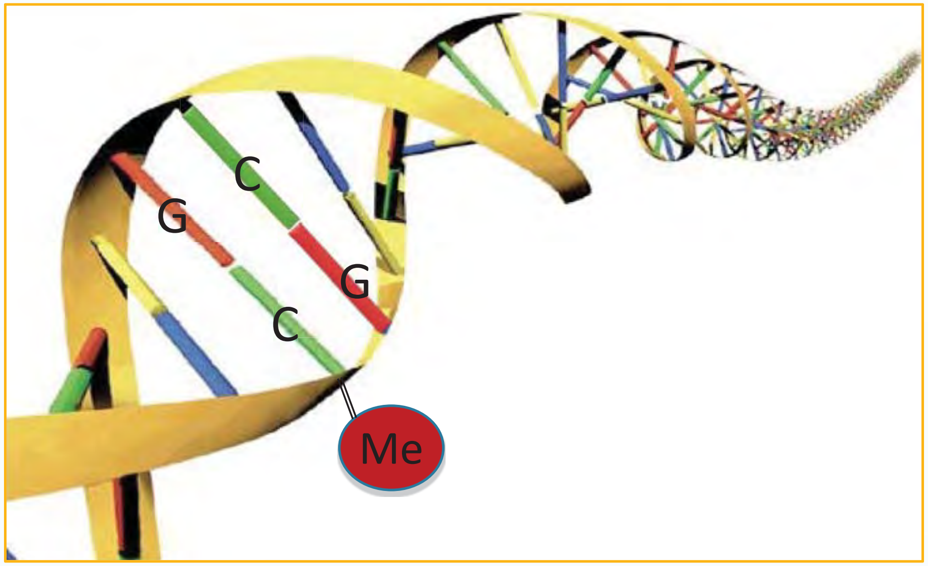
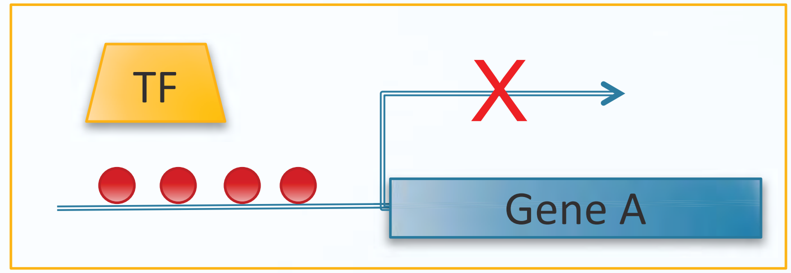
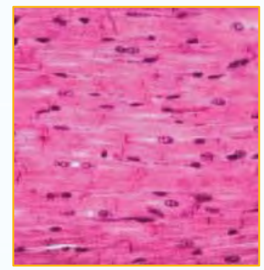
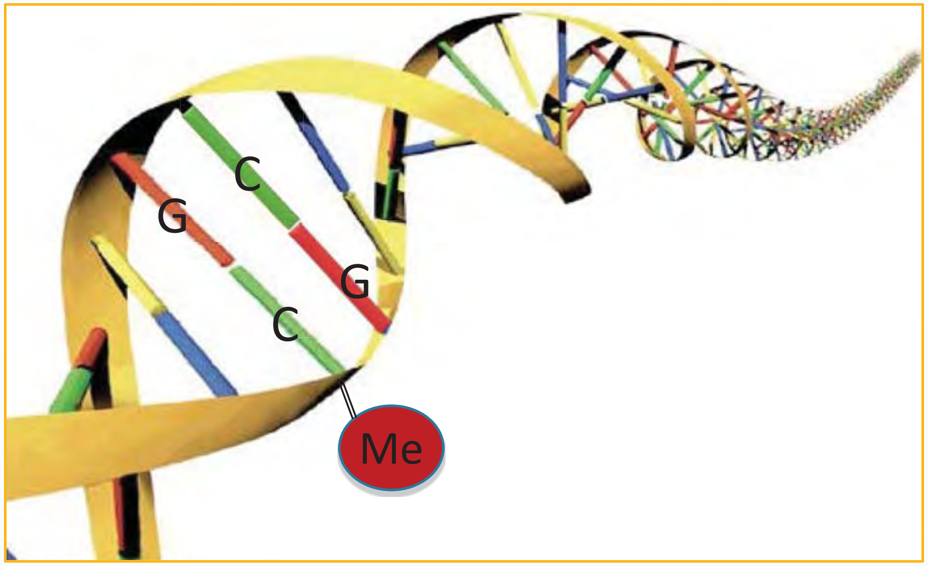
Neonate
Gestational Ages
in Days

Attachment B





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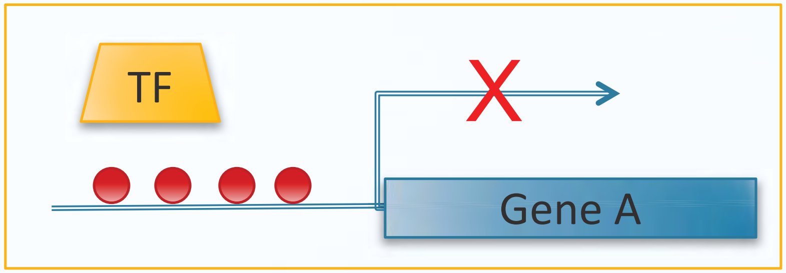
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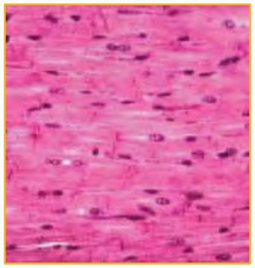

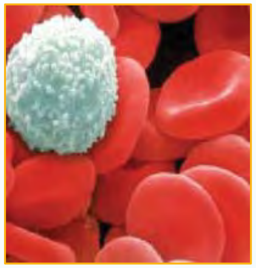


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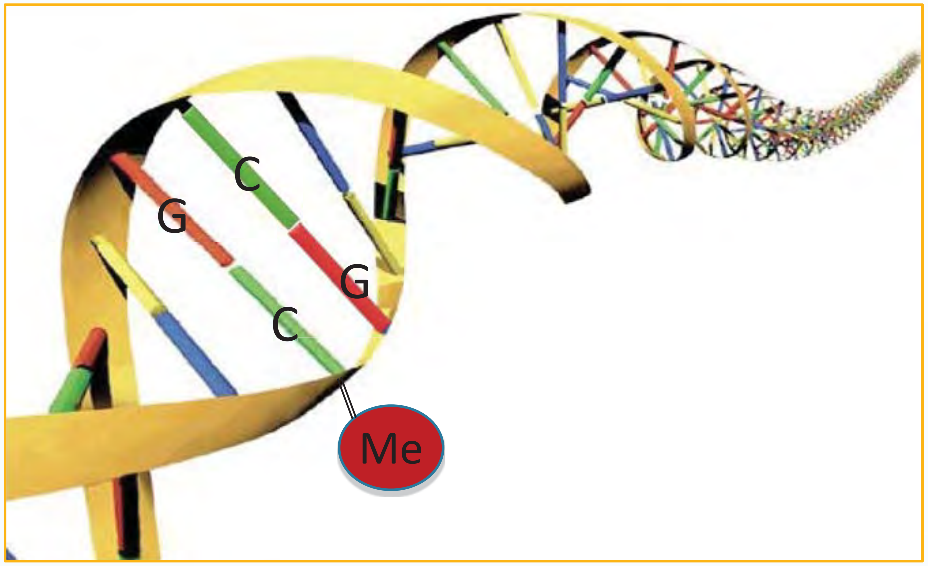
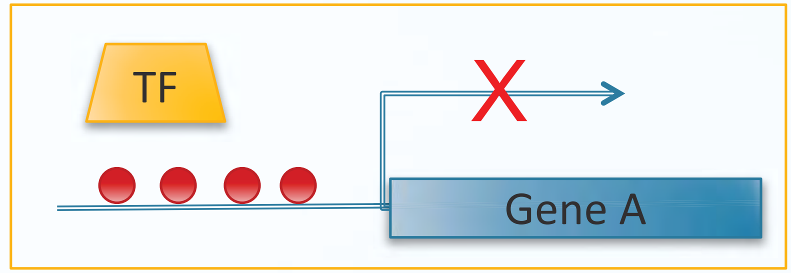
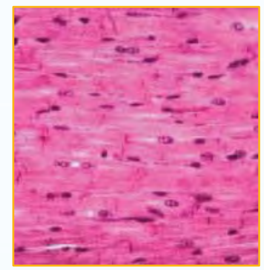
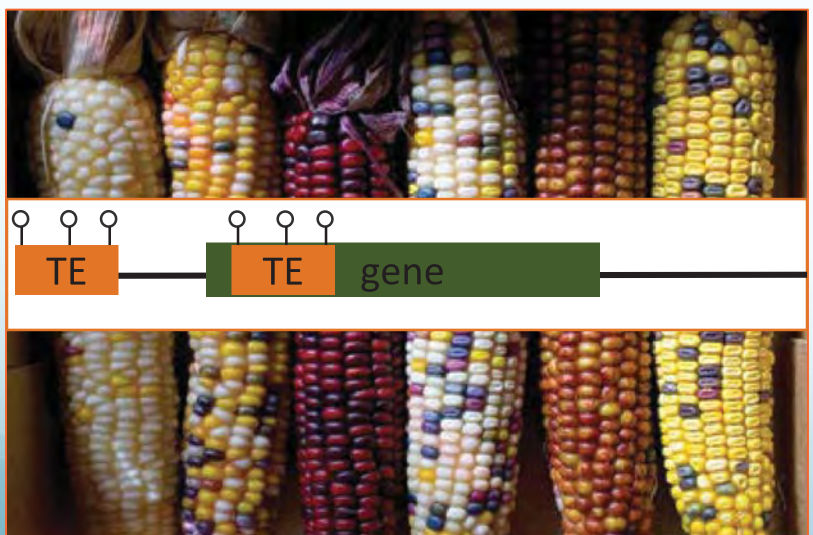






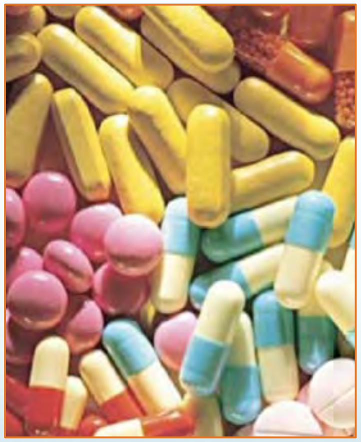


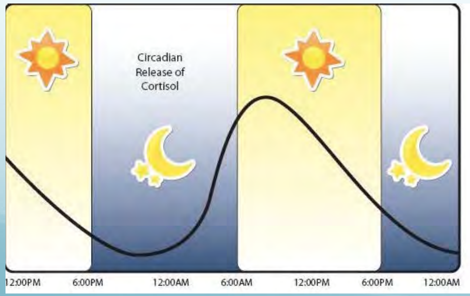
DNA Methylation

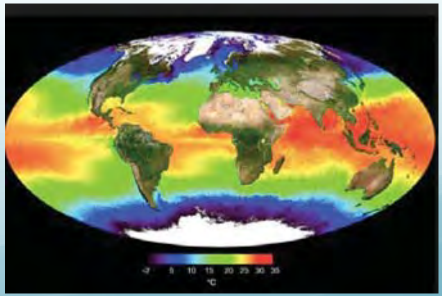
- Functions
- **DNA methylation & the environment**
- Epigenetic inheritance

DNA Methylation

- Many environmental factors have been shown to affect epigenetic marks such DNA methylation







Toxins

- Genetically identical female mice
- Different DNA methylation status of the Agouti gene
- Affected by toxins/diet

Source: Randy Jirtle

(Dolinoy et al., *PNAS*, 2007)

Temperature

- Sex determination in European sea bass is temperature dependent
- High temp early in development = more males
- Mechanism: Methylation of the aromatase gene

$$T \xrightarrow{\text{aromatase}} E2$$

(Navarro-Martin et al, *PLOS Genetics*, 2011)

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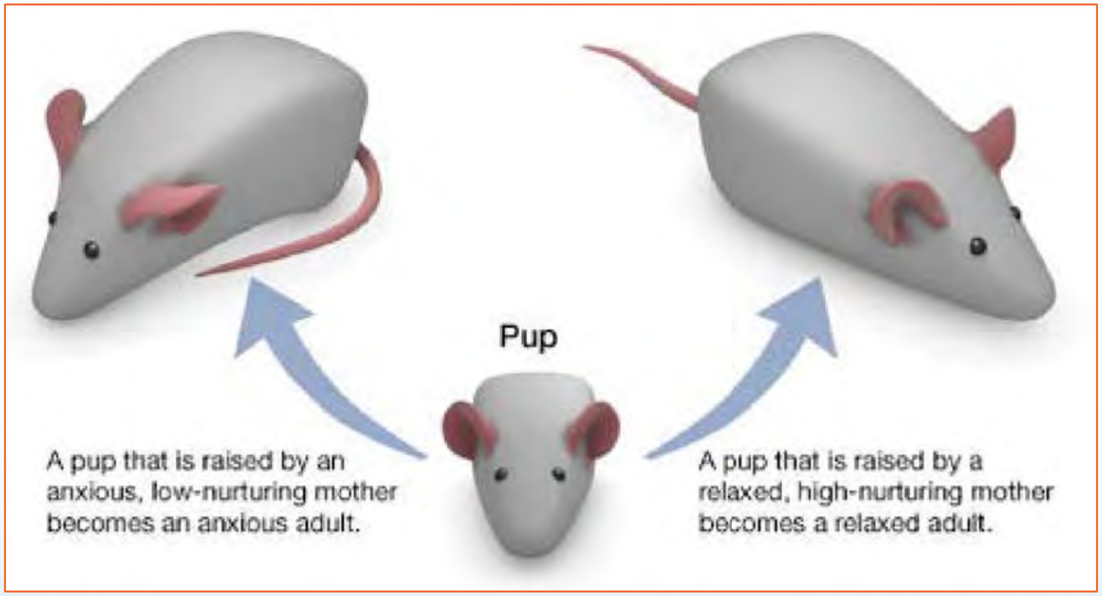
(Navarro-Martin et al, *PLOS Genetics*, 2011)

Behavior

- Licking/grooming behavior by rat mothers influences the DNA methylation status of the glucocorticoid receptor (a stress gene) in offspring



http://learn.genetics.utah.edu/content/epigenetics/rats/

(Weaver et al., *Nature Neuroscience*, 2004)

Nutrition – Dutch Hunger Winter

- Study the effects of developmental malnutrition by following women who were pregnant at this time
- Calorie restriction during early development (versus late development) had latent effects on adult health:
  - obesity
  - cardiovascular disease
  - insulin resistance
- DNA methylation differences in insulin-like growth factor gene

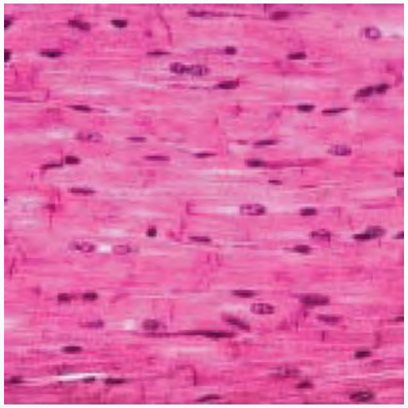
(Heijmans et al., *PNAS*, 2008)

DNA Methylation

- Functions
- DNA methylation & the environment
- **Epigenetic inheritance**

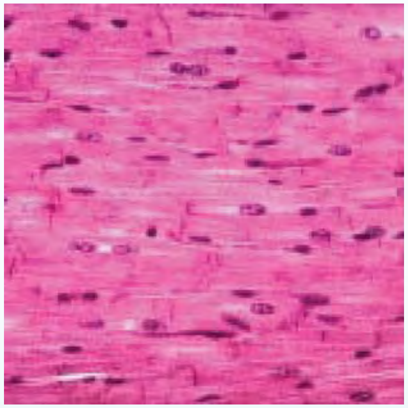
DNA methylation

- Epigenetic inheritance:

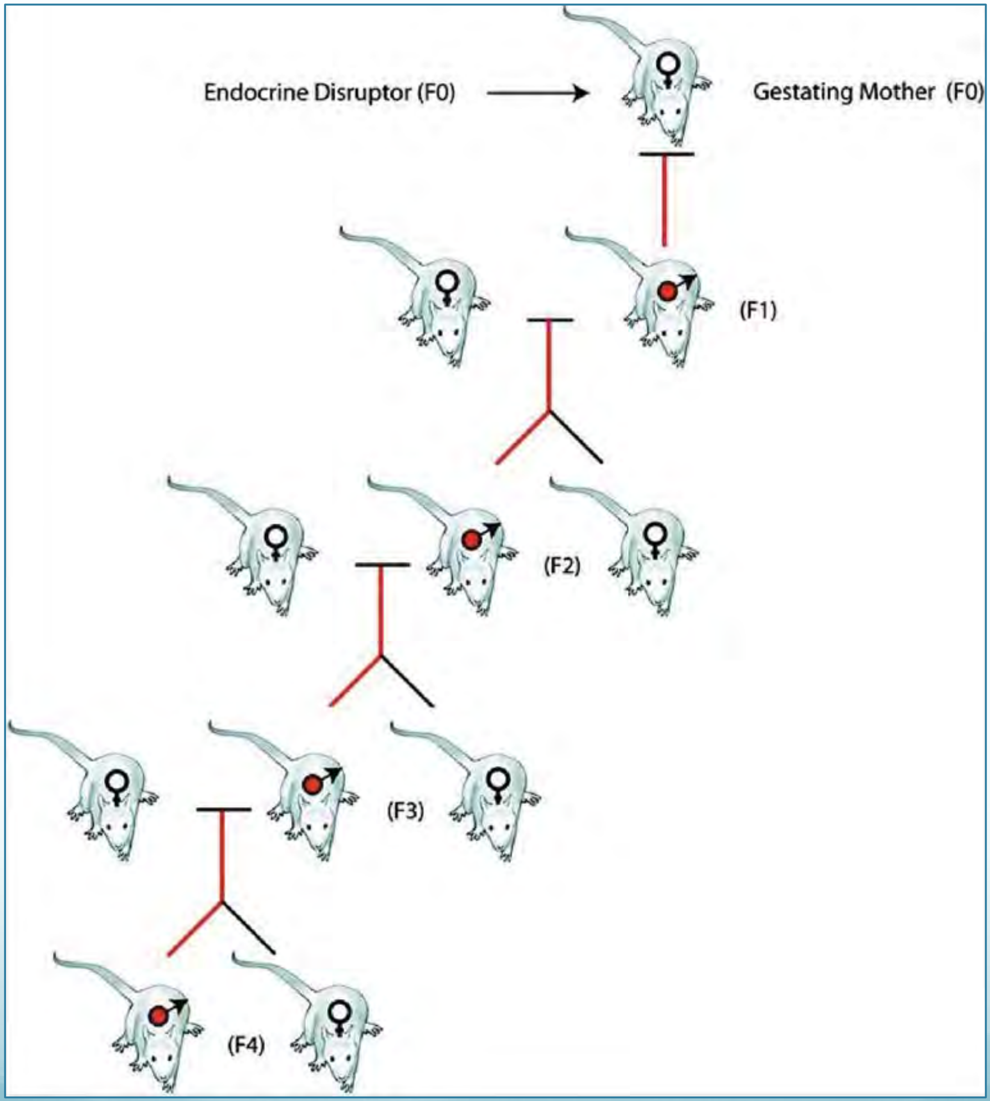




DNA methylation

- Epigenetic inheritance:
  - Mitotic inheritance
  - Meiotic (transgenerational) inheritance

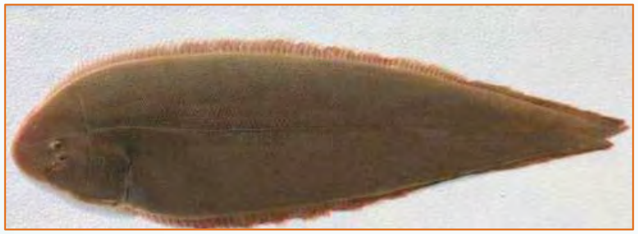

Transgenerational Epigenetic Inheritance: mammals



(Skinner 2007)

Transgenerational Epigenetic Inheritance: half-smooth tongue sole

ZW female

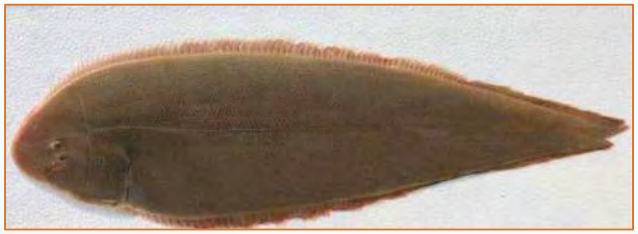


ZZ male

Transgenerational Epigenetic Inheritance: half-smooth tongue sole

NORMAL TEMPERATURE

ZW female



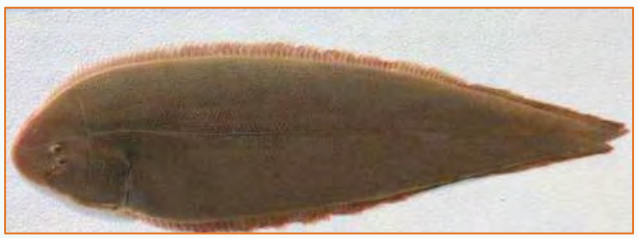
ZZ male

ELEVATED TEMPERATURE

Transgenerational Epigenetic Inheritance: half-smooth tongue sole

NORMAL TEMPERATURE

ZW female



ZZ male

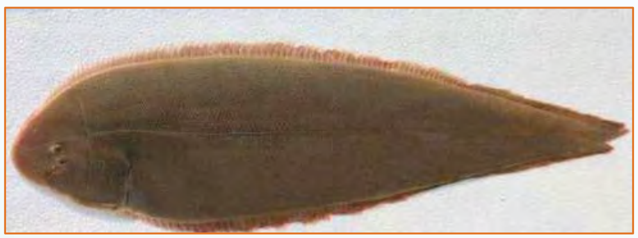
ELEVATED TEMPERATURE

ZW pseudomale

Transgenerational Epigenetic Inheritance: half-smooth tongue sole

NORMAL TEMPERATURE

ZW female



ZZ male

x

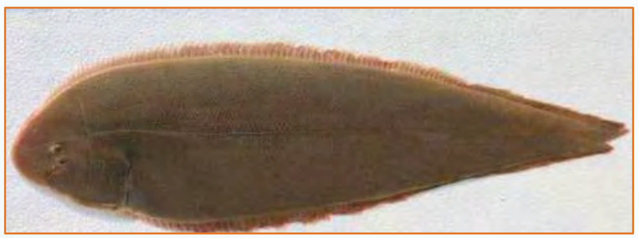
ELEVATED TEMPERATURE

ZW pseudomale

Transgenerational Epigenetic Inheritance: half-smooth tongue sole

NORMAL TEMPERATURE

ZW female



ZZ male

x

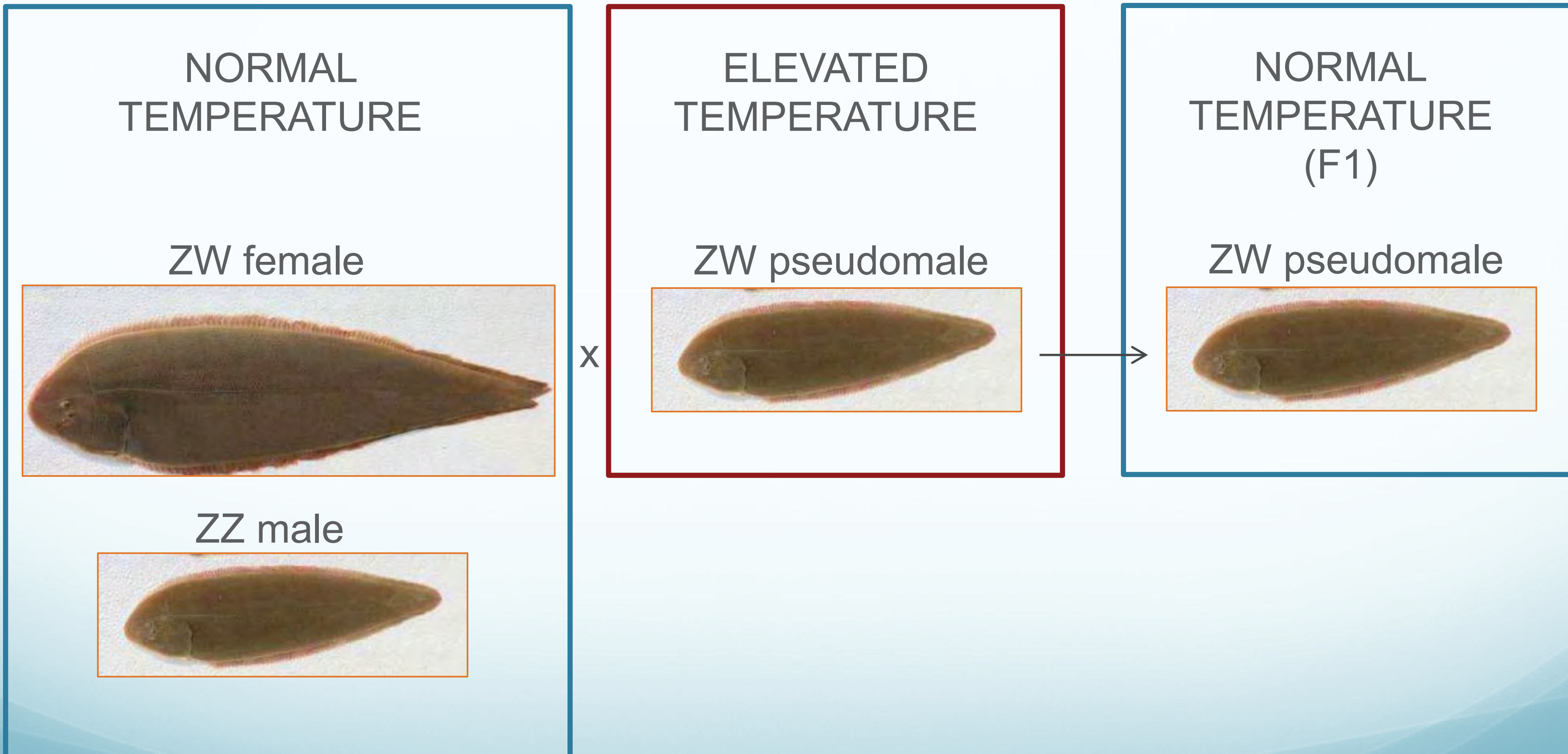
ELEVATED TEMPERATURE

ZW pseudomale

→

NORMAL TEMPERATURE (F1)

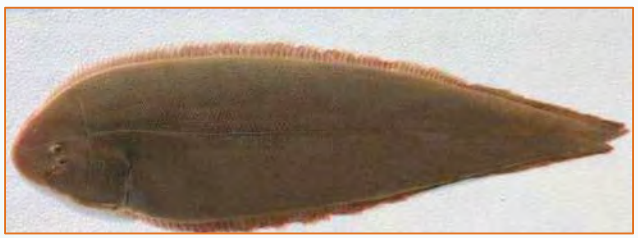
Transgenerational Epigenetic Inheritance: half-smooth tongue sole



Transgenerational Epigenetic Inheritance: half-smooth tongue sole

NORMAL TEMPERATURE

ZW female



ZZ male

x

ELEVATED TEMPERATURE

ZW pseudomale

NORMAL TEMPERATURE (F1)

ZW pseudomale

- Environment early in development changes phenotype, not genotype
- Phenotype is epigenetically inherited in the absence of environmental signal

DNA Methylation

- Functions
- DNA methylation & the environment
- Epigenetic inheritance

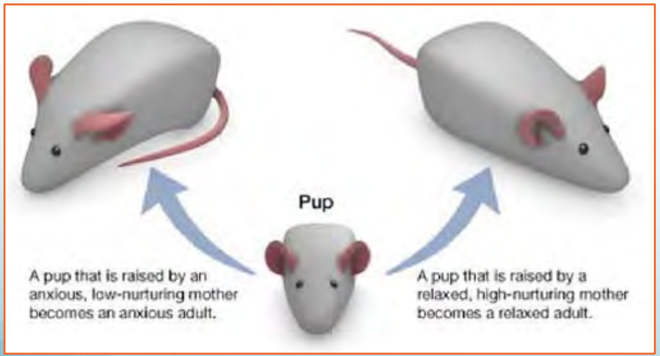
DNA Methylation

Environmentally-induced epigenetic changes are more likely to be persistent/heritable when exposure occurs during early development

DNA Methylation

Environmentally-induced epigenetic changes are more likely to be persistent/heritable when exposure occurs during early development

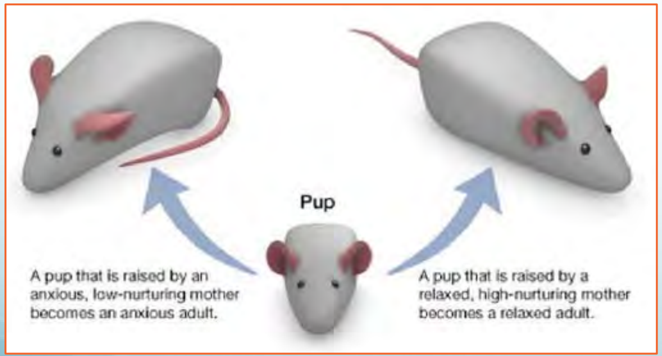
Adaptive:



DNA Methylation

<u>Environmentally-induced</u> epigenetic changes are more likely to be persistent/heritable when exposure occurs during <u>early development</u>

Adaptive:



Maladaptive:

Epigenetics: relevance to hatchery practices

Epigenetics: relevance to hatchery practices

- Salmon and steelhead reared in a hatchery are phenotypically different than wild fish

Epigenetics: relevance to hatchery practices

- Salmon and steelhead reared in a hatchery are phenotypically different than wild fish
- Possible mechanisms include:
  - Hatchery induced selection
  - Environmentally-induced, heritable, epigenetic change
  - Both

Epigenetics: relevance to hatchery practices

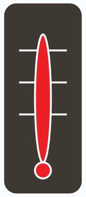
- Salmon and steelhead reared in a hatchery are phenotypically different than wild fish
- Possible mechanisms include:
  - Hatchery induced selection
  - **Environmentally-induced, heritable, epigenetic change**
  - Both

Epigenetics: relevance to hatchery practices

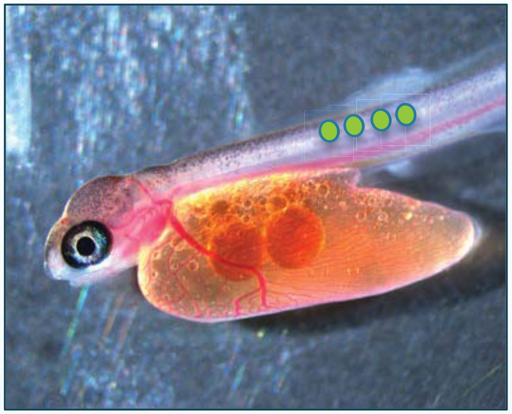
<u>Environmentally-induced</u> epigenetic changes are more likely to be persistent/heritable when exposure occurs during <u>early development</u>

Epigenetics: relevance to hatchery practices

photoperiod



temperature



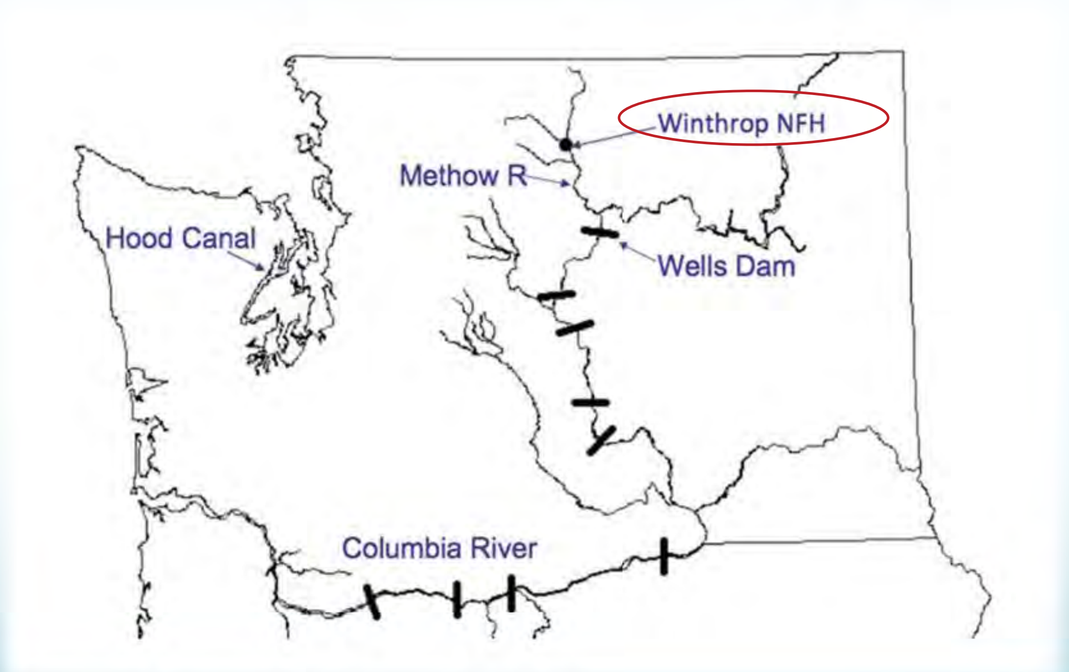
Olfactory cues

Water chemistry (pH, organics, toxins, O2)

Nutrients (yolk and exogenous food)

Steelhead & Epigenetics

Are there discernible epigenetic differences between hatchery and wild origin steelhead?



Steelhead & Epigenetics

- Returning adult fish were collected in 2014
- Identified as hatchery or natural origin
- Collected sperm and blood

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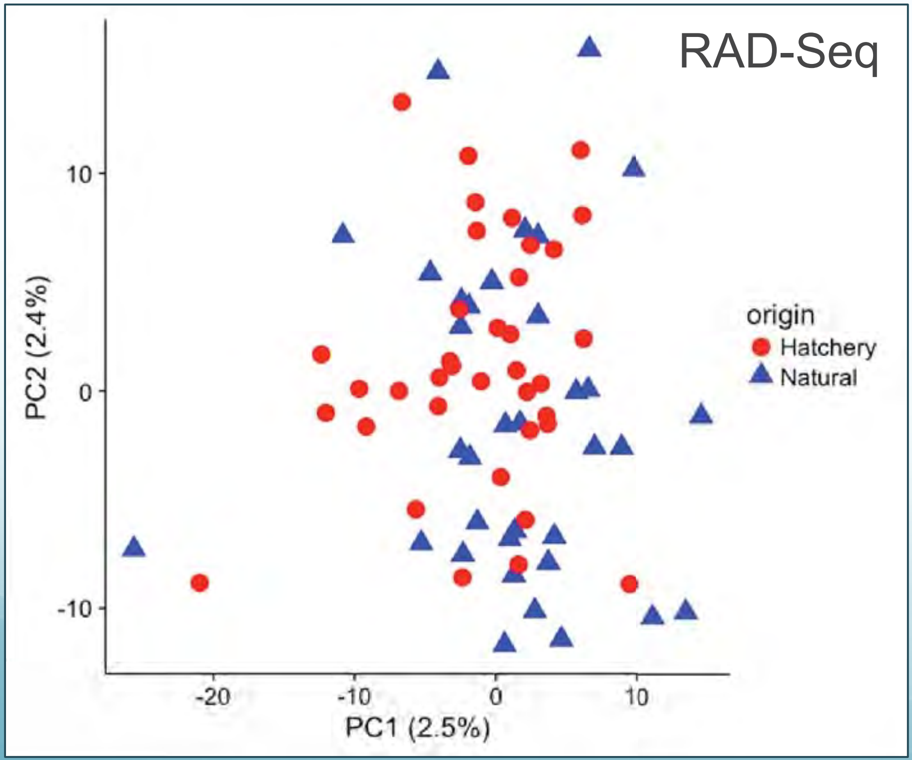
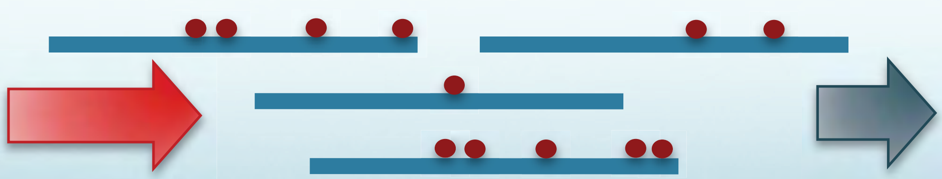
- Collected sperm and blood



Approach

- DNA methylation analysis
  - Red Blood Cells (RBC)
  - Sperm



genomic DNA

Results: RRBS

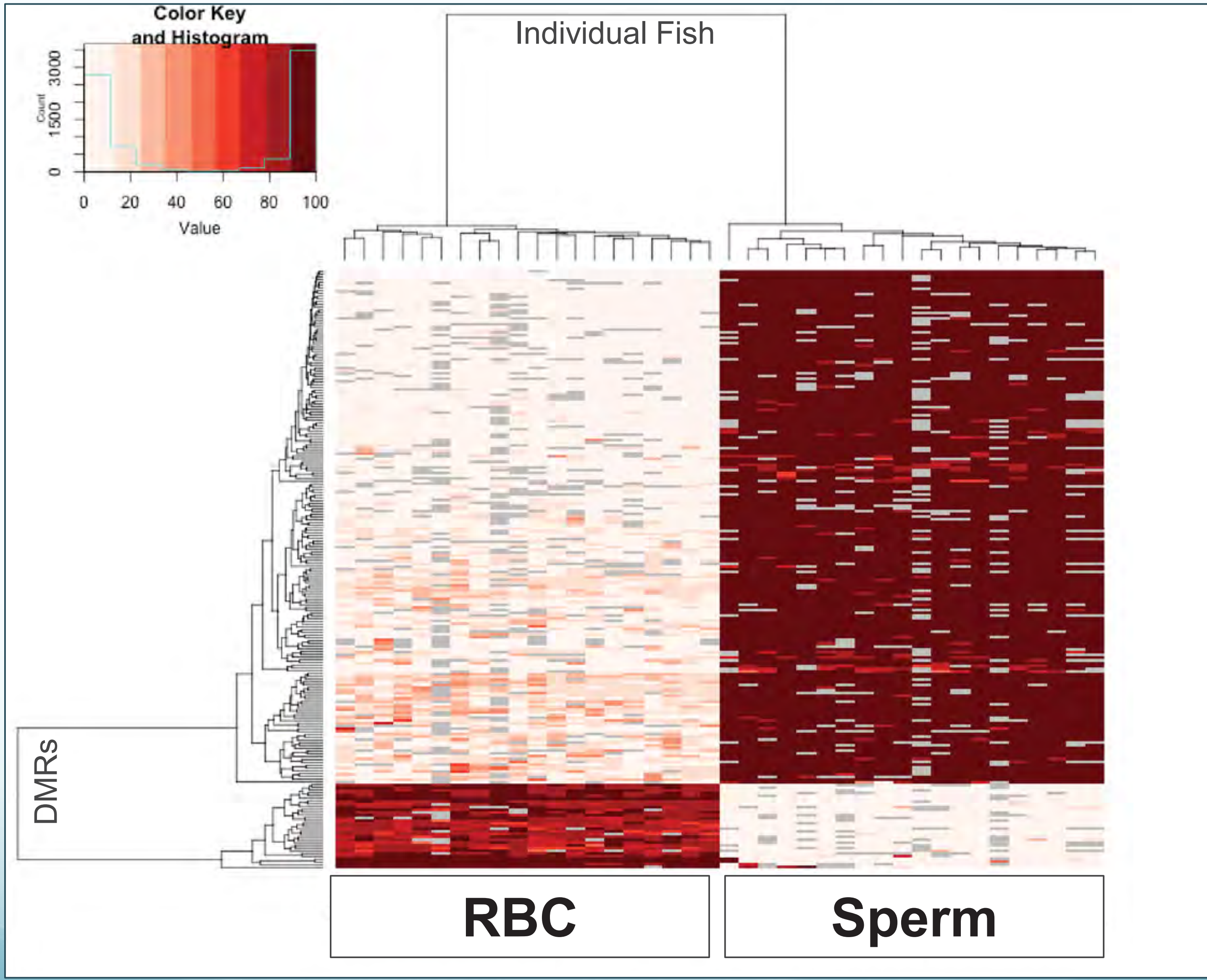
- Measured over 112,000 100bp regions in the genome
- Steelhead have a heavily methylated genome
  - 86% of CG are methylated in RBC
  - 94% of CG are methylated in Sperm

Cell-type Specific Methylation

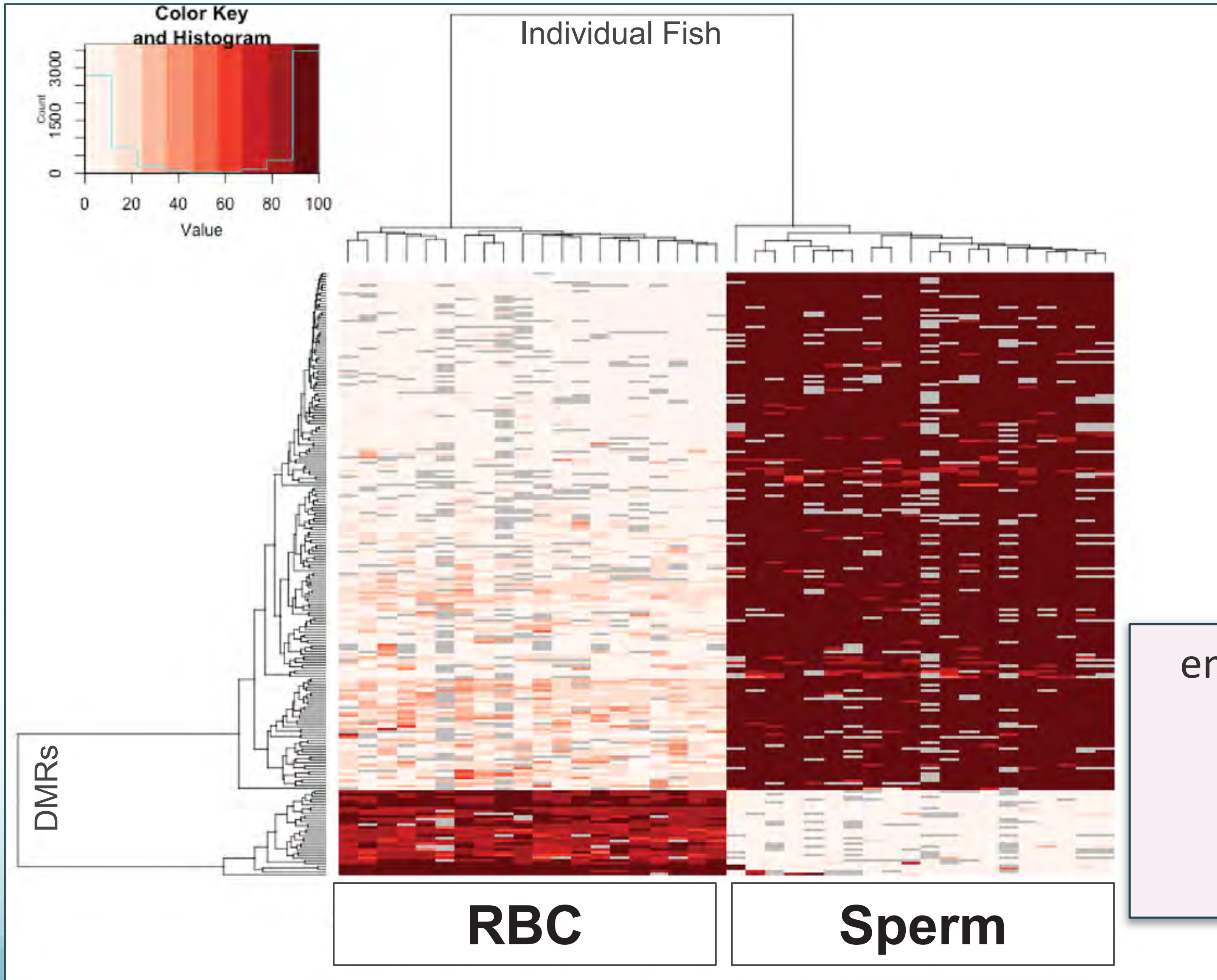
Cell-type Specific Methylation

- Differentially methylated regions* (DMRs) *region = average % methylation over 100bp
  - 3633 DMRs >20% difference in methylation
  - 218 DMRs >75% difference in methylation

Cell-type Specific Methylation

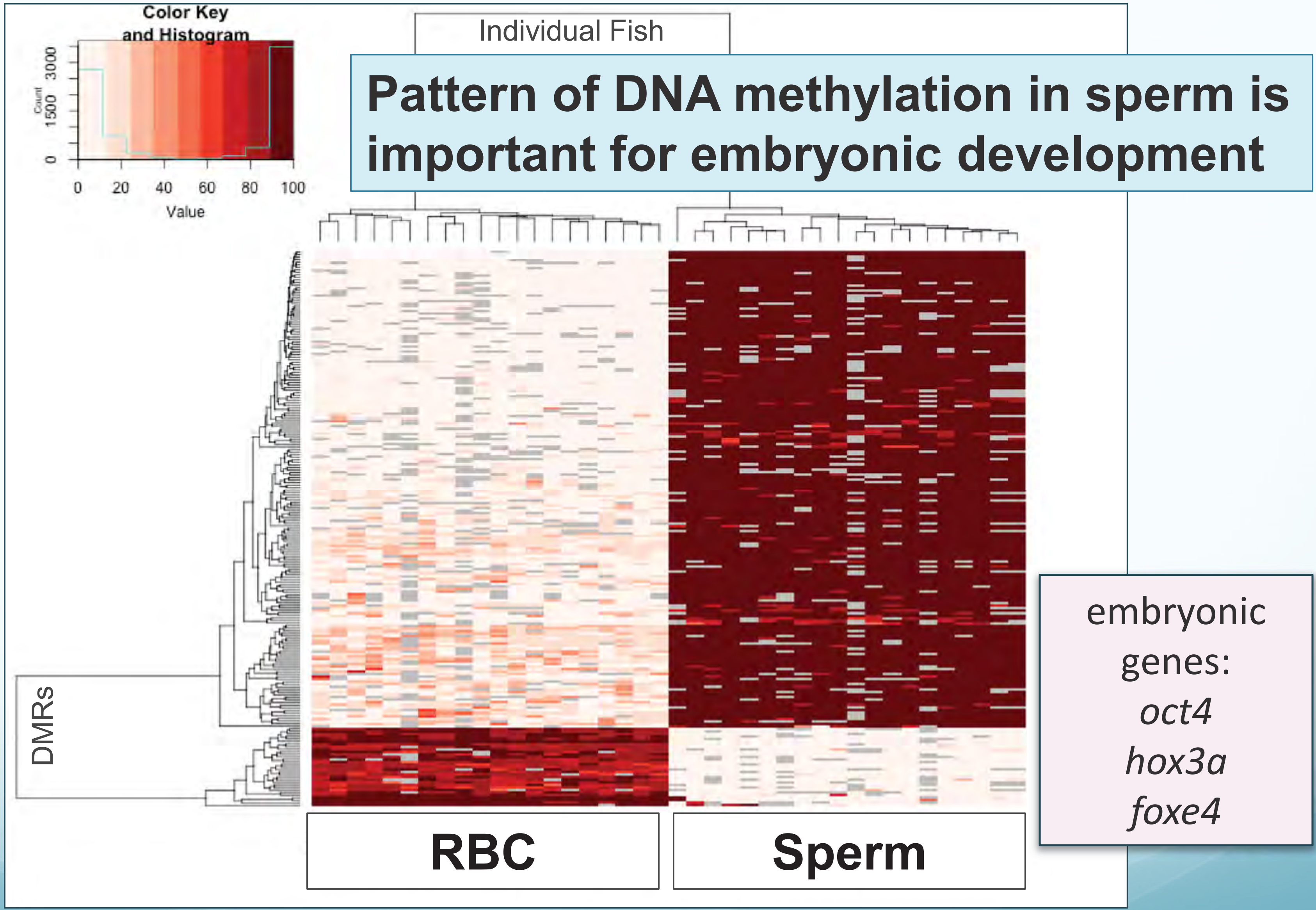


Cell-type Specific Methylation



embryonic
genes:
oct4
hox3a
foxe4

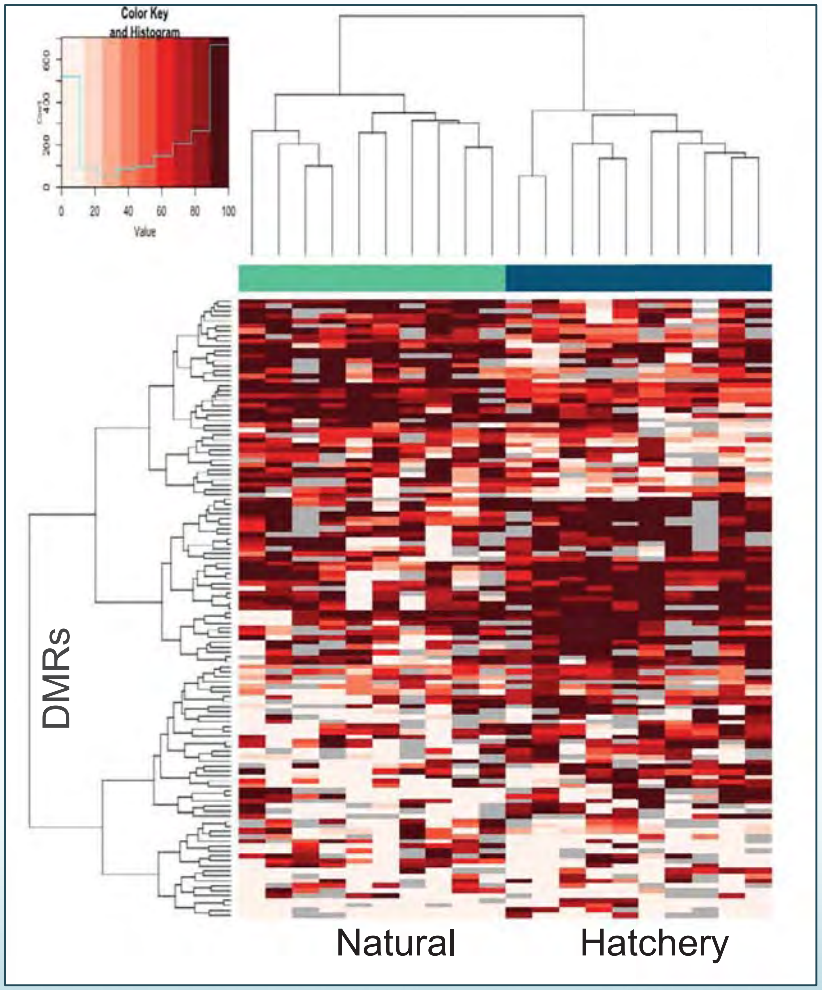
Cell-type Specific Methylation



Origin-Specific Methylation

- Differential methylation between hatchery and natural origin fish
  - 101 origin-specific DMRs in RBC
  - 125 origin-specific DMRs in sperm
  - 22 DMRs overlap between tissues

Origin Specific Methylation



Sperm

Summary

There are differences in DNA methylation between natural and hatchery-origin steelhead

Summary

There are differences in DNA methylation between natural and hatchery origin steelhead

- How do these DNA methylation changes affect gene expression and ultimately phenotype?

Summary

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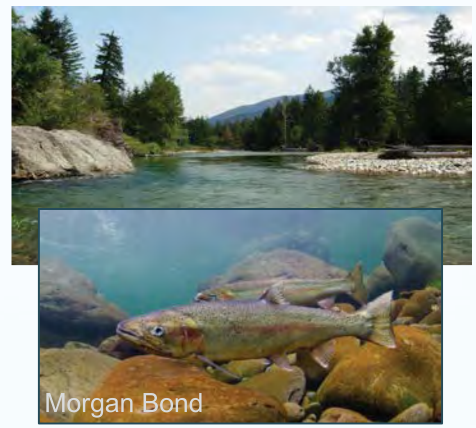
Summary

There are differences in DNA methylation between natural and hatchery origin steelhead

- How do these DNA methylation changes affect gene expression and ultimately phenotype?
- Which environmental parameters are influencing DNA methylation?
- How are epigenetic variation and genetic variation interrelated?
- Are environmentally-induced epigenetic changes transgenerationally inherited?

Concluding Remarks

- Epigenetics can help organisms *retain* (*and potentially pass on*) information about their environment.



- Epigenetics is an emerging tool to help understand how the environment affects phenotype in hatchery-reared fish, which could aid in minimizing heritable fitness loss in these populations.

Acknowledgements

UW SAFS

Graham Young

NOAA – Northwest Fisheries Science Center

Krista Nichols

Penny Swanson

Barry Berejikian

Chris Tatara

Mollie Middleton

Jon Dickey

Giles Goetz

Winthrop National Fish Hatchery:

Mathew Cooper (USFWS)

Chris Pasley (USFWS-WNFH)

Michael Humling (USFWS-WNFH)

Methodology and Bioinformatic Support

Melinda Baerwald (UC Davis)

Serge McGraw (University of Montreal)

Funding Sources:

NOAA
Bonneville Power Admin. (#1993-056)

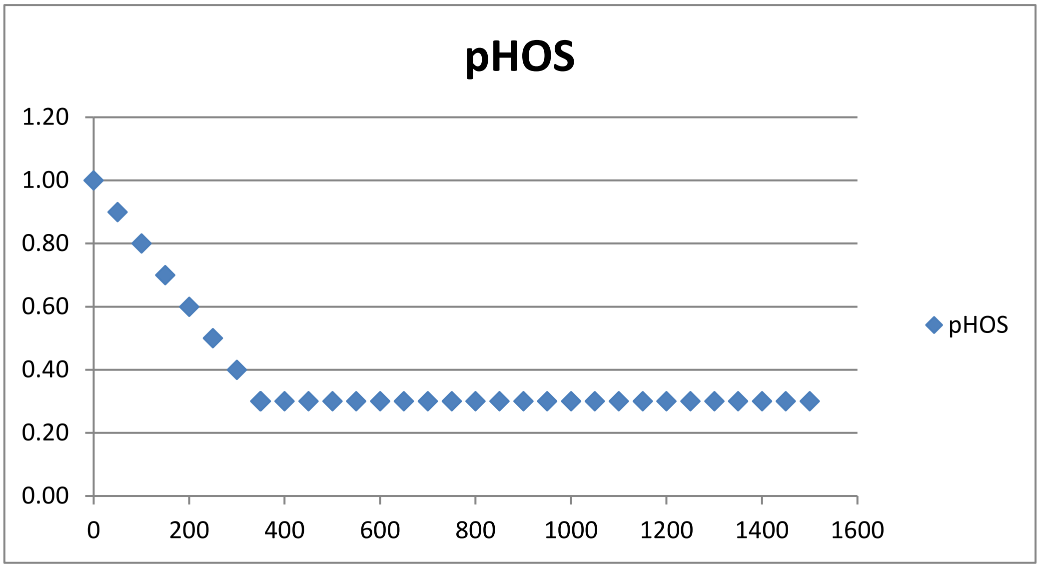
Next Steps: Controlled Experiment

Hatchery Tanks

Artificial Stream

Any epigenetic differences will be due to early rearing environment

				0.9			
				130			
Wild	Hatchery	**pHOS**	**Total**	**Wild Brood**	**Hatchery Brood**	**pNOB**	**PNI**
0	500	1.00	500	0	130	0	0
50	450	0.90	500	16	114	0.123077	0.120301
100	400	0.80	500	33	97	0.253846	0.240876
150	350	0.70	500	49	81	0.376923	0.35
200	300	0.60	500	66	64	0.507692	0.458333
250	250	0.50	500	83	47	0.638462	0.560811
300	200	0.40	500	99	31	0.761538	0.655629
349	150	0.30	499	116	14	0.892308	0.748387
350	150	0.30	500	116	14	0.892308	0.748387
400	171	0.30	571	117	13	0.9	0.75
450	193	0.30	643	117	13	0.9	0.75
500	214	0.30	714	117	13	0.9	0.75
550	236	0.30	786	117	13	0.9	0.75
600	257	0.30	857	117	13	0.9	0.75
650	279	0.30	929	117	13	0.9	0.75
700	300	0.30	1000	117	13	0.9	0.75
750	321	0.30	1071	117	13	0.9	0.75
800	343	0.30	1143	117	13	0.9	0.75
850	364	0.30	1214	117	13	0.9	0.75
900	386	0.30	1286	117	13	0.9	0.75
950	407	0.30	1357	117	13	0.9	0.75
1000	429	0.30	1429	117	13	0.9	0.75
1050	450	0.30	1500	117	13	0.9	0.75
1100	471	0.30	1571	117	13	0.9	0.75
1150	493	0.30	1643	117	13	0.9	0.75
1200	514	0.30	1714	117	13	0.9	0.75
1250	536	0.30	1786	117	13	0.9	0.75
1300	557	0.30	1857	117	13	0.9	0.75
1350	579	0.30	1929	117	13	0.9	0.75
1400	600	0.30	2000	117	13	0.9	0.75
1450	621	0.30	2071	117	13	0.9	0.75
1500	643	0.30	2143	117	13	0.9	0.75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1400
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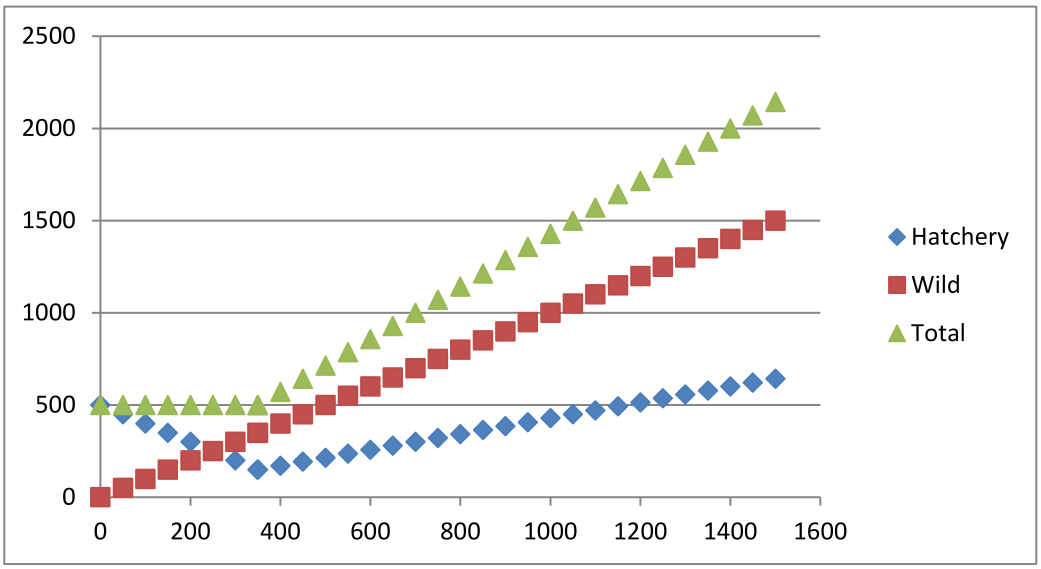
pHOS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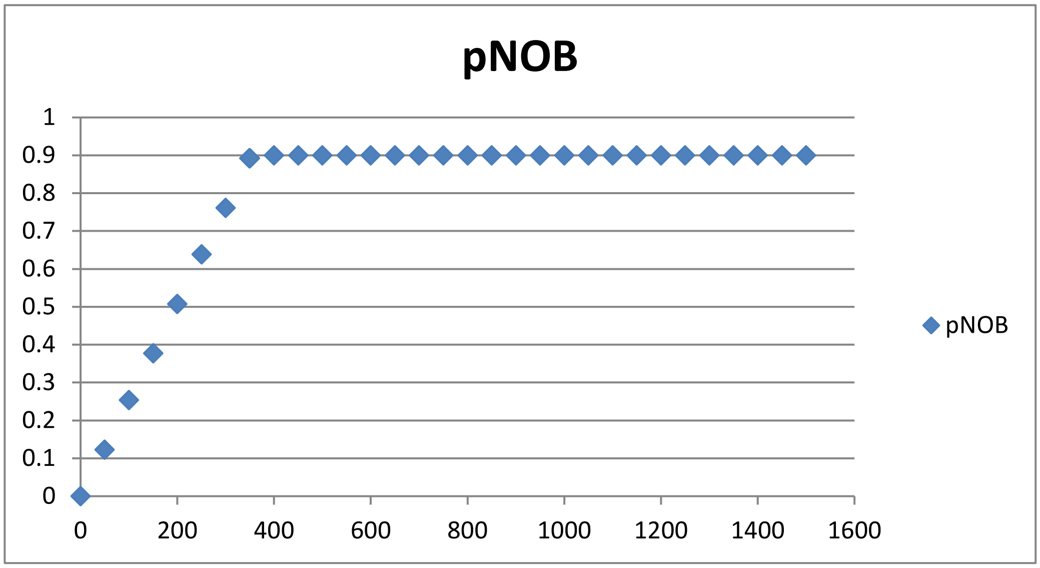
Hatchery
Wild
Total


pNOB
1
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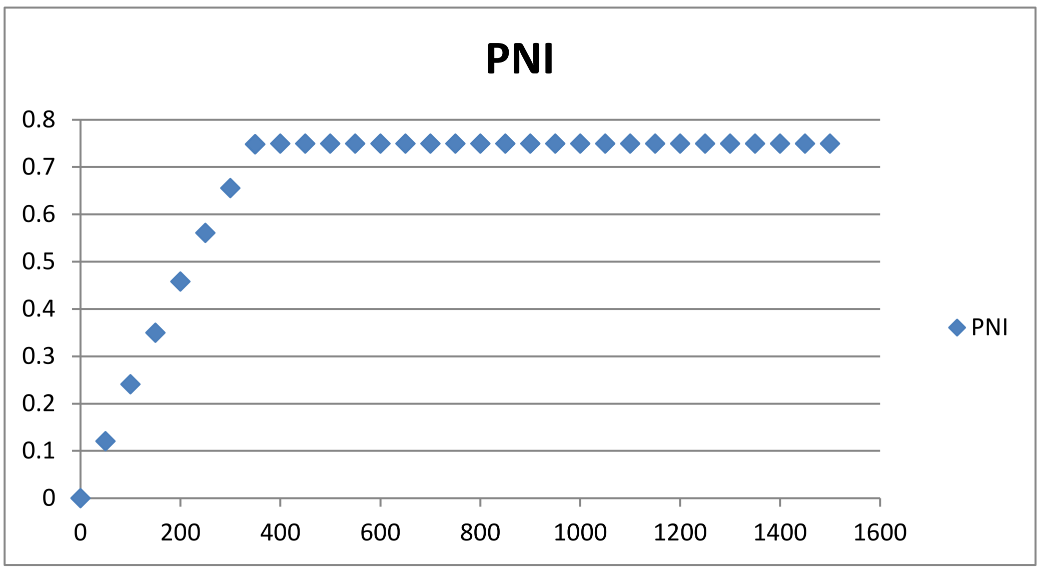
pNOB


PNI
0.8
0.7
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0.3
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200
400
600
800
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1200
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PNI

Approach to Determine Chelan PUD Coho Hatchery Mitigation

- Assume 93% juvenile mortality for Rocky Reach and Rock Island
- Calculate mitigation following the methods in "Recalculation of Mid-Columbia River Public Utility District Hatchery Production, 2014-2023 (January 2012).

  - Compensation for hatchery-origin smolts will be based upon projected hatchery smolt releases.
    - Hatchery coho released x project mortality

  - Compensation for natural-origin smolts will be based upon observed average natural origin adult returns at the individual PUD projects.
    - BAMP formula

Coho Hatchery Mitigation

	Release Years	Projected Annual Release Number	Compensation Rate	Hatchery Mitigation
Methow	2018	500,000	1-(0.93 x 0.93)	67,550
	2019-2021	1,000,000	1-(0.93 x 0.93)	135,100
	2022-2027	700,000	1-(0.93 x 0.93)	94,570

	Release Years	Projected Annual Release Number	Compensation Rate	Hatchery Mitigation
Wenatchee	2018-2020	1,000,000	1-0.93	70,000
	2021-2023	1,160,000	1-0.93	81,200
	2024-2027	810,000	1-0.93	56,700

Coho Natural Mitigation

BAMP formula

- average 10 year NORs/juvenile project survival rate=number of NORs absent unavoidable mortality
- number of NORs absent unavoidable mortality-average 10 year NORs absent unavoidable mortality=adult equivalents to meet NNI
- adult equivalents/mean 10 year SAR of hatchery program=coho natural mitigation number

Coho Natural Mitigation Rock Island

Coho returns to Rock Island Dam and proportion natural-origin, 2007-2016.

Dam	Year	CohoAdult	CohoJack	Total	Proportion Natural Origin	Estimated Natural Origin Return to Rock Island Dam
RIS	2007	16,604	548	17,152	0.0459	787
RIS	2008	6,736	1,657	8,393	0.0466	391
RIS	2009	19,805	2,100	21,905	0.0454	994
RIS	2010	6,209	1,486	7,695	0.0424	326
RIS	2011	30,341	704	31,045	0.0223	692
RIS	2012	8,115	162	8,277	0.0510	422
RIS	2013	2,361	252	2,613	0.0091	24
RIS	2014	47,345	242	47,587	0.0315	1,499
RIS	2015	4,360	139	4,499	0.0260	117
RIS	2016	2,359	130	2,489	0.0148	37
Average (2007-2016)		**14,424**	**742**	**15,166**	**0.0335**	**529**

Coho Natural Mitigation Rock Island

Smolt-to-adult survival of hatchery reared PIT-tagged coho released above Priest Rapids Dam, returning to Priest Rapids Dam.

Broodyear	Release Year	Number of Tags Released	Number of Tags Returned to PRD	SAR
2004	2006	29,327	230	0.784%
2005	2007	29,951	75	0.250%
2006	2008	29,830	331	1.110%
2007	2009	42,403	102	0.241%
2008	2010	34,689	619	1.784%
2009	2011	50,485	256	0.507%
2010	2012	48,942	75	0.153%
2011	2013	52,329	1,164	2.224%
2012	2014	53,652	186	0.347%
2013	2015	48,594	69	0.142%
Average (2004-2013)				**0.754%**

Coho Natural Mitigation

Rock Island

- Mean NOR coho 2006-2015=529
- Mean NOR in absence of project mortality=529/0.9300=569
- Adult equivalents to meet NNI=569-529=40
- Mean 10 year (1996-2006 Wenatchee program) SAR=0.75%
- Coho natural mitigation=40/0.0075=5,333 smolts

Coho Natural Mitigation Rocky Reach

Coho returns to Rocky Reach Dam and proportion natural-origin, 2007-2016.						
Dam	**Year**	**CohoAdult**	**CohoJack**	**Total**	**Proportion Natural Origin**	**Estimated Natural Origin Return to Rocky Reach Dam**
RRH	2007	4,634	104	4,738	0.0459	217
RRH	2008	2,944	782	3,726	0.0466	174
RRH	2009	5,611	326	5,937	0.0454	270
RRH	2010	2,181	510	2,691	0.0424	114
RRH	2011	7,812	139	7,951	0.0223	177
RRH	2012	2,397	43	2,440	0.0510	124
RRH	2013	486	48	534	0.0091	5
RRH	2014	13,101	69	13,170	0.0315	415
RRH	2015	2,016	124	2,140	0.0260	56
RRH	2016	391	27	418	0.0148	6
Average (2007-2016)		**4,157**	**217**	**4,375**	**0.0335**	**156**

Coho Natural Mitigation Rocky Reach

Smolt-to-adult survival of hatchery reared PIT-tagged coho released above Rocky Reach Dam, returning to Rocky Reach Dam.				
Broodyear	Release Year	Number of Tags Released	Number of Tags Returned to RRH	SAR
2004	2006	-	-	-
2005	2007	-	-	-
2006	2008	6,723	33	0.491%
2007	2009	11,371	30	0.264%
2008	2010	11,950	156	1.305%
2009	2011	20,952	80	0.382%
2010	2012	17,959	13	0.072%
2011	2013	23,969	420	1.752%
2012	2014	23,773	82	0.345%
2013	2015	21,665	20	0.092%
Average (2006-2013)				**0.588%**

Coho Natural Mitigation

Rocky Reach

- Mean NOR coho 2006-2015=43
- Mean NOR in absence of project mortality=43/0.9300=46
- Adult equivalents to meet NNI=46-43=3
- Mean 10 year (1996-2006 Methow program) SAR=0.59%
- Coho natural mitigation=3/0.0059=549

Release Years	Projected Release Numbers (Methow/Wenatchee)	Hatchery Mitigation	**Total Mitigation** Hatchery Mitigation + Natural Mitigation (5,882)
2018	1,500,000	137,550	143,432
2019	2,000,000	205,100	210,982
2020	2,000,000	205,100	210,982
2021	2,160,000	216,300	222,182
2022	1,860,000	175,770	181,652
2023	1,860,000	175,770	181,652
2024	1,510,000	151,270	157,152
2025	1,510,000	151,270	157,152
2026	1,510,000	151,270	157,152
2027	1,510,000	151,270	157,152

FINAL

720 Olive Way, Suite 1900
Seattle, Washington 98101
206.287.9130

ANCHOR QEA

Memorandum

To: Wells, Rocky Reach, and Rock Island HCP Hatchery Committees

Date: July 25, 2017

From: Tracy Hillman, HCP Hatchery Committees Chairman

cc: Sarah Montgomery, Anchor QEA, LLC

Re: Final Minutes of the June 21, 2017, HCP Hatchery Committees Meeting

The Wells, Rocky Reach, and Rock Island Hydroelectric Projects Habitat Conservation Plan (HCP) Hatchery Committees meeting was held at the Grant PUD office in Wenatchee, Washington, on Wednesday, June 21, 2017, from 9:00 a.m. to 12:00 p.m. Attendees are listed in Attachment A to these meeting minutes.

Action Item Summary

- Andrew Murdoch (Washington Department of Fish and Wildlife [WDFW]) will write an overview of proposed expanded sampling at the off-ladder fish trap (OLAFT) at Priest Rapids Dam (Item I-A). *(Note: this item is ongoing.)*
- Hatchery Committees representatives will review McLain Johnson's (WDFW) Genetic Monitoring Update (Item I-A). *(Note: Sarah Montgomery distributed the update on April 6, 2017. This item is ongoing, and the update will be discussed at an upcoming Hatchery Committees meeting [date TBD].)*
- Chelan PUD, Douglas PUD, and Grant PUD representatives will discuss internally HCP requirements and coverage options for the unlisted programs in the upper Columbia River basin (Item III-B).
- Charlene Hurst will distribute the draft proposed action for Methow steelhead programs to the Hatchery Committees for a 2-week review (Item IV-A). *(Note: Hurst sent the draft to Sarah Montgomery, which she distributed to the Hatchery Committees on June 22, 2017).*
- Tracy Hillman will make the following revisions to the Monitoring and Evaluation (M&E) Plan for PUD Hatchery Programs (2013 Update): 1) draft footnotes for Table 1 regarding run timing, redd distribution, and spawn timing, and 2) revise Objective 6 (Items I-A and III-C).
- Tracy Hillman will revise fish-per-pound (FPP) targets in Appendix 5 of the Hatchery M&E Plan according to the 2017 Broodstock Collection Protocols (Item III-C). *(Note: Hillman made this revision and Sarah Montgomery distributed a revised Appendix 5 and compilation of Appendices 2-5 on June 23, 2017.)*
- Tracy Hillman will invite Jeff Jorgensen (National Oceanic and Atmospheric Administration) to an upcoming Hatchery Committees meeting to present and discuss Wenatchee River spring-

run Chinook salmon life-cycle modeling (Item V-A). *(Note: Jorgensen plans to attend the Hatchery Committees August 16, 2017, meeting.)*

- Tracy Hillman will distribute Jorgensen et al.'s draft chapter, "Wenatchee River spring-run Chinook salmon life-cycle model: hatchery effects, calibration, and sensitivity analyses" to the Hatchery Committees (Item V-A). *(Note: Hillman sent the chapter to Sarah Montgomery, which she distributed to the Hatchery Committees on June 22, 2017.)*

Decision Summary

- There were no decisions discussed during today's meeting.

Agreements

- There were no agreements discussed during today's meeting.

Review Items

- Sarah Montgomery sent an email to the Hatchery Committees on June 15, 2017, notifying them the Draft 2016 Chelan PUD and Grant PUD Hatchery M&E Annual Report is available for a 30-day review, with comments due to Tracy Hillman by July 15, 2017.
- Sarah Montgomery sent an email to the Wells Hatchery Committee on June 22, 2017, notifying them the Draft Proposed Action for the Winthrop National Fish Hatchery and Wells Complex Steelhead Programs is available for review, with comments due to Charlene Hurst by Thursday July 6, 2017.
- Sarah Montgomery sent an email to the Hatchery Committees on June 27, 2017, notifying them that National Marine Fisheries Service's (NMFS') draft proposed action for the upper Columbia River unlisted programs is available for review, with comments due to Emi Kondo (NMFS) by July 17, 2017.

Finalized Documents

- There are no documents that have been recently finalized.

I. Welcome

A. Review Agenda, Review Last Meeting Action Items, and Approve the May 17, 2017, Meeting Minutes (Tracy Hillman)

Tracy Hillman welcomed the Hatchery Committees and asked for any additions or changes to the agenda. Catherine Willard added a Chelan Falls Broodstock Collection update, and Hillman added updates about the Draft 2016 Chelan PUD and Grant PUD Hatchery M&E Annual Report and the Independent Scientific Advisory Board's planned visit to the upper Columbia River basin.

The Hatchery Committees reviewed the revised draft May 17, 2017, meeting minutes. Sarah Montgomery said there are some outstanding comments to be discussed, which the Hatchery Committees reviewed and revised. Hatchery Committees representatives present approved the draft May 17, 2017, meeting minutes, as revised.

Action items from the Hatchery Committees meeting on May 17, 2017, and follow-up discussions were addressed *(note: italicized text below corresponds to agenda items from the meeting on April 19, 2017)*:

- *Andrew Murdoch (Washington Department of Fish and Wildlife [WDFW]) will write an overview of proposed expanded sampling at the off-ladder fish trap (OLAFT) at Priest Rapids Dam (Item I-A).*
  This item is ongoing. Mike Tonseth said the overview may be completed in July 2017.
- *Hatchery Committees representatives will review McLain Johnson's (WDFW) Genetic Monitoring Update for discussion at the Hatchery Committees June 21, 2017, meeting (Item I-A).*
  Sarah Montgomery distributed the update on April 6, 2017; Mike Tonseth postponed the update via email on June 13, 2017. Tonseth said this item may be discussed at the August 16, 2017, Hatchery Committees meeting.
  Regarding genetic sampling in the Wenatchee River and broodstocking in the Methow River, Todd Pearsons asked if genetic samples collected and analyzed for that project could also be used as the genetic analyses needed to meet the M&E objective. Tonseth said he believes the same samples and analyses can be used to meet both objectives. Pearsons requested that WDFW also discuss whether samples that have already been collected and samples collected as part of ongoing collection plans can be used in the M&E genetic monitoring scheme. Tonseth said he will provide that information in addition to the broader genetic sampling discussion.
- *Tracy Hillman will draft footnotes for Table 1 of the Monitoring and Evaluation (M&E) Plan for PUD Hatchery Programs (2013 Update) regarding run timing, redd distribution, and spawn timing (Item II-F).*
  This item is ongoing.
- *Sarah Montgomery will distribute Craig Busack's (National Marine Fisheries Service [NMFS]) 2013 document "Methow Basin Management Frameworks for Spring Chinook and Steelhead" to the Hatchery Committees (Item II-G).*
  Montgomery distributed the document following the meeting on May 17, 2017.

II. Chelan PUD

A. Chelan Falls Broodstock Collection (Catherine Willard)

Catherine Willard reminded the Hatchery Committees that Chelan PUD is continuing their pilot project to collect summer Chinook salmon broodstock at the Chelan River Habitat Channel Water Conveyance Canal Outlet. She said the pilot project is included in the 2017 Broodstock Collection Protocols, which were approved by the Hatchery Committees. Willard said she wants to ensure that the approval of Broodstock Collection Protocols provides Hatchery Committees approval for the pilot project, and asked if anyone has questions about the project. Mike Tonseth asked if installing the trap and making it operational was delayed this year. Willard responded yes, and broodstock collection is scheduled to begin in the second week of July instead of the first week as planned. Bill Gale said surplus summer Chinook salmon from the U. S. Fish and Wildlife Service (USFWS) Entiat National Fish Hatchery (NFH) are identified as the backup broodstock source in case of a shortfall in collection. He asked if USFWS and Chelan PUD have discussed the logistics of this arrangement for 2017 and when fish would be transferred. Willard said nothing has been discussed in 2017 besides what is included in the Broodstock Collection Protocols. Tonseth said mid-August is the check-in point to decide if surplus fish from Entiat NFH will be needed. Gale said staff at Entiat NFH prefer to surplus summer Chinook salmon early, so it is important to communicate broodstock needs with as much notice as possible. Gale also said that the State and Chelan PUD had some disease concerns with receiving brood late in the return cycle in 2016 and asked if this was still a issue of concern. Willard said the fish Chelan PUD received from Entiat NFH in 2016 were in fine condition for broodstock needs.

B. Tumwater Dam Pacific Lamprey Passage Feasibility Study Update (Alene Underwood)

Tracy Hillman said Chelan PUD has been working on a feasibility study for lamprey passage at Tumwater Dam. Alene Underwood said the report on the feasibility study has been in review by Chelan PUD management. Underwood said one question from management was, "what is Chelan PUD's legal requirement regarding lamprey passage at Tumwater Dam?" Another was, "if a passage structure is constructed, what is the expected biological benefit?" Underwood said staff are currently working to address these questions. Particularly, staff are working on the following three items: 1) distributing the feasibility study as soon as possible, 2) determining regulatory nexus and requirements including off-license mitigation, 3) preparing a biological evaluation to assess lamprey presence in the study area including historical data and potential expected abundance.

Bill Gale said the USFWS has continuing concerns about approving operations at Tumwater Dam through the Broodstock Collection Protocols due to impacts to Lamprey at this facility. Further, he said these impacts are directly related to Chelan PUD's Non-Target Taxa of Concern requirements in M&E plans. Gale urged Chelan PUD to release the feasibility study soon.

III. Joint HCP-HC/PRCC HSC

A. USFWS Bull Trout Consultation Update (Matt Cooper)

Matt Cooper said Karl Halupka (USFWS) has no progress to report on bull trout consultations. Emi Kondo asked who she should coordinate with at USFWS regarding the Methow steelhead consultations. Bill Gale said Kondo should coordinate with Sierra Franks.

B. NMFS Consultation Update (Brett Farman/Emi Kondo)

Unlisted Programs

Emi Kondo said she is providing an update on consultation for the unlisted programs in the upper Columbia River. The programs are Wenatchee summer Chinook salmon, Chelan Falls summer Chinook salmon, Wells summer Chinook salmon, Priest Rapids fall Chinook salmon, Methow summer Chinook salmon, and Ringold upriver bright fall Chinook salmon. She said the Ringold program will likely be a direct consultation with the U.S. Army Corps of Engineers, and her update today focuses on pathways to receive Endangered Species Act (ESA) coverage for the other five programs.

Section 10 vs Section 4(d) Coverage

Kondo said NMFS General Counsel favors using the Section 4(d) process for ESA coverage for these programs. She said the mechanism for receiving 4(d) coverage is that applicants provide NMFS with a detailed program plan and NMFS reviews then approves it. She said NMFS can also help develop the plan and one benefit of 4(d) is that applicants develop and have more control over their own programs. She said the other option for ESA coverage for these programs is a Section 10 incidental take permit. She said a Section 10 direct take permit has been used for the Methow spring Chinook salmon program and the process would be similar for Methow steelhead.

Todd Pearsons asked what the differences are in legal coverage, application material, and timeline between Section 10 and 4(d). Kondo said the legal difference is that Section 4(d) is more protective and provides a wider range of actions a program can operate by (such as a comprehensive plan), whereas Section 10 permits are very specific and operation would have to comply with permit conditions. She said application material is the same (comprehensive Hatchery and Genetic Management Plan [HGMP] for the public to review), and she said timelines for Section 4(d) are more flexible than Section 10, specifically when considering changing program operations, a situation in which Section 10 could result in additional consultation.

Brett Farman said the coverage mechanism for Section 4(d) and Section 10 is different in that Section 10 allows take under permitted actions to be exempt, whereas Section 4(d) allows for categories of actions meeting certain criteria not to be considered take. He said Section 4(d) is more flexible and would have fewer conditions. Kondo added that Section 4(d) is a continuing form of coverage compared to Section 10 which is an expiring form of coverage, and extending Section 10 coverage in lieu of a new permit is a legal vulnerability.

Alene Underwood asked if there is an existing exemption under ESA that would already apply to these unlisted programs. Farman said the exemptions are broad categories of actions (such as forestry, fisheries, and hatchery), and approved actions under these categories do not count as take. Kondo said NMFS can write a letter describing program coverage for 4(d) permit holders, specifying requirements such as monitoring requirements.

Underwood asked if a National Environmental Protection Act process applies to Section 4(d) coverage. Kondo said yes, it applies to both Section 4(d) and Section 10. Underwood asked how consultation with USFWS occurs through these permit pathways. Bill Gale said NMFS is the action agency, so NMFS consults with USFWS regarding bull trout.

Mike Tonseth said although the HCPs specify that NMFS will issue Section 10 coverage, permit applicants should consider using Section 4(d) because it affords the same level of protection and requirements, but is more flexible. He said unlisted programs do not change very much except during recalculation, so only reconsulting when needed (such as during a major program change) would be preferable to reconsulting every 10 years as would occur with Section 10.

Greg Mackey asked if permit applicants for the upper Columbia River unlisted programs could be issued different forms of coverage—some receiving Section 10 and some Section 4(d). Tonseth said the Biological Opinion (BiOp) would consider all six programs, but the permit coverage types can be different. He said the Ringold program, for example, will have Section 7 coverage because the U.S. Army Corps of Engineers is the action agency. Pearsons asked what materials (in addition to HGMPs) NMFS needs from permit applicants for pursuing Section 4(d) or Section 10 coverage. Kondo said she is currently drafting the proposed action section of the unlisted programs BiOp, which will then be reviewed by the permit applicants. Pearsons asked if the HGMPs will need to be revised. Tonseth said all the information necessary for writing the proposed action has been submitted to NMFS and the next step is determining whether any sufficiency letters have been issued by NMFS stating that HGMPs and their supplemental information are sufficient. Pearsons said Grant PUD's unlisted programs have been operating under an extension letter. Underwood said she does not believe Chelan PUD received a sufficiency letter for its programs. Kondo said she will move forward with the BiOp assuming no sufficiency letters have been issued and she will distribute the proposed action for a 2-week review soon. Pearsons said Grant PUD may need more than 2 weeks for review.

Gale asked Kondo to consider, while she is drafting the proposed action, that the USFWS will be using the language in the proposed action to begin considering how the consultation will impact bull trout. Gale said the USFWS will need the HGMPs and proposed action to begin consultation soon, so that programs can receive coverage before December 2017. Tonseth said the Ringold program is the only one requiring coverage by December 2017. Tonseth suggested that Kondo discuss the proposed action with Karl Halupka, as he may have started a gap analysis for this consultation that could be helpful.

Hatchery Committees representatives present generally stated that they prefer pursuing Section 4(d) coverage due to its flexibility, and Chelan PUD, Douglas PUD, and Grant PUD, as permit applicants, indicated they need to discuss coverage options internally and look at language in the HCP and consult legal counsel. Tonseth said if all the HCP signatories are amenable to using Section 4(d) coverage, amendments to the HCPs could be written. Tom Kahler added the Wells HCP states that hatchery programs should have Section 10 coverage; however, the HCP also mentions Section 4(d) coverage, so further assessment and discussion about coverage options is warranted.

C. Review Hatchery M&E Plan Objectives (All)

Tracy Hillman said the first objective to discuss is Objective 6, specifically, brood year stray rates.

Mike Tonseth suggested not assigning a target, but using the brood year stray rates as an indicator and management tool to help guide programs. Greg Mackey agreed and said in some cases, there are a number of actions a program could implement if a brood year stray rate is so high that it is impeding recovery efforts, and in other cases, there are limited actions available to make improvements in homing depending on the circumstances under which fish are released. Tonseth agreed and said he is concerned about setting an arbitrary target that is not actively managed for.

Hillman shared the draft Chelan PUD and Grant PUD Hatchery M&E Annual Report (which Sarah Montgomery distributed to the Hatchery Committees on June 15, 2017), and showed that Tables 5.34, 5.35, and 5.36 address stray rates. Specifically, Table 5.36 includes brood year stray rates, and the only proposed change would be deleting the language about the 5% target—the information about brood year stray rates would still be reported in the annual M&E report and can be viewed and assessed.

Kirk Truscott said without a target, there is potential for one party to believe there is an issue with brood year stray rates, but other parties may disagree. He said not having a target reduces direction and the potential to resolve these issues. Hillman said there is currently a brood year stray rate target of 5%, and some brood year stray rates are vastly over the target; however, this has not been a primary concern for the Hatchery Committees compared to the other stray rate targets. Bill Gale said brood year stray rate targets have been discussed extensively and some program changes have been made to address these high rates. Keely Murdoch said, for example, the intake and other items at the Chiwawa Acclimation Facility have been changed. Tonseth said those discussions and decisions were based mainly on recipient and between-population strays, not brood year stray rates.

Murdoch asked if removing the brood year stray rate target would affect discussions about the differences between homing and straying. Hillman said he does not believe it affects those discussions, because the tables in the annual report still includes both homing and straying rates. Gale said he is concerned that a program could achieve the recipient stray rate targets, but in a way that elevates the number of fish throughout all recipient targets. He said he does not favor a numbered target, but brood year stray rates are important to track. He proposed setting a qualitative target (e.g., "minimization") instead of a quantitative target. Brett Farman said there is still value in having a threshold value for context during discussions. He said removing the target altogether removes action incentives if there are continuing issues.

Mackey suggested thinking about brood year stray rates in a more integrated way, by considering escapement goals, the ratio of hatchery and wild fish on spawning grounds, and homing. He said homing is a tough metric to focus on, and broader management targets should be considered. For example, are the right number of fish in specific spots in the basin at the right ratio? Are released fish posing a risk? Is program size the right size so that not too much adult removal occurs?

Hillman said the current 5% brood year stray rate is not based on literature and is not even included in the text of the M&E Plan. He said it is included in the table and he thinks it was added to make statistical analyses easier. He said language should be added discussing the importance of this metric, minimizing strays, maximizing homing, and how the metric is related to other metrics with which it should be evaluated. He said he will draft this language for the Hatchery Committees to review.

Todd Pearsons advised against using the term "minimization" because it could put managers in a bad position, and suggested instead to integrate the stray rate variables and write new language.

Truscott suggested keeping the 5% brood year stray rate target and explaining in the annual report each year that it is not a management concern. Tonseth said this language can be added to the annual report regardless of whether the target remains. Tom Kahler said one concern for keeping the brood year stray rate target is how parties outside of the Hatchery Committees may interpret brood year stray rates not meeting the target. Truscott said his opinion is that it is preferable to have a target and explain why it was missed and why it is not biologically significant, rather than having no target at all. Catherine Willard added that in discussions about straying in the Methow basin, the questions regarding brood year stray rates were not about whether or not the target was exceeded; there were bigger concerns that were apparent with or without a target for comparison.

Tonseth suggested inserting an expectation that brood year stray rates fall in line with other metrics. He said, for example, in the Chewuch River, brood year stray rates are high and there are also facility limitations. Improvements to homing fidelity have been discussed, and a study design for adult translocation is one potential way to address the homing concerns. Hillman said setting a target for brood year stray rates would be difficult because Ford's work indicates that natural-origin stray rates in the Wenatchee basin range from 0 to 99%, and Chiwawa spring Chinook salmon from 1989 to 2004 had higher than 5% stray rates in all years except years when the program was not operating (Ford et al. 2015[1]). Truscott said he is wary of a situation where discussions about brood year stray rates are not considered because there is no longer a target. Gale said he thinks there is a stray problem in the Chiwawa River, and despite program changes and progress, if the brood year stray rate continues to be as high as 30% and other targets are being met, it should be a concern and should be discussed. Tonseth said brood year stray rates are calculated retrospectively and should be not relied on too heavily as a primary metric. Willard agreed and said return year data are better for assessing stray rates. Hillman summarized that he would draft new language for brood year stray rates under Objective 6 and provide a revised version for Hatchery Committees review.

Hillman said the next monitoring indicator objective in Table 1 of the M&E Plan for discussion is "determine if hatchery fish were released at program targets." He said these data are summarized in Appendix 5; however, k-factor targets are not included in the appendix. Mackey said appropriate k-factors for stocks included in Appendix 5 are unknown (and standard K-factors that have previously been used have been found to be inappropriate for the some stocks in the Upper Columbia). Tonseth agreed and said there are many fish culture differences; however, the expectation that the k-factor of hatchery fish is close to the k-factor for wild fish would be a reasonable target.

Hillman asked if there is anything in the M&E Plan that should be changed regarding this objective. Hillman pointed out that Appendix 5 lists the FPP target for Nason Creek at 18 to 24 FPP; however, in the Nason Creek chapter of the annual report, the program is compared to a target of 24 FPP. Pearsons said the Nason Creek program does not have a typical FPP goal because the growth profile

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[1] [1] Ford, M., A. Murdoch, and M. Hughes, 2015. Using parentage analysis to estimate rates of straying and homing in Chinook salmon (*Oncorhynchus tshawytcha*). *Molecular Ecology* 24:1109-1121.

is managed to reduce precocious maturation up to February. He said it is more accurate to compare the program to the target range of 18 to 24 FPP.

Hillman asked if the Chelan Falls summer Chinook salmon program has a range target for the same reason. Willard clarified that the target was changed to 13 FPP in the final 2017 Broodstock Collection Protocols and this target should be updated in Appendix 5. Hillman said he will make this update and distribute a revised version to the Hatchery Committees.

Hillman said the last objective in Table 1 for discussion is the monitoring indicator, "provide harvest opportunities when appropriate." Hatchery Committees representatives present voiced no changes or concerns for this objective.

Hillman said Table 2 of the M&E Plan addresses program objectives, indicators, and goals for segregated harvest augmentation hatchery programs including monitoring indicators. The monitoring indicator objectives in this table that have not been previously discussed include "determine if hatchery survival meets expectations," "determine if hatchery fish were released at program targets," and "provide harvest opportunities when appropriate." Hatchery Committees representatives present voiced no changes or concerns for these objectives.

Pearsons asked if this document will replace the 2013 update version. Hillman said yes, this document will be called Hillman et al. 2017.

Tonseth stated there will be no change to the genetic objectives because those updates are still pending.

D. Brood Year Stray Rate Targets (All)

The brood year stray rate targets discussion was covered under the Hatchery M&E Plan Objectives review in section III-C.

IV. Douglas PUD/WDFW/NMFS

A. Methow Steelhead Gene Flow (Greg Mackey/All)

Mike Tonseth said many discussions regarding Methow steelhead gene flow have taken place within the Joint Fishery Parties and in coordination meetings. Greg Mackey said the current plan includes moving the Douglas PUD 100,000 safety net steelhead release to the lower Methow River, where the fish used to be released. Keely Murdoch asked why the release was moved to Methow Fish Hatchery (FH). Tonseth said the release was moved to Methow FH to increase fidelity to the facility for gene flow management; however, steelhead do not reliably enter the volunteer channel and trap at Methow Hatchery nor ascend the ladder and go into the pond at WNFH. Tonseth said the Methow safety-net program is spring-acclimated in contrast to the Winthrop NFH program, which is fully acclimated. He said even the Winthrop NFH steelhead do not reliably return to the fish hatchery. Michael Humling (USFWS) said fine scale analyses of returning fish show that quite a few fish return to Spring Creek (the outlet of Winthrop NFH), but very few fish make it to the hatchery ponds.

Mackey said the latest gene flow plan includes areas for conservation zones and fishery zones. Tonseth said the terms may be revised. Bill Gale suggested the terms "natural production emphasis area" and "Methow mainstem," for referring to the differential gene flow management zones. Tonseth said management activities such as adult removal would occur in the Methow mainstem (previously called the fishery zone). Mackey said another item for discussion includes the proportion of hatchery-origin spawner (pHOS) targets for the two zones. Most recently discussed, the natural production emphasis zone would have a pHOS target of 0.25 and the overall basin target would be 0.5 (so the pHOS in the Methow mainstem zone could be higher than 0.5 as long as the overall basin target is met). Charlene Hurst suggested using a proportion of natural influence (PNI) target of 0.67 for the basin, instead of having a pHOS target. Tonseth said using a PNI instead of pHOS target for the basin makes more sense for meeting basin-wide objectives and in cases of low productivity.

Hurst said the proposed gene flow model includes weighting the fishery (Methow mainstem) zones at 30% of the population and the natural production emphasis zones at 70% of the population, which allows for higher pHOS in the Methow mainstem (such as a pHOS of 0.8 resulting in a basin-wide PNI of 0.71). She said one caveat to this is that the safety net program brood would have to be 100% from the conservation program, and she is not certain how often that is feasible. Mackey said that is not always feasible, and depends on whether broodstock is collected in the spring or in the fall. Tonseth agreed and said there is not enough mark differentiation to identify specific elements of programs. Tonseth said he recently distributed alternatives for marking so that adult returns to the conservation program could be better identified. Gale asked if all conservation program fish are marked with a coded wire tag (CWT). He said the program does not require many fish, so angling in the lower Methow River and transporting fish to Wells FH could work for broodstock collection instead of relying on broodstock collection at Wells Dam. Mackey said he thinks trapping at Wells Dam would achieve the desired number of broodstock, thus reaching a high percentage of safety net program source being from the conservation program. Tonseth said one concern for fall collection at Wells Dam is intercepting Wenatchee basin fish that have the same markings. Gale suggested reading the CWTs when fish are spawned and then backfilling with additional broodstock collection in the spring as needed. Truscott added that the passive integrated transponder (PIT) tag array in the lower Methow River can also be used to determine how many out-of-basin strays are in the area where broodstock is collected.

Gale said it would be reasonable to set the proportion of natural-origin broodstock target for the Winthrop and Twisp conservation programs at 0.9, . Hurst said she will use those pNOB values in consultation. Tonseth said with the current marking scheme, programs can acquire as much conservation hatchery-origin broodstock for the safety-net program as possible (i.e., almost 100%).

Hurst explained the the 25% pHOS in the conservation zone would only apply when the total spawning abundance in the Methow basin exceeds 500 spawners, in which case the pHOS in the conservation zone would be divided between programs such that conservation programs would have a pHOS target of 0.2 and the safety-net program would have a pHOS target of 0.05. Hurst said this would result in a basin-wide PNI of equal to or greater than 0.67 when the number of total spawners is greater than 500 fish, with the pHOS in the “fishery” zone being flexible as long as the basin-wide PNI target is met. Hurst also confirmed that the Methow FH release is being moved to a release location at a lower bridge and those fish will be reared at Wells FH. Gale asked if the 500 total spawners minimum is only natural-origin spawners. Mackey said no, the aggregate of hatchery plus wild spawners should be 500 fish, and when below 500 fish, the basin is managed for an escapement target of 500.

Tonseth summarized that PIT tag detections, viable salmon population (VSP) monitoring at Priest Rapids Dam, and maximizing PIT tags in steelhead will help managers track steelhead throughout the basin and maximize broodstock collection at favorable locations. Matt Cooper asked how the gene flow goals would be assessed. Tonseth said 5-year geometric means would be calculated, similar to the spring Chinook salmon programs. Cooper asked if every facility would perform parental based tagging analyses as part of this plan. Tonseth said yes. He also stated that Charlie Snow (WDFW) performs supplemental PIT tagging at Wells Dam during broodstock collection and run sampling. He summarized that maximizing tags and analyses for steelhead and maximizing steelhead trapping at Wells Dam to increase sample sizes will help inform managers where steelhead are going in the basin. Mackey said the lower Methow River PIT tag array is has low detection efficiency. WDFW is re-locating this array from its current location at Miller Hole. A new array will be installed at the new WDFW access site on the lower Methow.

Hurst said due to different pHOS targets for the conservation and safety-net programs, there is a need to differentiate between Wells FH mainstem releases from the safety-net releases in the Methow River. Tonseth said he is not sure if the juvenile PIT tag rate is high enough to address that question; however, tagging at Priest Rapids Dam and Wells Dam as part of the run composition assessment could improve differentiation. Tonseth said further discussion is warranted about how steelhead are marked in the upper Columbia River and how to maximize flexibility to implement and manage programs.

Hurst said regarding release sites for consultation, please provide the furthest upstream site so it can be factored into evaluating ecological effects, as well as the highest expected release number. Murdoch asked if all release sites need to be identified. Tonseth said no, and this topic and the marking topic can be discussed at the next coordination call.

Hurst said she will draft the proposed action for review and distribute it to the Hatchery Committees. Gale asked if the proposed action will be exclusive to Douglas PUD actions. Hurst said no, the proposed action will include Winthrop NFH actions in preparation for the BiOp. Sarah Montgomery clarified that the Wells Hatchery Committee will review the aspects of Hurst's plan pertaining to Douglas PUD actions.

V. HCP Administration

A. Hatcheries and Life Cycle Modeling (Hillman)

Tracy Hillman said Jeff Jorgensen and others have been working on a life-cycle model for Wenatchee River spring Chinook salmon, which includes a hatchery component. He said he asked Jorgensen if he would be interested in attending a Hatchery Committees meeting and presenting an overview of the model. Hillman said Hatchery Committees representatives could then provide questions and comments about Jorgensen's draft chapter describing the model (and Hillman has already provided some comments to Jorgensen). Hatchery Committees representatives present welcomed the idea of Jorgensen presenting the model, and Hillman said he would invite him to an upcoming meeting. Hillman said he will also distribute Jorgensen and others' draft chapter, "Wenatchee River spring-run Chinook salmon life-cycle model: hatchery effects, calibration, and sensitivity analyses," to the Hatchery Committees as background material.

Todd Pearsons said it would also be helpful for Jorgensen to share the comments he has received from the Independent Scientific Advisory Board (ISAB), and describe how he plans to incorporate those comments.

B. ISAB Visit (Hillman)

Tracy Hillman reminded the Hatchery Committees that the ISAB is visiting the upper Columbia River basin from July 19 to 21, 2017. He said the current plan is that they will take a 1-day field trip to both the Methow basin and the Wenatchee basin, and have 1 day for presentations and meetings.

C. Draft Hatchery M&E Annual Report (Hillman)

Tracy Hillman reminded the Hatchery Committees that the Draft 2016 Chelan PUD and Grant PUD Hatchery M&E Annual Report is available for a 30-day review, with comments due by July 15, 2017. Hillman said some sections of the report currently have placeholders. Specifically, he said 2016 data that rely on scale readings are incomplete because scale readings are not yet complete. He said the sockeye juvenile section is also missing data and there are some issues with Okanogan summer Chinook salmon data in the Regional Mark Information System. WDFW and the Colville Confederated Tribes are working to fix CWT data.

Tonseth added that WDFW will not be able to participate in Hatchery Committees tasks if Washington State does not have an approved budget by July 1, 2017, until the budget is approved.

D. Jeff Korth Retirement (Hillman)

Tracy Hillman reminded the Hatchery Committees that Jeff Korth (WDFW) is retiring at the end of June. Hatchery Committees representatives and alternates present collectively expressed best wishes for Korth in his retirement.

E. Next Meetings

The next Hatchery Committees meetings are on July 19, 2017 (Grant PUD), August 16, 2017 (Grant PUD), and September 20, 2017 (Grant PUD).

VI. List of Attachments

Attachment A List of Attendees

Attachment A
List of Attendees

Name	Organization
Tracy Hillman	BioAnalysts, Inc.
Sarah Montgomery	Anchor QEA, LLC
Catherine Willard*	Chelan PUD
Alene Underwood	Chelan PUD
Greg Mackey*	Douglas PUD
Tom Kahler*	Douglas PUD
Todd Pearsons‡	Grant PUD
Peter Graf‡	Grant PUD
Deanne Pavlik-Kunkel‡	Grant PUD
Bill Gale*	U.S. Fish and Wildlife Service
Matt Cooper*	U.S. Fish and Wildlife Service
Michael Humling	U.S. Fish and Wildlife Service
Brett Farman*†	National Marine Fisheries Service
Charlene Hurst*†	National Marine Fisheries Service
Emi Kondo†	National Marine Fisheries Service
Mike Tonseth*	Washington Department of Fish and Wildlife
Charlie Snow†	Washington Department of Fish and Wildlife
Keely Murdoch*	Yakama Nation
Kirk Truscott*	Colville Confederated Tribes

Notes:
* Denotes Hatchery Committees member or alternate
† Joined by phone
‡ Joined for the joint HCP-HC/PRCC HSC discussion

FINAL

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ANCHOR QEA

Memorandum

To: Wells, Rocky Reach, and Rock Island HCP Hatchery Committees

Date: August 21, 2017

From: Tracy Hillman, HCP Hatchery Committees Chairman

cc: Sarah Montgomery, Anchor QEA, LLC

Re: Final Minutes of the July 19, 2017, HCP Hatchery Committees Meeting

The Wells, Rocky Reach, and Rock Island Hydroelectric Projects Habitat Conservation Plan (HCP) Hatchery Committees meeting was via conference call on Wednesday, July 19, 2017, from 9:00 a.m. to 10:30 a.m. Attendees are listed in Attachment A to these meeting minutes.

Action Item Summary

- Andrew Murdoch (Washington Department of Fish and Wildlife [WDFW]) will write an overview of proposed expanded sampling at the off-ladder fish trap (OLAFT) at Priest Rapids Dam (Item I-A). *(Note: this item is ongoing.)*
- Hatchery Committees representatives will review McLain Johnson's Genetic Monitoring Update (Item I-A). *(Note: Sarah Montgomery distributed the update on April 6, 2017. This item is ongoing, and the update will be discussed at the August 16, 2017, Hatchery Committees meeting.)*
- Sarah Montgomery will clarify the review period for the Chelan PUD Draft 2018 Hatchery Monitoring and Evaluation (M&E) Implementation Plan and provide an update to the Hatchery Committees (Item II-A). *(Note: Montgomery sent a summary email with a clarification for the review period to the Hatchery Committees on July 25, 2017.)*
- Tracy Hillman will revise Appendix 4 of the Draft 2017 Update to the Monitoring and Evaluation Plan for PUD Hatchery Programs to include release number targets, and provide it for Hatchery Committees review (Item III-C). *(Note: Hillman revised the appendix and appended it to the Draft M&E Plan,, which Sarah Montgomery distributed to the Hatchery Committees on July 27, 2017.)*
- Tracy Hillman will revise the Draft 2017 Update to the M&E Plan for PUD Hatchery Programs and provide it for Hatchery Committees review (Item III-C). *(Note: Hillman revised the Draft 2017 Update to the M&E Plan for PUD Hatchery Programs for review, which Sarah Montgomery distributed to the Hatchery Committees on July 27, 2017.)*

Decision Summary

- There were no decisions discussed during today's meeting.

Agreements

- There were no agreements discussed during today's meeting.

Review Items

- Sarah Montgomery sent an email to the Rocky Reach and Rock Island Hatchery Committees on July 18, 2017, notifying them that the Chelan PUD Draft 2018 Hatchery M&E Implementation Plan is available for a 30-day review, with comments due to Catherine Willard by August 17, 2017. Chelan PUD indicated they will request approval of the Plan at the Hatchery Committees August 16, 2017, meeting.

Finalized Documents

- There are no documents that have been recently finalized.

I. Welcome

A. Review Agenda, Review Last Meeting Action Items, and Approve the June 21, 2017, Meeting Minutes (Tracy Hillman)

Tracy Hillman welcomed the Hatchery Committees and asked for any additions or changes to the agenda. Members made no additions or changes to the agenda.

The Hatchery Committees reviewed the revised draft June 21, 2017, meeting minutes. Sarah Montgomery said there are some outstanding comments to be discussed, which the Hatchery Committees reviewed and revised. Montgomery said she would check with Bill Gale about one paragraph before finalizing the minutes. Hatchery Committees representatives present approved the draft June 21, 2017, meeting minutes, as revised, and Montgomery confirmed the finalization via email on July 25, 2017.

Action items from the Hatchery Committees meeting on June 21, 2017, and follow-up discussions were addressed *(note: italicized text below corresponds to agenda items from the meeting on June 21, 2017)*:

- *Andrew Murdoch (Washington Department of Fish and Wildlife [WDFW]) will write an overview of proposed expanded sampling at the off-ladder fish trap (OLAFT) at Priest Rapids Dam (Item I-A).*
  This item is ongoing.
- *Hatchery Committees representatives will review McLain Johnson's (WDFW) Genetic Monitoring Update (Item I-A). (Note: Sarah Montgomery distributed the update on April 6, 2017.)*

This item is ongoing, and the update will be discussed at the August 16, 2017, Hatchery Committees meeting.

- *Chelan PUD, Douglas PUD, and Grant PUD representatives will discuss internally HCP requirements and coverage options for the unlisted programs in the upper Columbia River basin (Item III-B).*
  This item is complete.
- *Charlene Hurst will distribute the draft proposed action for Methow steelhead programs to the Hatchery Committees for a 2-week review (Item IV-A). (Note: Hurst sent the draft to Sarah Montgomery, which she distributed to the Hatchery Committees on June 22, 2017).*
  This item is complete.
- *Tracy Hillman will make the following revisions to the Monitoring and Evaluation (M&E) Plan for PUD Hatchery Programs (2013 Update): 1) draft footnotes for Table 1 regarding run timing, redd distribution, and spawn timing, and 2) revise Objective 6 (Items I-A and III-C).*
  Hillman made these updates and Sarah Montgomery distributed a revised version before the meeting.
- *Tracy Hillman will revise fish-per-pound (FPP) targets in Appendix 5 of the Hatchery M&E Plan according to the 2017 Broodstock Collection Protocols (Item III-C). (Note: Hillman made this revision and Sarah Montgomery distributed a revised Appendix 5 and compilation of Appendices 2-5 on June 23, 2017.)*
  This item is complete.
- *Tracy Hillman will invite Jeff Jorgensen (National Oceanic and Atmospheric Administration) to an upcoming Hatchery Committees meeting to present and discuss Wenatchee River spring-run Chinook salmon life-cycle modeling (Item V-A).*
  Hillman said this item is complete and Jorgensen plans to attend the Hatchery Committees August 16, 2017, meeting.
- *Tracy Hillman will distribute Jorgensen et al.'s draft chapter, "Wenatchee River spring-run Chinook salmon life-cycle model: hatchery effects, calibration, and sensitivity analyses" to the Hatchery Committees (Item V-A). (Note: Hillman sent the chapter to Sarah Montgomery, which she distributed to the Hatchery Committees on June 22, 2017.)*
  This item is complete.

II. Chelan PUD

A. Draft 2018 Hatchery M&E Implementation Plan (Catherine Willard)

Catherine Willard said the Chelan PUD Draft 2018 Hatchery M&E Implementation Plan is currently available for a 30-day review (Attachment B) and any comments or questions should be directed to her. She said the changes between the 2017 and 2018 plans are minor and include only date and authorship changes. Willard said Chelan PUD will request that the Rocky Reach and Rock Island Hatchery Committees approve this plan at the August 16, 2017, Hatchery Committees meeting. Sarah Montgomery said she will clarify the review dates for this document and provide an update to the Hatchery Committees.

III. Joint HCP-HC/PRCC HSC

A. USFWS Bull Trout Consultation Update (Matt Cooper)

Tracy Hillman said Matt Cooper (U.S. Fish and Wildlife Service [USFWS]) sent him an email update for this topic because USFWS staff are unable to attend today's meeting. Hillman summarized the update as follows:

- Karl Halupka is finishing revisions to the Biological Opinion for the batch of Wenatchee subbasin programs and expects it will be finalized by early August 2017.
- The USFWS reviewed a draft proposed action for mainstem unlisted hatchery programs and provided comments to the National Marine Fisheries Service (NMFS). After NMFS responds to comments, the USFWS will decide on a consultation approach for this batch of hatchery programs. Currently the batch does not include Similkameen summer Chinook salmon programs, which USFWS has asked NMFS about. (Note: Emi Kondo [NMFS] stated that she spoke with Halupka regarding this consultation and said the Similkameen summer Chinook salmon program has been analyzed as part of the Okanogan Tribal Resources Management Plan and therefore does not need further consultation or coverage.)
- The USFWS has begun reviewing the proposed action for the Methow summer steelhead program. The primary objective of the review is to inform the USFWS' selection of a pathway to take for completing consultation on this program. A memo similar to the one USFWS completed for the Methow spring Chinook salmon program is one of several options being considered. One key factor in this decision is the degree to which changes in the program since prior consultation may change the program's effects on bull trout and bull trout critical habitat.

Kondo said Charlene Hurst and Halupka have a coordination call on July 24, 2017, to discuss the upper Columbia River (UCR) unlisted programs consultation.

B. NMFS Consultation Update (Brett Farman/Emi Kondo)

Emi Kondo said she has an update on the UCR unlisted programs consultation. She said she received comments on the draft proposed action and expects a few more comments as well. She said the Hatchery Committees discussed the pathway for Endangered Species Act (ESA) coverage for these programs during the June 21, 2017, Hatchery Committees meeting. She said the next step for consulting on this bundle of programs is deciding on the ESA pathway (i.e., Section 10 or Section 4(d) coverage). She said Douglas PUD has indicated that they prefer pursuing Section 10 coverage, while Chelan PUD and Grant PUD have indicated they want to have more discussion with NMFS General Counsel before deciding. She said coordination calls are occurring next week and she can also set up additional calls for anyone interested. She said in addition to deciding on the ESA pathway, another important step is formally initiating consultation. She said the applicants will need to send a letter requesting initiation of consultation, to which NMFS can reply with a submissions letter. Kondo said the letter should describe the consultation process, and once the proposed action is finalized it can be submitted with the letter. Greg Mackey asked Kondo for an example of the letter.

Todd Pearsons said when Grant PUD submitted hatchery and genetic management plan (HGMP) documentation, they submitted a letter requesting coverage, and asked if sending a second letter requesting consultation would be duplicative. Kondo said she will check internally to see if the letter submitted with HGMP documentation is sufficient.

C. M&E Plan for PUD Hatchery Programs 2017 Update (All)

Tracy Hillman said he revised the M&E Plan for PUD Hatchery Programs to reflect changes discussed during the June 21, 2017, Hatchery Committees meeting and also made some editorial edits. Sarah Montgomery distributed the draft revised plan to the Hatchery Committees before the meeting on July 19, 2017 (Attachment C).

Hillman said he added footnotes to Table 1 and Table 2, indicating that more detailed information is included in the appendices. He said he revised the objective in Table 1 "Determine if *recipient* stray rate of hatchery fish is acceptable" (italics are new text) and added a clarifying paragraph to Objective 6 describing the different types of stray rates and stray rate metrics. He added clarifying language to Objective 3 (HRRs), and added references for the appropriate appendices throughout the descriptions of objectives.

Hillman asked the Hatchery Committees why length and weight targets are missing from Appendix 4, which includes fish per pound (FPP), coefficient of variation (CV), and condition factor targets. He said in the M&E Plan, there are targets for size, length, weight, and condition factor. He said Appendix 4 also does not include the number of fish targeted for release (currently in Appendix 2). He asked if Appendix 4 should be revised to include number of fish targeted for release and length and weight targets. Greg Mackey said adding those values to Appendix 4 might make the table unwieldy. Mackey said the statistical test for length was used more to compare the length of hatchery fish to wild fish, and was used less as a true target. Hillman recalled in the last comprehensive report, there were both length and weight targets at release for programs. He said he and Andrew Murdoch (WDFW) performed the analyses for the comprehensive report, and found that size and weight targets often cannot be achieved (i.e., either one can be met, but not both). He said the targets should be revised to better reflect how fish grow, but they have not yet been revised. He suggested adding these targets to Appendix 4. This will place all within-hatchery targets in one appendix. Hearing no objections, Hillman said he would make these revisions for the Hatchery Committees to review.

Hillman said he added clarifications to Objectives 4, 5, and 6 to redirect readers to related appendices. In Objective 5, he said he edited the language about spawn timing to be consistent with Appendix 4 and added an additional hypothesis, "$Ho_{5.2.1.3}$: The relationship between elevation and spawn timing of hatchery-origin fish = the relationship between elevation and spawn timing of natural-origin fish." Mackey asked if the term elevation is accurate or if the hypothesis should address river kilometer. Hillman said the analysis uses elevation, at least in the Chiwawa River; however, river kilometer can be used as a surrogate for elevation.

Todd Pearsons asked about Hillman's edits to the possible statistical analyses for Objective 5. Hillman said he changed the use of an analysis of covariance (ANCOVA) to "Graphic and regression analysis to assess relationships between elevation and spawn timing" because ANCOVAs use discrete variables and elevation is not a discrete variable. He said using continuous variables retains the most information in the data and this regression analysis would be similar to analyses for productivity. He said using an ANCOVA would not be wrong, but it is cleaner to perform regressions for spawn timing and elevation for both wild and hatchery fish, then compare the regressions.

Hillman said he added a paragraph to Objective 6 that the Hatchery Committees should review in detail and clarified percent stray rates throughout the section. Mackey said the paragraph is a good synopsis and asked if annual stray rates and brood-year stray rates would converge to approximately the same rate over a long period, for example 25 years. Hillman said that would typically be the case and was true for the Chiwawa River analysis. However, he said in the Twisp River the rates did not converge and depend on the size of the hatchery program and the size of the recipient population. He said all three stray rates should be examined, but brood-year stray rate targets are not included in the Recovery Plan or Technical Recovery Team documents.

Hillman said he also revised the title of section 6.1.1 to be "Brood-Year Stray Rates" instead of "Stray Rates among Populations by Brood Return," to match the statistical analyses being performed. Mackey agreed and said the title now reflects the analyses being performed and originally stray rates analyses may have been intended to be limited to populations.

Hillman said he also made edits to Objective 9. He asked whether length and weight targets (Q9.1.1) should be added to Appendix 5 and if the targets are going to be revised. Pearsons suggested using the broodstock collection protocol targets (FPP and CV), because they directly represent management guidance given to hatchery staff. Hillman agreed and said using FPP targets is easier and should be considered as a target instead of length and weight. Mackey agreed and said FPP can be extrapolated to determine length or weight per fish if those metrics are needed. Hillman said he will make this edit in the next revised version of the plan for review. Hillman said regarding Q9.3.1, that program K (condition factor) targets are listed as "TBD" in Appendix 5. Hillman said regarding Q9.4.1, the release targets currently identified in Appendix 2 could be moved to Appendix 5 for ease of finding information quickly.

Hillman said he is still working on Appendix 1, which discusses carrying capacity, and expects it will be finished in September 2017.

Pearsons asked about the timeline for finalizing the 2016 Hatchery M&E Annual Report. Hillman said he has received comments on the draft and is incorporating comments and revising the document. He said the report is due on September 15, 2017, but will likely be completed before that date. Pearsons said it would be good to provide the annual report and the revised Hatchery M&E Plan for PUD Hatchery Programs (2017 Update) to the Independent Scientific Advisory Board in early fall so they can incorporate the most recent documents in their review and said he has no problems with the current timelines for finalizing these documents.

IV. HCP Administration

A. Next Meetings

The next Hatchery Committees meetings are on August 16, 2017 (Grant PUD), September 20, 2017 (Grant PUD), and October 18, 2017 (Grant PUD).

V. List of Attachments

Attachment A List of Attendees
Attachment B Chelan PUD Draft 2018 Hatchery M&E Implementation Plan
Attachment C Draft Hatchery M&E Plan for PUD Hatchery Programs (2017 Update)

Attachment A
List of Attendees

Name	Organization
Tracy Hillman	BioAnalysts, Inc.
Sarah Montgomery	Anchor QEA, LLC
Catherine Willard*	Chelan PUD
Greg Mackey*	Douglas PUD
Todd Pearsons‡	Grant PUD
Peter Graf‡	Grant PUD
Deanne Pavlik-Kunkel‡	Grant PUD
Brett Farman*	National Marine Fisheries Service
Emi Kondo	National Marine Fisheries Service
Keely Murdoch*	Yakama Nation
Kirk Truscott*	Colville Confederated Tribes

Notes:
* Denotes Hatchery Committees member or alternate
‡ Joined for the joint HCP-HC/PRCC HSC discussion

Chelan County PUD Hatchery Monitoring and Evaluation Implementation Plan 2018

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Prepared by:

Catherine Willard

Deleted: Alene Underwood and

July 2017

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Contents

1. INTRODUCTION 1
2. AQUACULTURE MONITORING 4
2.1 Broodstock Collection and Stock Assessment 5
2.2 In-Hatchery Monitoring 5
2.3 Release Monitoring 6
3. JUVENILE MONITORING 8
3.1 Freshwater productivity of Supplemented Stocks 8
3.2 Tributary Evaluations 9
4. ADULT MONITORING 10
4.1 Spawning Escapement Estimates 12
Wenatchee Steelhead 12
Chiwawa and Methow Spring Chinook 12
Wenatchee Summer Chinook 13
4.2 Harvest Reporting 13
5. DATA MANAGEMENT , ANALYSIS, AND REPORTING 14
5.1 Data Management 14
5.2 Data Analysis 14
5.3 Reporting 14
6. Lake Wenatchee Sockeye Salmon 14
6.1 Juvenile Monitoring 15
6.2 Adult Monitoring 15
Appendix A 20

1. Introduction

The Habitat Conservation Plan (HCP) specifies that a monitoring and evaluation plan will be developed for the hatchery program. The approach to monitoring the hatchery programs was guided by the "*Monitoring and Evaluation Plan for PUD Hatchery Programs: 2013 Update"* (Hillman et al. 2013) and the "*Conceptual Approach to Monitoring and Evaluating the Chelan County Public Utility District Programs*" (Murdoch and Peven 2005).

The purpose of this document is to define the tasks associated with the approved scope of work to implement Chelan PUD's (CPUD's) hatchery monitoring and evaluation (M&E) plan for 2018. Additionally, monitoring and evaluation activities for Lake Wenatchee sockeye in 2018 are included in this document. As monitoring tasks are completed in 2017 and are evaluated for their efficacy, methodologies to accomplish the tasks defined in the 2018 Implementation Plan may be modified [with Habitat Conservation Plan's Hatchery Committee (HCP-HC) approval].

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The work described in this plan has Endangered Species Act (ESA) coverage provided by NFMS Section 10(a)(1)(A) permits 18121 and 1395 and Section 10(a)(1)(B) permit 1347. All activities conducted under this Implementation Plan shall adhere to all terms and conditions as specified in the referenced permits. These permits allow for changes to monitoring or research protocols with the caveat that such modifications are approved by NMFS prior to implementing those changes. Terms and conditions relevant to monitoring and evaluating the hatchery programs have been used to inform the various measurements below and associated scopes of work with entities performing the work. A report summarizing compliance with the terms and conditions set forth under the above-references permits is required for submittal to NMFS; a copy of this completed report will be provided to the HCP HC.

The Implementation Plan includes all four components of the hatchery M&E Program including: (1) aquaculture monitoring; (2) juvenile monitoring; (3) adult monitoring; and (4) data, analysis and reporting. Under each component are study design elements that will be used to inform the overarching program components. Figure 1 illustrates the relationship of the components and study design elements used to address each component. Table 1 depicts which study design element is being performed by entity, and the associated objectives for each study design element as referred to in Hillman et al. 2013. For Lake Wenatchee sockeye salmon, the proposed M&E activities cover juvenile and adult life history stages and provide the data necessary to track or estimate viable salmonid population parameters (VSP) and is described in Section 6.0.

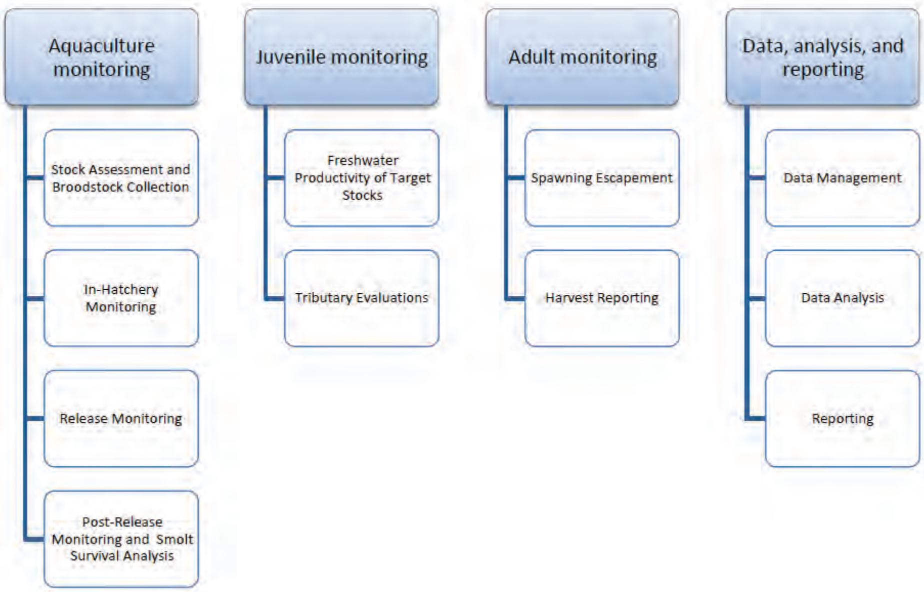

Figure 1. The four components of the hatchery monitoring and evaluation program and the study design elements within each component.

Table 1. Study design elements performed by entity, and the associated objectives for each study design element as referred to in Hillman et al. 2013.

Monitoring and evaluation component	Objectives[1]	Study Design Elements	Chiwawa spring Chinook	Wenatchee summer Chinook	Methow spring Chinook[4]	Chelan Falls summer Chinook[5]	Wenatchee Steelhead
Aquaculture Monitoring	3,5,8	Stock assessment and broodstock collection	WDFW	WDFW	WDFW	WDFW	WDFW
	5, 8	In-hatchery monitoring	WDFW CPUD[2]	WDFW CPUD[2]	WDFW Biomark[3]	WDFW CPUD[2]	WDFW CPUD[2]
	9	Release monitoring	WDFW	WDFW	WDFW	WDFW	WDFW
	9	Post-release monitoring and smolt survival analysis	WDFW	WDFW	WDFW	WDFW	WDFW
Juvenile monitoring	2	Freshwater productivity of stocks	WDFW	WDFW	WDFW	NA	WDFW
		Tributary evaluations	WDFW	WDFW	WDFW	NA	WDFW
Adult monitoring	1,2,3,4,5,6, 8,10	Spawning escapement	CPUD	WDFW	WDFW	BioAnalysts	WDFW
	8	Harvest reporting	WDFW	WDFW	WDFW	WDFW	WDFW
Data, analysis, and reporting	All	Data management	WDFW CPUD BioAnalysts	WDFW BioAnalysts	WDFW	WDFW BioAnalysts	WDFW BioAnalysts
		Data analysis	WDFW CPUD BioAnalysts	WDFW BioAnalysts	WDFW	WDFW BioAnalysts	WDFW BioAnalysts
		Reporting	WDFW CPUD BioAnalysts	WDFW BioAnalysts	WDFW	WDFW BioAnalysts	WDFW BioAnalysts

[1] Monitoring questions relative to Objective 7 will be addressed at the next 10 year HCP check-in.
[2]CPUD crews will PIT tag in-hatchery fish.
[3]Biomark will PIT tag in-hatchery fish.
[4]In 2018, monitoring and evaluation for the Methow spring Chinook program is described in "Implementation of Comprehensive Monitoring and Evaluation of Wells Hatchery Complex Programs".
[5]Because the Chelan summer Chinook program is primarily an augmentation program, monitoring and evaluation efforts focus on straying, release characteristics, and harvest.

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2. Aquaculture Monitoring

The aquaculture monitoring component is comprised of two basic elements: (1) stock assessment and broodstock collection at adult trapping locations and (2) in-hatchery monitoring including spawning, rearing, and release of juveniles. Data collected during these elements primarily support monitoring questions 5.1.1, 5.2.1, 8.1.1, 8.2.1, 8.3.1, 8.3.2, 8.4.1, 9.1.1, 9.2.1, 9.3.1 and 9.4.1, but also contribute data to monitoring questions 3.2.1, and 3.2.2 (Hillman et al. 2013). Table 2 below provides a summary of the variables to be measured in 2018 under the aquaculture monitoring component and what objective the measure(s) supports. The text that follows in this section further describes the activities.

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Table 2. Monitoring and Evaluation Plan (Hillman et al. 2013) objectives and the associated measured variables for the aquaculture monitoring component.

Objectives	Measured Variables *(Applicable Study Component(s))*
Objective 3: Determine if the hatchery adult-to adult survival (i.e., hatchery replacement rate, HRR) is greater than the natural adult-to adult survival (i.e., natural replacement rate, NRR) and the target hatchery survival rate.	• Number of hatchery and naturally produced fish collected for broodstock (*Broodstock Collection and Stock Assessment*) • Number of broodstock used by brood year (hatchery and naturally produced fish) (*Broodstock Collection and Stock Assessment*)
Objective 5: Determine if the run timing, spawn timing, and spawning distribution of the hatchery component is similar to the natural component of the target population or is meeting program-specific objectives.	• Ages of hatchery and naturally produced fish sampled via PIT tags or stock assessment monitoring (*Broodstock Collection and Stock Assessment*) • Time (Julian date) of ripeness of hatchery and natural origin steelhead captured for broodstock (*Broodstock Collection and Stock Assessment*)
Objective 8: Determine if hatchery programs have caused changes in phenotypic characteristics of the natural populations.	• Size (length), gender, and total/salt age of broodstock (*Broodstock Collection and Stock Assessment*) • Assess age of fish (*Broodstock Collection and Stock Assessment*) • Length, weight, and age (covariate) of hatchery and natural-origin broodstock after eggs have been removed (*Broodstock Collection and Stock Assessment*) • Number and weight of eggs (*Broodstock Collection and Stock Assessment*)
Objective 9: Determine if hatchery fish were released at the programmed size and number.	• Fork length and weights of random samples of hatchery juveniles at release (*Release Monitoring*) • Monthly individual lengths and weights of random samples of hatchery juveniles (*In-Hatchery Monitoring*) • Numbers of smolts released from the hatchery (*Release Monitoring*)

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2.1 Broodstock Collection and Stock Assessment

Broodstock collection and stock assessment for Wenatchee summer steelhead, Wenatchee summer Chinook, Methow spring Chinook, Chelan Falls summer Chinook, and Chiwawa River spring Chinook, hatchery programs will, in most instances, occur concurrent to and consistent with the Broodstock Collection Protocol approved annually by the HCP-HC and relevant permits. Data collection during broodstock collection will be consistent with Murdoch and Peven (2005). A representative sample of fish trapped throughout the entire run, either collected for broodstock or released back to the river, will be sampled for origin, age, sex, size, and migration timing. Biological sampling of all fish trapped will include presence of internal (CWT or PIT) and external (VIE) tags or marks, scales, length, and sex (determined by ultrasound). PIT tags will be injected into all target species (Chinook and steelhead), whether collected for broodstock or released back to the river to monitor for potential fallbacks. All non-target species will be enumerated daily. Measures of central tendency and spread will be calculated and reported for each metric.

2.2 In-Hatchery Monitoring

The in-hatchery monitoring component will begin when adult fish are collected and retained for broodstock and ends when juvenile fish are released. Life stage specific in-hatchery survival and growth rates, disease monitoring, and an estimate of the number of fish released will be collected and analyzed according to Murdoch and Peven (2005). Additional data to be collected includes individual lengths and weights of juveniles during monthly sampling, and the weight of gonadal mass and body of spawned broodstock. Measures of the central tendency and spread will be calculated and reported for each metric.

Fish Marking

All of Chelan PUD's hatchery fish will be coded-wire tagged (CWT) and externally marked or marked as otherwise agreed to by the HCP HC. A comprehensive marking strategy will be developed by the HCP-HC and included as an Addendum to this Plan. The identification of these hatchery-produced fish is needed for a suite of adult metrics and may be used for adult management and/or fisheries as contemplated by the co-managers.

Using methods described in Keller and Murauskas (2012), hatchery fish will be PIT-tagged (Table 3) at Eastbank Hatchery approximately two to four weeks before the fish are transferred to acclimation ponds or in the spring prior to release. Additional PIT-tagging may occur for program specific studies/comparisons as approved by the HCP-HC. The data collected from the PIT-tags will assist in release monitoring, migration timing, juvenile survival, and smolt-to-adult survival. For all fish marking, quality control check will be performed during and immediately following tagging and prior to release.

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Table 3. Chelan PUD's hatchery program release goals and recommended number of fish PIT tagged.

Program	Release goals	Number of fish PIT tagged[1]	PIT tag rate (%)
Chiwawa spring Chinook	144,026	10,000	6.9
Wenatchee steelhead	247,300	20,000	8.0
Wenatchee summer Chinook	318,816 (CPUD Program) 181,184 (GPUD Program)	20,600	4.1
Methow spring Chinook	60,156	5,000	8.3
Chelan Falls summer Chinook	576,000	10,000	1.7

[1] Additional PIT tagging may take place for Chelan PUD approved studies and/or comparisons.

2.3 Release Monitoring

Hatchery fish will be released during smoltification in the spring, typically between 15 April and 1 June. Whenever possible, the exact release dates will coincide with environmental conditions that promote a rapid emigration that minimizes both the potential negative ecological interactions of hatchery fish with naturally produced fish and predation on hatchery fish by avian or other predators. The default release method will incorporate a volitional approach, as approved by the HCP HC, unless it can be demonstrated other approaches are better. The monitoring data collected for each stock are described below.

Chiwawa and Methow Spring Chinook

Pre-release sampling data will be conducted consistent with Murdoch and Peven (2005), including individual weights to the nearest 0.1 gram. Data collected will support monitoring questions 9.1, 9.2, 9.3 and 9.4 in the updated monitoring and evaluation plan (Hillman et al. 2013). PIT tag monitoring of spring Chinook released in the Chiwawa River will occur during the release period (April). Juvenile Chinook will pass through two 92-cm diameter PIT-tag antennas connected to Allflex 310 readers and Quantitative Sampling Technologies (QST) QuBE data logger. The release location and type (i.e., volitional, forced, or trucked) are recorded for each observation file created and uploaded to the PTAGIS database maintained by the Pacific States Marine Fisheries Commission after each year of release. PIT-tagged fish in each observation (release) file are assumed to represent untagged fish. Observation files contain the PIT tags associated with the original tag files and will be used for analysis (see Post-release Monitoring Section). The total number of fish released will be based on the population size at CWT tagging (100%), subtracting mortality enumerated by hatchery staff that occurred from tagging to release.

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Wenatchee Summer Steelhead–
Pre-release sampling will be conducted consistent with Murdoch and Peven (2005), including individual weights to the nearest 0.1 gram. Data collected will support monitoring questions 9.1, 9.2, 9.3 and 9.4 in the updated monitoring and evaluation plan. Monitoring of steelhead released in the Wenatchee River sub-basin will occur during loading of fish into transport trucks, unless fish are released directly into the Chiwawa River. Steelhead will pass through a series of PIT-tag antennas, each connected to a data logger, thereby allowing the creation of a PIT-tag observation file for each truckload of steelhead consisting of unique tag records. The release location (stream and rkm), release type (volitional or forced), and hatchery group (HxH or WxW) will be recorded for each tag file created. PIT-tagged fish in each observation (release) file are assumed to represent untagged fish. However, because PIT-detection efficiency during loading will not be 100%, the number of fish in each truckload will be estimated using volumetric displacement. Observation files contain the PIT tags associated with the original tag files and will be used for analysis (see Post-release Monitoring Section). The total number of fish released will be based on the population size at CWT tagging (100%), subtracting mortality enumerated by hatchery staff that occurred from tagging to release.

Wenatchee and Chelan Falls Summer Chinook
Pre-release sampling will be conducted consistent with Murdoch and Peven (2005), including individual weights to the nearest 0.1 gram. Data collected will support monitoring questions 9.1, 9.2, 9.3 and 9.4 in the updated monitoring and evaluation plan. Should PIT tagging occur, a monitored release strategy consistent with other Chinook stocks (i.e., Chiwawa Spring Chinook) will be implemented. The total number of fish released will be based on the population size at CWT tagging (100%), subtracting mortality enumerated by hatchery staff that occurred from tagging to release.

2.4 Post-Release Monitoring and Survival Analysis
Data will be collected during rearing, acclimation, release, and the emigration period that may prove valuable in explaining variability in adult survival (Murdoch and Peven 2005). Rearing densities have been reported to influence the survival of hatchery fish (Martin and Wertheimer 1989; Banks 1994) and may also be linked to disease prevalence during rearing (Banks 1994; Ogut and Reno 2004). Acclimation of hatchery fish before release has been found to increase survival and reduce stray rates when the duration of the acclimation period is sufficient (Clarke et al. 2010, 2012; Rosenberger et al. 2013). These metrics (i.e., rearing density and acclimation period) will be collected annually to determine their influence on fish survival.

PIT-tagged groups of hatchery fish will be used to estimate survival during their emigration. Variation in survival during the emigration period may also inform observed adult survival rates. Survival during emigration and travel will be estimated using interrogation or release files and the standard Cormack-Jolly-Seber (CJS) estimator. CJS estimates are termed apparent survival estimates because it is unknown whether fish suffered mortality (e.g., size or time of release) or simply failed to emigrate (i.e., residualized or were precocial males). In the latter case, the proportion of PIT-tagged fish detected in the Methow sub-basin, Wenatchee or Columbia rivers after the emigration period is complete may explain variation in smolt survival rates. The post-release performance of PIT-tag groups will be estimated and monitored annually, consistent

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with methods in Murdoch and Peven (2005). Additionally, precocity of hatchery releases will be evaluated by examining the proportion of PIT tag releases detected in adult fish ladders and tributaries within the same year as release.

3. Juvenile Monitoring

Data collected during these elements primarily support monitoring questions 2.1.1 and 2.2.1. and the monitoring objectives described in Table 4 (Hillman et al. 2013). Table 4 below provides a summary of the variables to be measured in 2018 under the juvenile monitoring component and what objective the measure supports. The text that follows in this section further describes the activities.

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Table 4. Monitoring and Evaluation Plan (Hillman et al. 2013) objectives and the associated measured variables for the juvenile monitoring component.

Objective	Measured Variables *(Applicable Study Component(s))*
Objective 2: Determine if the proportion of hatchery fish on the spawning grounds affects the freshwater productivity of supplemented stocks.	• Number of juveniles (smolts, parr [where appropriate], and emigrants) (*Freshwater Productivity of Supplemented Stocks*)

3.1 Freshwater productivity of Supplemented Stocks

Steelhead, Spring Chinook, and Summer Chinook

The freshwater productivity of supplemented stocks in the Wenatchee sub-basin will be monitored using smolt traps in the Chiwawa River and the lower Wenatchee River consistent with historical trapping efforts. Additionally, a newly derived analytical method which uses PIT-tag mark-recapture data will be utilized that reduces bias and increases precision by including estimates of emigration during the winter non-trapping periods. Up to 3,000 parr will be PIT tagged in the Chiwawa River in the fall, based on the spatial distribution and abundance estimated during parr snorkel surveys, to generate estimates of migration during the non-trapping periods. A random sample of a minimum of 10 percent of fish per remote site will be held in a live box for 24 hours to evaluate tag loss and delayed mortality. Using PIT tagged parr detections at the lower Chiwawa PIT array during the non-trapping period, the total number of PIT-tagged parr that emigrated will be estimated, and then expanded by the tag rate. Overwinter mortality of PIT-tagged parr is assumed to be the same as non-PIT-tagged parr. Overwinter survival estimates of Chiwawa River parr will be derived by estimating survival to the lower Wenatchee PIT tag array and analyses with the TribPit Survival software program and/or estimating survival of fall parr and spring smolts to McNary. PIT-tag mark-recapture trials conducted during the trapping period in the fall will also be used to estimate detection probabilities of the PIT-tag array at a given discharge level. Abundance and variance will be estimated using the same methods as those used in the smolt trap estimate. The estimated abundance and variance from each method and time period (trapping and non-trapping

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periods) will be summed to estimate a total production estimate. Under the proposed methodology, unbiased estimates of abundance during the entire migration period will be generated with relatively high precision (PSE < 15%), which is consistent with NOAA Fisheries' recommendations (Crawford and Rumsey 2011). Historical estimates will be revised using the new estimation techniques.

Specific actions to monitor the freshwater productivity of supplemented spring Chinook salmon in the Methow sub-basin have yet to be determined. As these become available, the plan will be amended and presented to the HC by December.

3.2 Tributary Evaluations

Chiwawa River

Snorkel surveys will be utilized to estimate parr abundance within the Chiwawa subwatershed during the summer. This approach has been used in the Chiwawa subwatershed since 1992. In parallel to addressing Objective 2, additional juvenile data can help to assess the habitat carrying capacity in each tributary. This information can add value to the overall M&E plans and help inform management decisions.

Sampling will follow a stratified random sampling design. Landscape classification will be used to stratify streams in the Chiwawa subwatershed that support juvenile Chinook salmon. In the Chiwawa subwatershed, WDFW found that classification "explained" most of the variability in fish numbers caused by geology, land type, valley bottom type, stream state condition, and habitat type (Hillman 2013). The same classification method was used to identify sections of the Little Wenatchee River (reference area) that corresponded to discrete reaches in the supplemented subwatersheds, but that had no release of hatchery Chinook. Consistent with previous efforts, habitat types within each land-class or reach will be identified and quantified annually. At least three units of each habitat type within each reach will be randomly selected for estimating densities of salmon and trout. Thus, overall sampling consists of a stratified- random sampling design, which increases the accuracy and precision of population estimates.

Densities of salmon and trout will be estimated in August and September by direct underwater observation within the randomly-selected habitat units. Underwater methods will follow those described by Thurow (1994), Dolloff et al. (1996), and O'Neal (2007). Habitat surface areas and volumes will be estimated during fish sampling. Numbers of fish counted will be adjusted for detection probabilities using the models published in Hillman et al. (1992). For each habitat type within a state type and reach stratum, the mean density of salmon and trout will be calculated as the ratio of mean numbers to mean area or volume sampled (Cochran 1977). Total numbers of fish will be estimated per habitat type within a state type and reach stratum as the product of mean density of fish in a given habitat type, times total area or volume of that habitat type within the stratum (Cochran 1977). Total numbers of fish within the supplemented subwatershed will be estimated as the sum of all population numbers per habitat type in state type/reach strata. Bootstrapping methods will be utilized to estimate variance and percent errors (based on 95% confidence interval) for total numbers of fish.

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4. ADULT MONITORING

The adult monitoring component is comprised of two basic elements: (1) estimating spawning escapement and (2) harvest monitoring. Data collected during these elements primarily support monitoring questions 1.1.1, 1.2.1, 2.1.1, 2.2.1, 3.2.1, 3.2.2, 4.1.1, 5.1.1, 5.2.1, 5.3.1, 5.3.2, 6.3.1, but also contribute data to monitoring questions 6.1.1, 6.2.1, 8.1.1, 8.2.1, 8.4.1, 10.1.1, 10.1.2, 10.1.3 and 10.1.4. Table 5 below provides a summary of the variables to be measured in 2018 under the adult monitoring component and what objective the measure(s) supports. The text that follows in this section further describes the activities.

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Table 5. Monitoring and Evaluation Plan (Hillman et al. 2013) objectives and the associated measured variables for the adult monitoring component.

Objective	Measured Variables *(Applicable Study Component(s))*
Objective 1: Determine if conservation programs have increased the number of naturally spawning and naturally produced adults of the target population and if the program has reduced the natural replacement rate (NRR) of the supplemented population.	• Number of hatchery and naturally produced fish on spawning grounds *(Spawning Escapement Estimates)* • Number of hatchery and naturally produced fish taken for broodstock (*Broodstock Collection and Stock Assessment*) • Number of hatchery and naturally produced fish taken in harvest (if recruitment is to the Columbia) *(Harvest Reporting)*
Objective 2: Determine if the proportion of hatchery fish on the spawning grounds affects the freshwater productivity of supplemented stocks.	• Number of hatchery and naturally produced fish on the spawning grounds (*Spawning Escapement Estimates*) • Number of redds *(Spawning Escapement Estimates)*
Objective 3: Determine if the hatchery adult-to-adult survival (i.e., hatchery replacement rate, HRR) is greater than the natural adult-to-adult survival (i.e., natural replacement rate, NRR) and the target hatchery survival rate.	• Number of hatchery and naturally produced fish on spawning grounds *(Spawning Escapement Estimates)* • Number of hatchery and naturally produced fish harvested *(Harvest Reporting)*
Objective 4: Determine if the proportion of hatchery-origin spawners (pHOS or PNI) is meeting management target.	• Number of hatchery and naturally produced fish on spawning grounds *(Spawning Escapement Estimates)*
Objective 5: Determine if the run timing, spawn timing, and spawning distribution of the hatchery component is similar to the natural component of the target population or is meeting program-specific objectives.	• Time (Julian date) of hatchery and naturally produced salmon carcasses or marked steelhead detected on spawning grounds within defined reaches *(Spawning Escapement Estimates)* • Time (Julian date) of arrival at mainstem projects and within tributaries (e.g., traps, PIT arrays) with

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Objective	Measured Variables *(Applicable Study Component(s))*
	the intent to identify biologically significant differences *(Spawning Escapement Estimates)* • Location (GPS coordinates) of female salmon carcasses observed on spawning grounds *(Spawning Escapement Estimates)*
Objective 6: Determine if stray rate of hatchery fish is below the acceptable levels to maintain genetic variation among stocks.	• Number of hatchery fish collected for broodstock (*Broodstock Collection and Stock Assessment*) • Number of hatchery fish taken in fishery (*Harvest Reporting*) • Locations of live and dead strays (used to tease out overshoot) *(Spawning Escapement Estimates)* • Number of hatchery carcasses (PIT-tagged and/or CWT) found in non-target and target spawning areas or number of returning spawners counted via PIT-tag detection or at weirs in close temporal proximity to spawning areas (stray data into the Entiat sub-basin will be obtained from USFWS Fisheries Resource Office-Leavenworth) *(Spawning Escapement Estimates)*
Objective 8: Determine if hatchery programs have caused changes in phenotypic characteristics of natural populations.	• Total and salt (ocean) age and gender of hatchery and naturally produced salmon carcasses collected on spawning grounds *(Spawning Escapement Estimates)* • Whenever possible, age at maturity and sex ratio will be measured at weirs or dams near the spawning stream to avoid the size-related carcass recovery bias on spawning grounds (carcass sampling or ultrasound on live fish) *(Spawning Escapement Estimates)* • Assess age of fish, including harvested fish *(Spawning Escapement Estimates and Harvest Reporting)*
Objective 10: Determine if appropriate harvest rates have been applied to conservation, safety-net, and segregated harvest programs to meet the HCP/SSSA goal of providing harvest opportunities while also contributing to population management and minimizing risk to natural populations.	• Numbers of hatchery fish taken in harvest *(Harvest Reporting)* • Numbers of natural-origin fish taken in harvest *(Harvest Reporting)*

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4.1 Spawning Escapement Estimates

Chelan Summer/Fall Chinook

Chinook spawning ground surveys will be conducted in the Chelan River and (see Appendix A for survey reaches). Spawning ground surveys will be conducted via foot or raft beginning late September and continuing until spawning has ended (usually mid-November). Frequency of surveys will vary depending on method.

Summer Chinook carcass surveys will be conducted in the Chelan River beginning in September and ending in November consistent with methods described in Murdoch and Peven (2005). A representative sample (i.e., 20%) of spawners as determined by spawner abundance and distribution (typically 100% of the carcasses encountered in the Chelan River) will be sampled. Biological data will include collection of scale samples for age analysis, length measurements (POH and FKL), gender, egg voidance, and a check for tags or marks. DNA samples (five-hole punches from operculum) will be collected as needed to address different objectives. These data will be used to assess length-at-age, size-at-age, egg voidance, origin (hatchery or naturally produced), stray rates, and genetics. All carcass surveys will be conducted within the historical reaches.

Wenatchee Steelhead

The number of hatchery and naturally produced steelhead returning to the Wenatchee sub- basin will be estimated using a PIT tag mark recapture model. The estimated spawner abundance for the Wenatchee steelhead population will be a combination of PIT tag-based tributary and redd-based mainstem Wenatchee River estimates. Steelhead redd counts will be conducted weekly in all major spawning areas in the mainstem Wenatchee River (see Appendix A for survey reaches); minor spawning areas in the mainstem Wenatchee River will be surveyed once, based on the spawn timing in adjacent major spawning areas, to estimate redd abundance at peak spawning. The estimated total number of redds in the Wenatchee River mainstem will be expanded by the sex ratio of the population to estimate spawner abundance. Spawner abundance in tributaries of the Wenatchee River will be estimated using a PIT tag mark recapture model.

Chiwawa Spring Chinook

Chiwawa spring Chinook spawning escapement will be estimated based on the total number of redds found in each tributary (Murdoch et al. 2010) using methods described in Murdoch and Peven (2005). Weekly redd and carcass surveys will be conducted simultaneously from the first week of August through September (see Appendix A for survey reaches). Redd-based estimates assume that each female constructs one redd, which WDFW has found to be appropriate for this population (Murdoch et al. 2009). The total number of redds in each reach will be estimated using methods described in Millar et al. (2012) and using the observer efficiency model currently under development by WDFW. Redd counts will be expanded and the number of hatchery and naturally produced fish will be estimated using methods in Murdoch et al. (2010). Carcasses encountered during surveys will be sampled according to methods outlined in Murdoch and Peven (2005). All CWTs (i.e., snout or adipose) from carcasses will be read and the data entered into the Regional Mark Processing Center database within one year of collection.

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Additionally, all redds and female carcasses will be geo-referenced using hand-held GPS devices. Carcass recovery bias has been detected in the Chiwawa spring Chinook population (Murdoch et al. 2010) and if not corrected will bias estimates of hatchery and naturally produced fish on the spawning grounds. While it may be appropriate to correct for carcass recovery bias for some monitoring questions (e.g., 2.2), when comparisons to reference populations are made in monitoring questions 1.1.and 1.2, carcass bias will not be corrected because other monitoring programs have not corrected for a similar bias.

Wenatchee Summer Chinook

Wenatchee summer Chinook spawning ground counts will begin the first week in September and continue through the end of spawning in November (see Appendix A for survey reaches). Total census redd counts will be conducted by foot or raft depending on stream size, flow, and density of spawners within the stream reach (see Appendix A for survey reaches). All stream reaches will be surveyed once per week. Redd data will be collected using methods described in Murdoch and Peven (2005). The total number of redds in each reach will be estimated using methods described in Millar et al. (2012) and using the observer efficiency model currently under development by WDFW. Weekly ground-based census counts and the true number of redds (determined via intensive surveys) will be compared in order to generate observer efficiency. River characteristics (e.g., channel width, water depth, discharge, visibility, and habitat complexity), observer experience, and survey effort will be incorporated into a model to predict observer efficiency in all river reaches. Predicted redd generate observer efficiency for each river reach will be used to adjust ground-based redd counts to estimate the total reach redd count. Ground-based surveys will also be used to estimate redd life for each river reach. The estimated spawner abundance in the Wenatchee River and an associated level of precision will be calculated using the estimated total redd count for each reach, mean redd life, and the sex ratio of the population similar to methods described in Millar et al. (2012). Salmon carcass data collected during spawning ground surveys will be consistent with Murdoch and Peven (2005). All CWTs (i.e., snout or adipose) from carcasses will be sent to the WDFW lab in Olympia. The CWT lab will extract and read CWTs and submit all required information to RMIS within one year of collection.

4.2 Harvest Reporting

In years when the expected hatchery adult returns are in excess of the levels needed to meet the hatchery program goals (i.e., broodstock and/or escapement), surplus fish may be available for harvest. Harvesting or removal of surplus hatchery fish may have benefits to the natural populations by reducing potential negative ecological and genetic impacts (e.g., density dependent effects, loss of fitness, and loss of genetic variation). The contribution of hatchery fish to fisheries will be monitored using CWT recoveries on a brood-year basis supporting Objective 10.

To obtain the necessary data to determine if the harvest rates are meeting objectives, a statistically valid creel program will be designed and implemented for all sport and/or conservation fisheries in the Upper Columbia River to estimate harvest of hatchery fish from

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both Chelan and Grant County PUD funded hatchery programs (Murdoch and Peven 2005). Information collected during creel surveys are an integral component to calculating the HRR (Objective 3), particularly given most CWT recoveries for PUD mitigation programs occur in the Upper Columbia River and its tributaries, with the exception of summer Chinook where most CWT recoveries occur in ocean fisheries. Because of considerable time lags in reporting of CWT's to the Regional Marking Information System (RMIS) database, it requires an ongoing query of recovery data until the number of estimated fish does not change.

5. Data Management, Analysis, and Reporting

5.1 Data Management

A Microsoft Access database maintained by WDFW will contain all the monitoring data collected for hatchery evaluations. The database will contain and manage all data associated with aquaculture monitoring, juvenile monitoring, and adult monitoring.

All data entered into the database are evaluated for quality control and quality assurance by WDFW. Quality control checks using analyses such as modified Z-scores, boxplots, and the Generalized Extreme Studentized Deviate Procedure (Iglewicz and Hoaglin 1993) will be conducted for all data entry. In the event outliers are identified, discussion will occur on whether identified outliers are true data points or transcription errors. This process ensures that the data used to test statistical hypotheses are correct and accurate.

5.2 Data Analysis

The analyses proposed are consistent with the Monitoring and Evaluation Plan for PUD Hatchery Programs: 2013 Update (Hillman et al. 2013). Each of the objectives will be addressed using the appropriate statistical tests, as well as graphic analyses that convey relevant information.

5.3 Reporting

An annual M&E report will be generated following the completion of each calendar year and will be available for HCP-HC review by June 1 of the following year. Additionally, monthly progress reports will be made available to the HCP-HC.

6. Lake Wenatchee Sockeye Salmon

The Chelan PUD will conduct monitoring and evaluation (M&E) activities to track key population attributes related to Lake Wenatchee sockeye salmon in 2018(Table 6). In the absence of a sockeye hatchery program, M&E activities are no longer rooted in the context of evaluating the effects of sockeye salmon supplementation, but instead focus directly on the performance of the natural population, which is a unique departure from historic monitoring obligations. Broadly, the proposed M&E activities cover juvenile and adult life history stages and provide the data necessary to track or estimate viable salmonid population parameters (VSP): abundance, productivity, spatial structure and diversity (McElhaney et al. 2000). The data collected may also have utility in future hatchery compensation recalculation efforts.

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Chelan PUD is conducting these M&E activities to support commitments made under the 2011 hatchery recalculation effort, which also included a steelhead production commitment for a sockeye species swap (SOA 2011). This section of the implementation plan describes the specific commitments by juvenile and adult life history stages.

6.1 Juvenile Monitoring

Chelan PUD will conduct or fund activities to monitor and evaluate the temporal distribution and age/size of out-migrating smolts, and estimate smolt production (Table 6). Smolt production will be estimated from data collected at the lower Wenatchee smolt trap and via back calculations based on collected adult return data (i.e., age-at-return estimates, SARs, and adult escapement to the tributaries). Collectively, these activities include: (1) funding of the lower Wenatchee River smolt trap concurrent with efforts aimed at evaluating Chelan PUD funded supplemented populations in the Wenatchee River sub-basin; (2) tagging up to 5,000 PIT tags for natural-origin juveniles encountered during smolt trapping activities and collecting scale samples at this location; and (3) estimating adult escapement estimates to the tributaries, and collection of adult return data at Tumwater (see the *Adult Monitoring* section for details) to back-calculate smolt production.

The monitoring data obtained will provide a useful set of tools for evaluating the performance of natural origin sockeye salmon within the sub-basin and downstream and also support the evaluation of VSP parameters [e.g., outmigration timing and size (diversity); and PIT tagging juveniles for SAR estimates (productivity)].

6.2 Adult Monitoring

Several M&E activities associated with adult returns of Lake Wenatchee sockeye salmon will be conducted and/or funded by Chelan PUD (Table 6). These efforts include (1) continuation of accurate adult counts at Rock Island, Rocky Reach, and Tumwater dams; (2) sampling of scales for age distribution, sex ratio determination, and returns of PIT-tagged adults at Tumwater Dam; (3) reach-specific conversion estimates between Rock Island Dam and spawning grounds in the White and Little Wenatchee rivers (i.e., Rock Island to Tumwater Dam to spawning tributaries); and (4) providing between 250 to 1,000 PIT tags to estimate adult spawning escapement in the Little Wenatchee and White rivers utilizing PIT tags and mark-recapture techniques (the software program Sample Size 2.0.7, developed by the University of Washington School of Aquatic and Fisheries Science (P. Westhagen, J. Lady, and J. Skalski) was used to determine the minimum number of tags required (i.e., 250) to estimate adult sockeye escapement at a +/- 7 percent confidence interval). Chelan PUD will adjust the number of PIT-tagged individuals in order to maintain precision in estimates at the lowest rate of interference to migrating populations, if it is warranted due to annual changes in escapement and detection probabilities. In an effort to PIT tag the run at large, adults will be PIT tagged at Tumwater consistent with the Tumwater Operations Protocol, daily throughout the run.

Collectively, these data will provide reliable metrics of adult returns and spawning escapement (abundance), recruits-per-spawner (productivity), distribution of spawners among tributaries (spatial structure), and run-timing and age structure for adult immigrants (diversity).

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Table 6. Chelan PUD's proposed Lake Wenatchee sockeye salmon monitoring and evaluation activities.

Life History Stage	M&E Activity	Entity Performing the Activity	Related analysis	VSP parameter addressed
Juvenile	Concurrent operation of the lower Wenatchee smolt trap to collect juvenile outmigration data	WDFW	Generate distribution of outmigration timing, estimate smolt production and determine average smolt size.	Diversity and productivity
Juvenile	PIT tagging smolts at lower Wenatchee smolt trap (up to 5,000 fish annually) and collecting/aging scale samples	WDFW	Estimate smolt-to-adult returns.	Productivity
Juvenile	Develop adult return based smolt production estimates	WDFW	Use collected data (i.e., adult age-at-return data, SARs, adult escapement to the tributaries) to back-calculate smolt production.	Productivity
Adult	Rock Island and Rocky Reach Dam adult counts	CPUD	Initial spawner abundance (Okanogan stock separation)	Abundance and spatial structure
Adult	PIT tag subsample (250 adults) of returning adults at Tumwater Dam to support mark-recapture evaluation	WDFW	Calculate spawner abundance and relative distribution among ~~in~~ tributaries	Abundance and spatial structure
Adult	Collect and age scales[1] and determine sex via ultrasound from returning adults at Tumwater Dam	WDFW	Estimate age-at-return, sex ratio, and relative productivity of contributing spawner cohorts	Productivity and diversity
Adult	Tumwater Dam adult counts	WDFW	Estimate potential spawner abundance (pre Lake-Wenatchee harvest), potential productivity (recruits/spawner), and run timing distribution	Abundance and diversity
Adult	Operate PIT detection arrays on Little Wenatchee and White River	WDFW	Calculate spawner abundance (post-Lake Wenatchee harvest and other mortality), actual productivity (recruits/spawner), and entry-to-spawning-habitat timing distribution, and spatial spawner distribution among tributaries	Abundance, productivity, spatial structure, and diversity
All	Data management, analysis, and reporting	BioAnalysts CPUD	------	NA

[1] Scales would be collected concurrently from adults that are PIT tagged at Tumwater Dam.

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Appendix A

Designated survey reaches for Methow subbasin summer Chinook spawning ground surveys.

River	Reach	Code	RM
Methow	Mouth to Methow Bridge	M1	0.0-14.78
	Methow Bridge to Carlton Bridge	M2	14.78-27.17
	Carlton Bridge to Twisp Bridge	M3	27.17-39.55
	Twisp Bridge to MVID	M4	39.55-44.85
	MVID to Winthrop Bridge	M5	44.85-49.80
	Winthrop Bridge to Hatchery Dam	M6	49.80-51.55

Designated survey reaches for Wenatchee River basin summer Chinook spawning grounds surveys. Asterisks denotes reaches where redd observer efficiency will be assessed.

Reach Code	Reach Section	River Mile
W10	Lake Wenatchee to Bridge	54.20-53.58
	Bridge to Swamp *	53.58-52.66
	Swamp to Chiwawa River	52.66-48.39
W9	Chiwawa River to Schugart Flats	48.39-47.93
	Schugart Flats to Old Plain Bridge	47.93-46.21
	Old Plain Bridge to RR Bridge	46.21-41.91
	RR Bridge to RR Tunnel	41.91-39.28
	RR Tunnel to Swing Pool *	39.28-36.67
	Swing Pool to Tumwater Br	36.67-35.55
W8	Tumwater Br to Swiftwater Campground *	35.55-33.50
	Swiftwater Campground to Unimproved Campground	33.50-33.08
	Unimproved Campground to Tumwater Dam	33.08-30.91
W7	Tumwater Dam to Penstock Br	30.91-28.66
	Penstock Br to Icicle Road Br *	28.66-26.43
W6	Icicle Road Br to Icicle Mouth	26.43-25.61
	Icicle Mouth to Boat Takeout *	25.61-24.49
	Boat Takeout to Leavenworth Br	24.49-23.90
W5	Leavenworth Br to Irrigation Flume *	23.90-22.77
	Irrigation Flume to Peshastin Br	22.77-20.00
W4	Peshastin Br to Dryden Dam *	20.00-17.76
W3	Dryden Dam to Williams Canyon	17.76-15.54
	Williams Canyon to Upper Cashmere Br	15.54-10.22
	Upper Cashmere Br to Lower Cashmere Br	10.22-9.49
W2	Lower Cashmere Br to Old Monitor Br *	9.49-7.12
	Old Monitor Br to Sleepy Hollow Br	7.12-3.27
W1	Sleepy Hollow Br to River Bend *	3.27-1.73
	River Bend to Siphon	1.73-1.29
	Siphon to Mouth	1.29-0.45

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Designated survey reaches for Wenatchee Basin spring Chinook spawning grounds surveys.

Reach Code	Reach Section	River Mile
Chiwawa River and Tributaries (Rock and Chikamin)		
C7	Buck Cr to Phelps Cr	36.39-33.46
C6	Phelps Cr (Trinity) to Maple Cr Br	33.46-29.64
C5	Maple Cr Br to Atkinson Flats	29.64-26.59
C4	Atkinson Flats to Schaefer Cr	26.59-24.24
C3	Schaefer Cr to Rock Cr Campground	24.24-22.97
R1 - Rock	Mouth to Chiwawa River Road Bridge	0.00-1.05
C2	Rock Cr Campground to Grouse Cr	22.97-12.27
K1 - Chikamin	Mouth to Chiwawa River Road Bridge	0.00-0.68
C1	Grouse Cr to Mouth	12.27-0.00
Nason Creek		
N4	White Pine Creek to Lower R.R. Bridge	16.09-13.68
N3	Lower R.R. Bridge to Hwy 2 Bridge	13.68-9.13
N2	Hwy 2 Bridge to Kahler Cr	9.13-4.46
N1	Kahler Cr to Mouth	4.46-0.00
White River and Tributaries (Panther and Napeaqua)		
H4	Falls to Grasshopper Meadows	21.16-19.78
T1 - Panther	Boulder field to Mouth	0.43-0.00
H3	Grasshopper Meadows to Napeaqua River	19.78-17.59
Q1 - Napeaqua	Take out to Mouth	0.91-0.00
H2	Napeequa River to Sears Cr Bridge	17.59-11.97
H1	Sears Cr Bridge to Mouth	11.97-0.00
Little Wenatchee River		
L3	Rainy Cr to Lost Cr	10.78-6.74
L2	Lost Cr to Old Fish Weir	6.74-2.13
L1	Old Fish Weir to Mouth	2.13-0.00
Upper Wenatchee River		
W10	Lake Wenatchee to Chiwawa River	54.20-48.39
Chiwaukum Creek		
U1	Metal bridge to Mouth	1.0 – 0.0
Icicle River		
I1	Hatchery to Mouth	3.02-0.00
Peshastin Creek and Tributaries (Ingalls Creek)		
D1 - Ingalls	Trailhead to mouth	0.64-0.00
P2	Ingalls Creek to Camas Cr	9.14-5.63
P1	Camas Cr to Mouth	5.63-0.00

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Designated survey reaches for Wenatchee River basin steelhead spawning grounds surveys. Asterisks denote index reaches. Spawning escapements in tributaries will be estimates using PIT-tag arrays.

Reach Code	Reach Section	River Mile
W10	Lake Wenatchee to Chiwawa River*	54.20-48.39
W9	Chiwawa River to Tumwater Bridge*	48.39-35.55
W8	Tumwater Br to Swiftwater Campground	35.55-33.50
	Swiftwater Campground to Unimproved Campground*	33.50-33.08
	Unimproved Campground to Tumwater Dam	33.08-30.91
W7	Tumwater Dam to Icicle Road Bridge	30.91-26.43
W6	Icicle Road Br to Leavenworth boat ramp*	26.43-24.49
	Boat Takeout to Leavenworth Bridge	24.49-23.90
W5	Leavenworth Bridge to Peshastin Bridge	23.90-20.00
W4	Peshastin Bridge to Dryden Dam	20.00-17.76
W3	Dryden Dam to Lower Cashmere Bridge	17.76-9.49
W2	Lower Cashmere Bridge to Sleepy Hollow Bridge *	9.49-3.27
W1	Sleepy Hollow Bridge to Mouth	3.27-0.45

Tributary	River mile of PIT tag array
Mission Creek	0.54
Peshastin Creek	1.91
Chumstick Creek	0.31
Icicle River	0.26
Chiwaukum Creek	0.24
Chiwawa River	0.58
Nason Creek	0.52
Little Wenatchee River	1.74
White River	1.65

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MONITORING AND EVALUATION PLAN FOR PUD HATCHERY PROGRAMS

2017 Update

July 19, 2017

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Monitoring and Evaluation Plan for PUD Hatchery Programs

This document is a revision of the monitoring and evaluation (M&E) plan of the salmon and steelhead hatchery programs funded by Douglas, Chelan, and Grant County Public Utility Districts (PUDs; see Table 4). Several programmatic changes, evaluation of data collection methods, and M&E results from the past five years, along with shifting management paradigms affect M&E needs, all of which have occurred under advancing fish culture and monitoring techniques. As required by the programs, this document is a result of a five-year review intended to expand on and coalesce previous M&E documents (BAMP 1998; Cates et al. 2005; Murdoch and Peven 2005; Hays et al. 2006; Pearsons and Langshaw 2009a, 2009b) with inclusion of new information.

Fishery management agencies developed the following general goal statements for hatchery programs, which were adopted by the HCP Hatchery Committees and PRCC Hatchery Sub-Committee (hereafter, Hatchery Committees):

1. Support the recovery of ESA-listed species by increasing the abundance of the natural adult population, while ensuring appropriate spatial distribution, genetic stock integrity, and adult spawner productivity.

2. Increase the abundance of the natural adult population of unlisted plan species, while ensuring appropriate spatial distribution, genetic stock integrity, and adult spawner productivity. In addition, provide harvest opportunities in years when spawning escapement is sufficient to support harvest.

3. Provide salmon for harvest and increase harvest opportunities, while segregating returning adults from natural tributary spawning populations.

Following the development of Hatchery and Genetic Management Plans (HGMPs), artificial supplementation programs are now characterized into three categories. The first type, integrated conservation programs, are intended to support or restore natural populations. These programs focus on increasing the natural production of targeted fish populations. A fundamental assumption of this strategy is that hatchery fish returning to the spawning grounds are reproductively similar to naturally produced fish. The second type, safety-net programs, are extensions of conservation programs, but are intended to function as reserve capacity for conservation programs in years of low returns. The safety-net provides a demographic and genetic reserve for the natural population. That is, in years of abundant returns they function like segregated programs, and in low return years they can be managed as conservation programs. Lastly harvest augmentation programs are intended to increase harvest opportunities while limiting interactions with wild-origin counterparts.

Monitoring is needed to determine if the hatchery programs are meeting the intended management objectives of conservation, safety-net, or harvest augmentation programs. Objectives for hatchery programs are generally grouped into three categories of performance indicators:

1. In-Hatchery: Is the program meeting the hatchery production objectives?

2. In-Nature: How do fish from the program perform after release?

    a. Conservation Program:
        i. How does the program affect target population abundance and productivity?
        ii. How does the program affect target population long-term fitness?

    b. Safety-Net Program:
        i. How does the program affect target population long-term fitness?

    c. Harvest Augmentation Program:
        i. Does the program provide harvest opportunities?

3. Risk Assessment: Does the program pose risks to other populations?

Objectives in this plan have been organized in a hierarchy where productivity indicators are the primary metrics used to assess if conservation and safety-net program goals have been met; harvest rates and effects on non-targeted populations are used for harvest programs. In cases where productivity indicators are not available or results are equivocal, monitoring indicators may be used to help evaluate the performance of the program. Evaluations of monitoring indicators may not provide sufficiently powerful conclusions on which to base management actions, although they may provide insight as to why a productivity indicator did or did not meet the program goal. Therefore, the relationship between hatchery programs and indicators can be viewed in a chain-of-causation: management actions within the hatchery programs affect the status of monitoring indicators, which in turn influence productivity indicators (Figure 1).

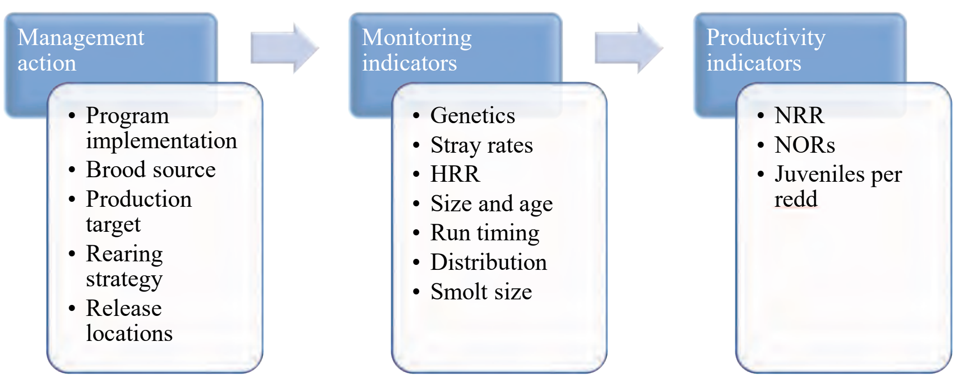

Figure 1. Relationship of indicators to the assessment of supplementation programs. Management actions affect monitoring indicators, which influence productivity indicators. Monitoring indicators may be used to hypothesize the magnitude of influence on productivity.

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The primary goal of a conservation program is to contribute to the rebuilding and recovery of naturally reproducing populations within their native habitat. In this plan, natural replacement rates (NRR), recruitment of naturally-produced fish (NOR), and juvenile productivity (juveniles per redd) are important indicators for assessing the success of supplementation. These indicators are difficult to measure precisely and are quite variable in space and time. Therefore, monitoring indicators can be evaluated to help assess if productivity was related to the hatchery programs or other factors (Table 1).

A flow of information following sequential, logical steps will be employed to evaluate supplementation programs, consistent with the indicators described in Table 1. For example, a hatchery program, at a minimum, must be able to produce more adults per spawner than would occur in the natural environment. Should the program fail this test, hatchery operations should be evaluated to determine if improvements can correct the problem. If a program successfully replaces the required number of adults, it is then evaluated against a reference population or condition, if available, to determine if it has increased the overall number of naturally-spawning fish (including both hatchery- and natural-origin adults), increased the number of natural-origin spawners, and to test if productivity of the natural population has changed. When these goals are met, the program is considered successful. When these goals are not met, monitoring indicators may infer why the program is not achieving its goals

If suitable reference populations are not available, other comparisons can be used to help evaluate treatment responses. Evaluation of programs may pursue the following approaches:

- Comparison to reference population(s) that do not contain pre-treatment data
- Before treatment and after treatment comparisons
- Comparison to standard(s)
- Comparison to other suitable reference conditions

Methodologies for selecting reference streams, analyzing data from treatment and reference stream comparisons, and other comparisons are presented in Hillman et al. (2012).

The primary goals of a safety-net program are to provide demographic and genetic reserves for a population that is supplemented by a conservation program (Table 2). Harvest and adult management may be used to control escapement of spawners when appropriate. Monitoring focuses on estimating the number of fish that escape to spawn naturally and stray rates and in-hatchery performance evaluation.

The primary goal of a harvest augmentation program is to increase harvest opportunities, while segregating adults from natural spawning populations. In this plan, harvest opportunity, survival rates, and stray rates are important indicators for assessing the success of harvest augmentation. These indicators are more readily quantified compared to productivity indicators (Table 2). A flow of information will be employed to evaluate harvest augmentation programs. Since harvest augmentation programs are typically segregated, monitoring indicators will be used to determine the success of a program.

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Both monitoring and productivity indicators will be used to evaluate the success of hatchery programs. In the event that the statistical power of tests that involve productivity indicators is insufficient to inform sound management decisions, some of the monitoring indicators may be used to guide management. The overarching goals of conservation, safety-net, and harvest augmentation programs, as described above, are provided below in greater detail. The flow chart (Figure 3) shows the relationship of overarching program goals, the strategies used to meet the goals, the monitoring and evaluation objectives used to evaluate the strategies and determine if goals are being met, and the adaptive management cycle associated with the programs. See Tables 1 and 2 for the indicators under each objective. The logic depicted in this flow chart shall be used to assess M&E results and apply those results to management decisions. Table 4 presents the current hatchery programs releasing fish in the Upper Columbia Basin.

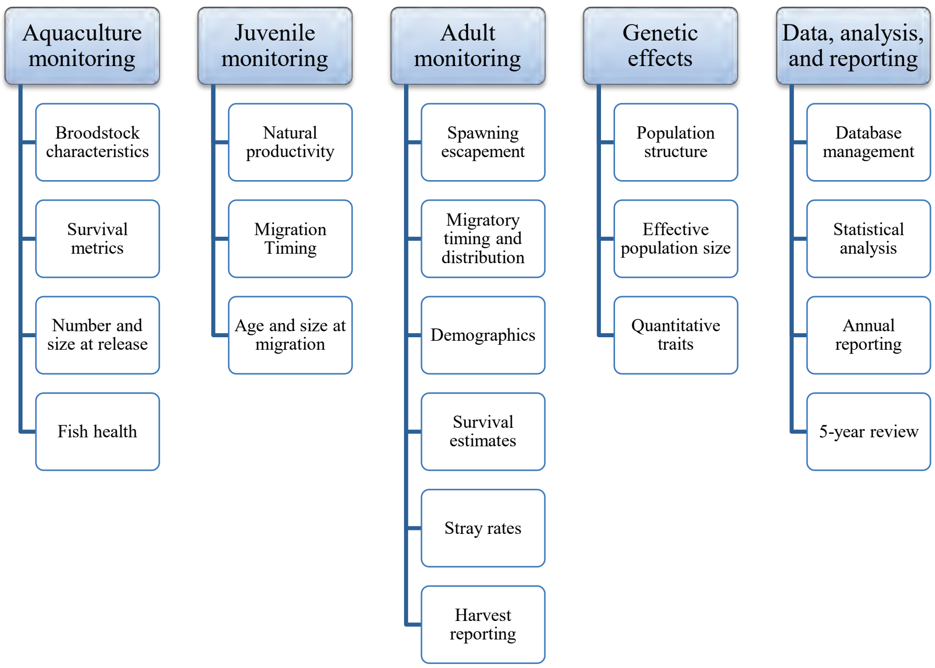

Figure 2. Overview of Monitoring and Evaluation Plan Categories and Components (not including regional objectives).

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Table 1. Program objectives, indicators, and goals for conservation hatchery programs including productivity and monitoring indicators (also applies to safety-net programs when used to support a conservation program).

	Objective	Indicator	Target	Program goals: Rebuild natural populations	Program goals: Maintain genetic diversity	Program goals: Opportunity for harvest
Productivity indicators	Determine if the program has increased the number of naturally spawning adults	Abundance of natural spawners	Increase	✓		✓
		Adult productivity (NRR)	No decrease	✓		
	Determine if the proportion of hatchery fish affects freshwater productivity	Residuals vs. pHOS	No relationship	✓		
		Juveniles per redd vs. pHOS	No relationship	✓		
Monitoring indicators	Determine if run timing and distribution meets objectives	Migration timing	No difference	✓	✓	
		Spawn timing[1]	No difference	✓	✓	
		Redd distribution[2]	No difference	✓	✓	
	Determine if program has affected genetic diversity and population structure	Allele frequency (hatchery vs. wild)	No difference		✓	
		Genetic distance between populations	No difference		✓	
		Effective population size	Increase		✓	
		Age and size at maturity	No difference		✓	
	Determine if hatchery survival meets expectations	HRR	HRR > NRR	✓		
		HRR	HRR ≥ Goal[3]	✓		
	Determine if recipient stray rate of hatchery fish is acceptable	Out of basin	≤ 5%	✓	✓	
		Within basin	≤ 10%	✓	✓	
	Determine if hatchery fish were released at program targets	Size and number	= Target[4]	✓		
	Provide harvest opportunities when appropriate	Harvest	Escapement goals			✓

[1] Hatchery and natural-origin fish should spawn at the same time across the range of elevations within the spawning distribution of each stock.

[2] Hatchery and natural-origin fish should spawn in the same locations. Exceptions are the Carlton Summer Chinook and Dryden Summer Chinook programs (see Appendix 4).

[3] HRR targets are identified in Appendix 2.

[4] Number and size targets are identified in Appendix 2 and 4, respectively.

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Table 2. Program objectives, indicators, and goals for segregated harvest augmentation hatchery programs including monitoring indicators.

	Objective	Indicator	Target	Program goals: Rebuild natural populations	Program goals: Maintain genetic diversity	Program goals: Opportunity for harvest
Monitoring indicators	Determine if hatchery survival meets expectations	HRR	HRR > NRR			✓
		HRR	HRR ≥ Goal[1]			✓
	Determine if stray rate of hatchery fish is acceptable	Out of basin	≤ 5%		✓	
		Within basin	≤ 10%		✓	
	Determine if hatchery fish were released at program targets	Size and number	= Target[2]			✓
	Provide harvest opportunities when appropriate	Harvest	Escapement goals			✓

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[1] HRR targets are identified in Appendix 2.

[2] Number and size targets are identified in Appendix 2 and 4, respectively.

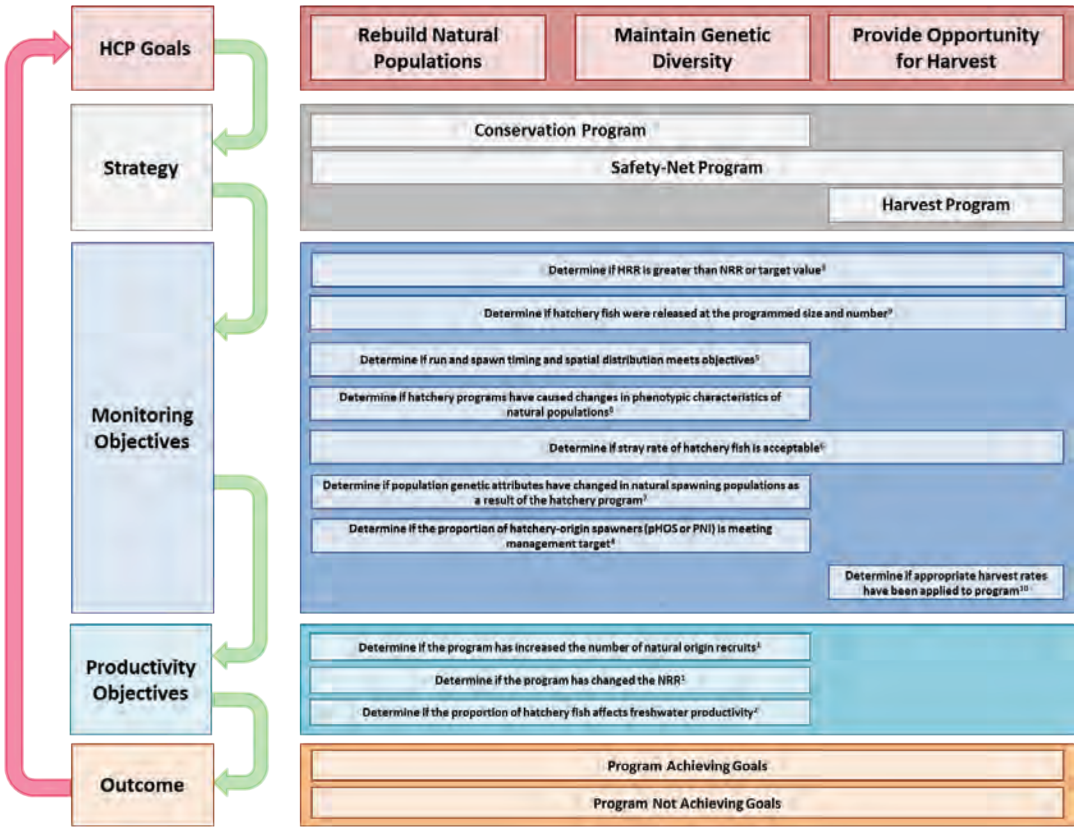

Figure 3. **Adaptive management flow chart depicting HCP goals, associated strategies to meet the goals, the monitoring and evaluation objectives (indicated in superscript), and the adaptive management feedback cycle. The strategies, objectives, and outcomes are aligned vertically under the corresponding goals.**

Table 3. Hatchery programs in the mid-Columbia River Basin, 2012. Funding entities included Douglas PUD (D), Chelan PUD (C), Grant PUD (G), Bonneville Power Administration (B), Bureau of Reclamation (O), and Army Corps of Engineers (A) and are listed in order of contribution. Total artificial production targets in the mid-Columbia River exceeds 20 million juveniles annually.

Program	Species	Basin	Purpose	Funding Entity	Production
Methow[5]	Spring Chinook [1]	Methow	NNI/Conservation	G, C, D	223,765
Chief Joseph[7]	Spring Chinook	Okanogan	Reintroduction/Harvest	B, G, C, D	900,000
Chiwawa[5]	Spring Chinook [1]	Wenatchee	NNI/Conservation	C	144,026
White[5]	Spring Chinook [1]	Wenatchee	NNI/Conservation	G	74,556
Nason[5]	Spring Chinook [1]	Wenatchee	NNI/Conservation	G	149,114
Winthrop[7]	Spring Chinook [2]	Methow	Safety-Net	O	400,000
Leavenworth	Spring Chinook [2]	Wenatchee	Harvest	O	1,200,000
Wells[5]	Steelhead [1]	Columbia	Inundation/Safety-Net	D	160,000
Winthrop[7]	Steelhead [1]	Methow	Conservation	O	100,000-200,000
Wells[5]	Steelhead [1]	Methow	Inundation/Safety-Net	D	100,000
Wells/Omak[5, 6]	Steelhead [1]	Okanogan	NNI/Conservation	G	100,000
Wells[5]	Steelhead [1]	Twisp	Inundation/Conservation	D	40,000
Wells[5]	Steelhead [1]	Twisp	NNI/Conservation	D	8,000
Chiwawa[5]	Steelhead [1]	Wenatchee	NNI/Conservation	C	22,000
Chiwawa[5]	Steelhead [1]	Wenatchee	Inundation/Harvest	C	165,000
Chiwawa[5]	Steelhead [1]	Wenatchee	Species trade	C	60,300
Wells[5]	Summer Chinook [2, 3]	Columbia	Inundation/Harvest	D	484,000
Chief Joseph[7]	Summer Chinook [3]	Okanogan	NNI/Cons./Harvest	B, G, C, D	700,000
Chelan Falls[5]	Summer Chinook [2]	Chelan	Inundation/Harvest	C	400,000
Chelan Falls[5]	Summer Chinook [2]	Chelan	NNI/Conservation	C	176,000
Wells[5]	Summer Chinook [2]	Columbia	Inundation/Harvest	D	320,000
Entiat	Summer Chinook	Entiat	Harvest	O	400,000
Carlton[5]	Summer Chinook	Methow	NNI/Conservation	G	200,000
Chief Joseph[7]	Summer Chinook	Okanogan	NNI/Cons./Harvest	B, G, C, D	1,300,000
Dryden[5]	Summer Chinook	Wenatchee	NNI/Conservation	C, G	500,000
Priest[5]	Fall Chinook[3]	Columbia	Inundation/Harvest	G	5,000,000
Priest[5]	Fall Chinook[3]	Columbia	NNI/Harvest	G	325,543
Priest[5]	Fall Chinook[4]	Columbia	Fry loss/Harvest	G	1,000,000
Priest[5, 7]	Fall Chinook[3]	Columbia	Harvest	A	1,700,000
Ringold[7]	Fall Chinook[3]	Columbia	Harvest	A	3,000,000
Yakama Nation	Coho	Wenatchee	Reintroduction/Harvest	B, G, C, D	1,000,000
Yakama Nation[8]	Coho	Methow	Reintroduction/Harvest	B, G, C, D	500,000
Skaha	Sockeye	Okanogan	Reintroduction/Harvest	C, G	≤ 5 M eggs

[1] Species listed under the Endangered Species Act.
[2] Segregated program.
[3] Sub-yearling production.
[4] Fry production.
[5] Program covered by this M&E Plan.
[6] Program also partially covered by CCT M&E Plan.
[7] Program affects PUD-funded programs covered by this plan.
[8] Planned to increase within the next 5 years.

OBJECTIVES, QUESTIONS, AND HYPOTHESES

Productivity Indicators: Adults

Objective 1: Determine if conservation programs have increased the number of naturally spawning and naturally produced adults of the target population and if the program has reduced the natural replacement rate (NRR) of the supplemented population.

At the core of a conservation program is the objective of increasing the number of spawning adults (i.e., the combined number of naturally produced and hatchery fish) in order to affect a subsequent increase in the number of returning naturally produced fish or natural origin recruits (NOR). In order for the natural population to remain stable or to increase, the Natural Replacement Rate (NRR), or the ratio of NORs to the parent spawning population, must be at a level where parents are being replaced by their offspring as spawners in the next generation. It is possible to affect an increase in natural origin spawners through supplementation with a stable or decreasing NRR. However, if the NRR is below replacement (NRR<1.0), termination of the supplementation program will result in a declining natural population should that state of NRR persist. The proportion of the hatchery-origin spawners (pHOS) that will increase natural production without creating adverse effects to the genetic diversity or reproductive success rate of the natural population is unknown, and may be dependent on how individual hatchery programs are operated, as well as available spawning and rearing habitat. Some programs may restrict pHOS to reduce the risk to the natural population with the intent of optimizing productivity, concomitantly reducing the overall number of spawners. All other objectives of the M&E Plan either directly support this objective or seek to minimize negative effects of the conservation programs on non-target stocks of concern.

Differences in carrying capacities of supplemented and non-supplemented streams can confound the analysis of the effects of supplementation on total number of spawners returning to the streams. For example, if the supplemented population is at carrying capacity and the non-supplemented population is not, the total number of spawners returning to the non-supplemented population may show an increasing trend over time, while the supplemented population would show no increasing trend. To avoid concluding that the supplementation program has no effect or perhaps a negative effect on total spawners, density corrections should be included in the analyses. Hypotheses that may require density corrections are noted under each monitoring question.

1.1 Natural Replacement Rates of Supplemented[1] Populations (*Productivity Indicator*)

Monitoring Questions:

Q1.1.1 Has the supplementation program changed the adult productivity (NRRs) of the supplemented populations?[2]

Target Species/Populations:

- Q1.1.1 applies to all conservation and safety-net stocks.

Statistical Hypotheses 1.1.1[3]:

- $Ho_{1.1.1.1}$: Slope in NRRs before supplementation ≤ slope in NRRs after supplementation.
- $Ho_{1.1.1.2}$: Differences in slopes in NRRs between supplemented and reference populations before supplementation ≤ differences in slopes in NRRs between supplemented and reference populations after supplementation.
- $Ho_{1.1.1.3}$: Mean NRRs before supplementation ≤ mean NRRs after supplementation.
- $Ho_{1.1.1.4}$: Mean ratio scores in NRRs before supplementation ≤ Mean ratio scores in NRRs during supplementation.
- $Ho_{1.1.1.5}$: Mean ratio scores in NRRs (adjusted for density dependence) before supplementation ≤ Mean ratio scores in NRRs (adjusted for density dependence) during supplementation. [This hypothesis adjusts NRRs for density-dependent effects (see Hillman et al. 2012 for details; Appendix 7).]
- $Ho_{1.1.1.6}$: There is no association between the proportion of hatchery-origin spawners (pHOS) and the residuals from the smooth hockey stick stock-recruitment curve; rho = 0. [If there is a significant negative association between pHOS and the residuals, then hatchery fish may be reducing the productivity of the wild population.]

Measured Variables:

- Number of hatchery and naturally produced fish on spawning grounds
- Number of naturally produced fish harvested

Derived Variables:

- Number of naturally produced recruits by brood year for both naturally produced parents and hatchery parents (≥age-3).
- NRRs (calculated as NORs/spawner).
- Stock-recruit models, parameters, and residuals.
- Includes ratio scores of NRRs (requires reference population[s]).
- Includes calculation of ratios NORs (requires reference population).
- Appendix 1: Spawning escapement and carrying capacity information (as applicable)

[1] Supplementation programs may include a safety net component.
[2] Because adult productivity is affected by the abundance of the population (i.e., productivity decreases with increasing abundance), the goal of supplementation is to increase or maintain productivity, but not decrease it.
[3] Quality and quantity of data will determine which hypotheses are evaluated. See Hillman et al. 2012 (Appendix 7) for details.

Spatial/Temporal Scale:
- Calculated annually based on brood year.
- Time series.

Possible Statistical Analysis:
- These analyses shall be performed every 5-years. Use graphic analyses, trend analyses, t-tests, Aspin-Welch tests, and randomization tests to evaluate the statistical hypotheses (see Hillman et al. 2012; Appendix 7). The specific analysis used will depend on the availability of reference conditions.
- Correlation analysis will examine associations between hatchery adult composition and NRRs.
- On a five-year period, correlate productivity with extraneous factors such as ocean productivity indices.

Analytical Rules:
- This is a productivity indicator that will be used to assess the success of the supplementation program.
- Type I Error of 0.05.

1.2 Natural Origin Recruits of Supplemented Populations (*Productivity Indicator*)

Monitoring Questions:

Q1.2.1: Has the supplementation program changed the abundance of NORs within the supplemented population?

Target Species/Populations:
- Q1.2.1 applies to all supplemented or safety net stocks.

Statistical Hypotheses 1.2.1[4]:
- $Ho_{1.2.1.1}$: Slope in NORs[5] before supplementation ≥ slope in NORs after supplementation.
- $Ho_{1.2.1.2}$: Differences in slopes in NORs between supplemented and reference populations before supplementation ≥ differences in slopes in NORs between supplemented and reference populations after supplementation.
- $Ho_{1.2.1.3}$: Mean NORs before supplementation ≥ mean NORs after supplementation.
- $Ho_{1.2.1.4}$: Mean ratio scores in NORs before supplementation ≥ Mean ratio scores in NORs during supplementation.
- $Ho_{1.2.1.5}$: Mean ratio scores in NORs/Maximum Recruitment before supplementation ≥ Mean ratio scores in NORs/Maximum Recruitment during supplementation. [This hypothesis adjusts NORs for the capacity of the habitat; it tests the fraction of the habitat saturated with NORs (see Hillman et al. 2012 for details).]

[4] Quality and quantity of data will determine which hypotheses are evaluated. See Hillman et al. 2012 (Appendix 7) for details.
[5] "Slope in NORS" refers to abundance of NORs across time (years).

- $Ho_{1.2.1.6}$: There is no association between the proportion of hatchery-origin spawners (pHOS) and NORs; rho = 0. [If there is a significant negative association between pHOS and NORs, then hatchery fish may be reducing the reproductive success of the wild population.]

Measured Variables:
- Number of hatchery and naturally produced fish on spawning grounds.
- Number of hatchery and naturally produced fish taken for broodstock.
- Number of hatchery and naturally produced fish taken in harvest (if recruitment is to the Columbia).

Derived Variables:
- NORs (number of naturally produced recruits (total recruits) by brood year for both naturally produced parents and hatchery parents [≥age-3]).
- Stock-recruit models, parameters, and residuals.
- Includes ratio scores of NORs (requires reference population[s]).
- Estimates of carrying capacity.

Spatial/Temporal Scale:
- Calculate annually based on brood year.
- Time series.

Possible Statistical Analysis:
- These analyses shall be performed every 5-years. Use graphic analyses, trend analyses, t-tests, Aspin-Welch tests, and randomization tests to evaluate the statistical hypotheses (see Hillman et al. 2012). The specific analysis used will depend on the availability of reference conditions.
- Correlation analysis will examine associations between hatchery adult composition and NORs.
- On a five-year period, correlate NORs with extraneous factors such as ocean productivity indices.

Analytical Rules:
- This is a productivity indicator that will be used to assess the success of the supplementation program.
- Type I Error of 0.05.

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Productivity Indicators: Freshwater Environment

Objective 2: Determine if the proportion of hatchery fish on the spawning grounds affects the freshwater productivity of supplemented stocks.

Out-of-basin effects (e.g., smolt passage through the hydro system, harvest, and ocean productivity, etc.) influence the survival of smolts after they migrate from the tributaries. These effects introduce substantial variability into the adult-to-adult survival rates (NRRs and HRRs) and may mask in-basin effects (e.g., habitat quality, density-dependent mortality, and differential reproductive success of hatchery and naturally produced fish). Therefore, an estimate of freshwater productivity may help inform the performance of hatchery and natural origin spawners.

The objective of estimating freshwater productivity in the Upper Columbia ESU/DPS is to estimate the survival from egg to a critical juvenile life stage(s) of target stocks. Smolt or juvenile production models generated from the information obtained through these programs will provide a level of predictability with greater sensitivity to in-basin effects than spawner-recruitment models that take into account all effects.

Differences in the current carrying capacities of supplemented and non-supplemented streams can confound the effects of supplementation on numbers of juveniles per redd. For example, if the supplemented population is at or above carrying capacity and the non-supplemented population is not, numbers of juveniles per redd in the non-supplemented population may be significantly greater than the number of juveniles per redd in the supplemented population. In addition, pHOS may be correlated with overall spawner abundance. In these cases, it is difficult or impossible to separate density-dependent effects from the influence of pHOS on freshwater productivity. To avoid concluding that the supplementation program has no effect or perhaps a negative effect on juveniles per redd, the capacity of the habitats must be included in the analyses. The Supplementary Hypotheses presented below are designed to address the confounding effects of different densities on the analyses.

2.1 Juvenile Productivity (*Productivity Indicator*)

Monitoring Questions:

Q2.1.1: Has the supplementation program changed the number of juveniles (smolts, parr, and/or emigrants) per redd within the supplemented population?

Q2.2.1: Does the number of juveniles per redd decrease as the proportion of hatchery spawners increases?[6]

Target Species/Populations:

- Both Q2.1.1 and Q2.2.1 apply to all conservation stocks.

[6] Information is needed to estimate the effects of density dependence on these questions. Consider spatial distribution of redds.

Statistical Hypotheses for 2.1.1[7]:

- $Ho_{2.1.1.1}$: Slope in juveniles/redd before supplementation ≤ slope in juveniles/redd after supplementation.
- $Ho_{2.1.1.2}$: Differences in slopes in juveniles/redd between supplemented and reference populations before supplementation ≤ differences in slopes in juveniles/redd between supplemented and reference populations after supplementation.
- $Ho_{2.1.1.3}$: Mean juveniles/redd before supplementation ≤ mean juveniles/redd after supplementation.
- $Ho_{2.1.1.4}$: Mean ratio scores in juveniles/redd before supplementation ≤ Mean ratio scores in juveniles/redd during supplementation.
- $Ho_{2.1.1.5}$: Mean ratio scores in juveniles/redd (adjusted for density dependence) before supplementation ≤ Mean ratio scores in juveniles/redd (adjusted for density dependence) during supplementation. [This hypothesis adjusts juveniles/redd for density-dependent effects (see Hillman et al. 2012 for details; Appendix 7).]
- $Ho_{2.1.1.6}$: There is no association between the proportion of hatchery-origin spawners (pHOS) and the residuals from the smooth hockey stick stock-recruitment curve; rho = 0. [If there is a significant negative association between pHOS and the residuals, then hatchery fish may be reducing the productivity of the wild population.]

Statistical Hypotheses for 2.2.1:

- $Ho_{2.2.1.1}$: There is no association between the proportion of hatchery-origin spawners (pHOS) and the residuals from the smooth hockey stick stock-recruitment curve; rho = 0. [If there is a significant negative association between pHOS and the residuals, then hatchery fish may be reducing the productivity of the wild population.]
- $Ho_{2.2.1.2}$: The slope between proportion of hatchery spawners and juveniles/redd is ≥ 0.

Measured Variables:

- Number of hatchery and naturally produced fish on spawning grounds.
- Numbers of redds.
- Number of juveniles (smolts, parr [where appropriate], and emigrants).

Derived Variables:

- Number of juveniles per spawner.
- Number of juveniles per redd.
- Carrying capacity.

Spatial/Temporal Scale:

- Calculate annually based on brood year.
- Time series.

Possible Statistical Analysis:

[7] Quality and quantity of data will determine which hypotheses are evaluated. See Hillman et al. 2012 for details.

- These analyses shall be performed every five-years. Use graphic analyses, trend analyses, t-tests, Aspin-Welch tests, and randomization tests to evaluate the statistical hypotheses (see Hillman et al. 2012; Appendix 7). The specific analysis used will depend on the availability of reference conditions.
- Correlation analysis will examine associations between hatchery adult composition and juveniles/redd.

Analytical Rules:

- This is a productivity indicator that will be used to assess the success of the supplementation program.
- Type I Error of 0.05.

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Monitoring Indicators: Natural Environment

Objective 3: Determine if the hatchery adult-to-adult survival (i.e., hatchery replacement rate, HRR) is greater than the natural adult-to-adult survival (i.e., natural replacement rate, NRR) and the target hatchery survival rate.

The survival advantage from the hatchery (i.e., egg-to-smolt) must be sufficient to produce a greater number of returning adults than if broodstock were left to spawn naturally. If a hatchery program cannot produce a greater number of adults than naturally spawning fish, then the program should be modified or discontinued. Production levels were initially developed using historical run sizes and smolt-to-adult survival rates (BAMP 1998). Using the stock specific NRR and agreed upon target values (see Appendix 2), comparisons to actual survival rates will be made to ensure the expected level of survival has been achieved.

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3.1 Hatchery Replacement Rates (HRRs) (*Monitoring Indicator*)

Monitoring Questions:

Q3.2.1: Is the adult-to-adult survival rate of hatchery fish (HRR) greater than or equal to the adult-to-adult survival rate (NRR) of naturally produced fish?

Q3.2.2: Is the adult-to-adult survival rate of hatchery fish (HRR) greater than or equal to the Target Value identified in Appendix 2[8]?

Target Species/Populations:

- Q3.2.1 applies to all conservation stocks.
- Q3.2.2 applies to all stocks.

Statistical Hypothesis 3.2.1:

- $Ho_{3.2.1.1}$: $HRR_{\text{Year } x} \geq NRR_{\text{Year } x}$

Statistical Hypothesis 3.2.2:

- $Ho_{3.2.2.1}$: HRR ≥ Target Value identified in Appendix 2

Measured Variables:

- Number of hatchery and naturally produced fish on spawning grounds.
- Number of hatchery and naturally produced fish harvested.
- Number of hatchery and naturally produced fish collected for broodstock.
- Number of broodstock used by brood year (hatchery and naturally produced fish).

Derived Variables:

- Number of hatchery and naturally produced adults by brood year (≥age-3).
- HRR (number of returning adults per brood year/broodstock)
- NRR (from Objective 1)
- Appendix 2: HRR targets identified in Appendix 2

[8] Target values may be adjusted by the hatchery committees.

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Spatial/Temporal Scale:

- Calculate annually based on brood year.
- Time series.

Possible Statistical Analysis:

- For Q3.2.1 use graphic analysis and paired-sample quantile tests to compare HRR to NRR
- For Q3.2.2 use graphic analysis and one-sample quantile tests to compare HRR to the target value.
- On a five-year period, correlate HRRs with extraneous factors such as ocean productivity indices.

Analytical Rules:

- This is a monitoring indicator that will be used to support management decisions.
- Type I Error of 0.05.

Objective 4: Determine if the proportion of hatchery-origin spawners (pHOS or PNI) is meeting management target.

Certain hatchery programs have pHOS or PNI targets, while others do not. HGMPs and permits inform the selection of targets, which are identified in Appendix 3.

4.1 Attainment of proportion of hatchery-origin spawners (pHOS or PNI) target (*Monitoring Indicator*)

Monitoring Questions:

Q4.1.1: Is the estimated proportion of hatchery-origin spawners (pHOS) less than or equal to the management target, and/or, is the estimated Percent Natural Influence (PNI) greater than or equal to the management target identified in Appendix 3?

Target Species/Populations:

- Q4.1.1 applies to all conservation and safety-net stocks that have a defined pHOS or PNI target or sliding scale (see Appendix 3).

Statistical Hypothesis 4.1.1:

- $Ho_{4.1.1.1}$: pHOS > target value or $PNI_{\text{Supplemented population}}$ < target value identified in Appendix 3

Measured Variables:

- Number of hatchery and naturally produced fish on spawning grounds

Derived Variables:

- pHOS or PNI
- Appendix 3: PNI and pHOS targets and sliding scales identified in Appendix 3

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Spatial/Temporal Scale:
- Calculate annually.
- Analyzed as time series.

Possible Statistical Analysis:
- Use graphic analysis and summary statistics to compare pHOS or PNI to the target value in Appendix 3.

Analytical Rules:
- This is a monitoring indicator that will be used to support management decisions.

Objective 5: Determine if the run timing, spawn timing, and spawning distribution of the hatchery component is similar to the natural component of the target population or is meeting program-specific objectives.

Strategies for conservation programs typically intend that hatchery and natural-origin fish spawn together and in similar locations. However, in some cases, strategies may differ from this paradigm (e.g., summer Chinook salmon in the Wenatchee and Methow rivers; see Appendix 4). Phenotypic plasticity or selection resulting from the hatchery environment (i.e., domestication) may affect run (migration) timing, spawn timing, and spawning distribution. If conservation programs do not adequately represent the genetic diversity of the natural population, and if phenotypic traits in supplementation fish related to fitness deviate from the naturally produced spawning population, the goals of supplementation may not be achieved. Hatchery adults that migrate and/or spawn at different times or are spatially segregated from natural-origin fish may be subject to reduced fitness. Hatchery adults that spawn at different times or locations than natural-origin fish would be reproductively isolated from the natural population. The extent of such isolation, ranging from no isolation to substantial isolation, may be exploited for management purposes in some cases.

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5.1 Migration Timing (*Monitoring Indicator*)

Monitoring Questions:

Q5.1.1: Is the migration timing of hatchery and naturally produced fish from the same age class similar?

Target Species/Populations:
- Q5.1.1 applies to all conservation stocks.

Statistical Hypotheses 5.1.1:
- Ho$_{5.1.1.1}$: Migration timing $_{\text{Hatchery Age X}}$ = Migration timing $_{\text{Naturally produced Age X}}$
- Ho$_{5.1.1.2}$: The cumulative frequency of migration timing of hatchery-origin fish = the cumulative frequency of migration timing of natural-origin fish.

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- $Ho_{5.1.1.3}$: The 10th percentile, 50th percentile (mode), 90th percentile, and mean migration timing of hatchery-origin fish = the 10th percentile, 50th percentile (median), 90th percentile, and mean migration timing of natural-origin fish.

Measured Variables:
- Ages of hatchery and naturally produced fish sampled via pit tags or stock assessment monitoring.
- Time (Julian date) of arrival at mainstem projects and within tributaries (e.g., traps, PIT arrays) with the intent to identify biologically significant differences.

Derived Variables:
- Mean Julian date for a given age class.

Spatial/Temporal Scale:
- Calculate annually based on return year and age class.
- Time series.

Possible Statistical Analysis:
- Use graphic analyses (cumulative frequency polygons), paired t-tests, Aspin-Welch tests, and randomization tests.

Analytical Rules:
- This is a monitoring indicator that will be used to support management decisions.
- Type I Error of 0.05.

5.2 Timing of Spawning (*Monitoring Indicator*)

Monitoring Questions:

Q5.2.1: Is the timing of spawning similar for conservation hatchery and naturally produced fish?

Target Species/Populations:
- Q5.2.1: Applies to all semelparous species and populations supplemented by conservation programs. Steelhead can only be assessed for natural spawning in situations where hatchery and natural origin fish can be appropriately marked and detected.

Statistical Hypotheses 5.2.1:
- $Ho_{5.2.1.1}$: The cumulative frequency of spawn timing of hatchery-origin fish = the cumulative frequency of spawn timing of natural-origin fish.
- $Ho_{5.2.1.2}$: The 10th percentile, 50th percentile (mode), 90th percentile, and mean spawn timing of hatchery-origin fish = the 10th percentile, 50th percentile (mode), 90th percentile, and mean spawn timing of natural-origin fish.
- $Ho_{5.2.1.3}$: The relationship between elevation and spawn timing of hatchery-origin fish = the relationship between elevation and spawn timing of natural-origin fish.

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Measured Variables:

- Time (Julian date) and elevation (m) of hatchery and naturally produced salmon carcasses or marked steelhead detected on spawning grounds within defined reaches.
- Time (Julian date) of ripeness of hatchery and natural origin steelhead captured for broodstock.

Derived Variables:

- Mean Julian date.

Spatial/Temporal Scale:

- Calculate annually based on return year.
- Time series.

Possible Statistical Analysis:

- Use graphic analyses (cumulative frequency polygons), paired t-tests, Aspin-Welch tests, and randomization tests.
- Graphic and regression analysis to assess relationships between elevation and spawn timing.

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Analytical Rules:

- This is a monitoring indicator that will be used to support management decisions.
- Type I Error of 0.05.

5.3 Spatial Distribution of Redds (*Monitoring Indicator*)

Monitoring Questions:

Q5.3.1: Is the distribution of redds similar for conservation hatchery and naturally produced fish?

Q5.3.2: Is the distribution of redds similar to defined management targets (see Appendix 4)?

Target Species/Populations:

- Q5.3.1 applies to all conservation program stocks.
- Q5.3.2 applies only to conservation program stocks with specific spawning distribution targets (Carlton and Dryden summer Chinook programs; Appendix 4).

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Statistical Hypothesis 5.3.1:

- $Ho_{5.3.1.1}$: The distribution of hatchery-origin redds (hatchery females) = the distribution of natural-origin redds (natural-origin females).

Statistical Hypothesis 5.3.2:

- $Ho_{5.3.2.1}$: The distribution of hatchery-origin redds (hatchery females) = the target distribution identified in Appendix 4.

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Measured Variables:

- Location (GPS coordinate) of female salmon carcasses observed on spawning grounds. The distribution of hatchery and naturally produced steelhead redds may be evaluated if marking or tagging efforts provide reasonable results.

Derived Variables:

- Location of female salmon carcass at the historic reach scale and at the 0.1 km scale.
- Calculate percent overlap in distribution across available spawning habitat or historical reaches.
- Appendix 4: Management targets for spatial distribution of spawners or redds (as applicable).

Spatial/Temporal Scale:

- Calculate annually based on return year.
- Time series.

Possible Statistical Analysis:

- Use graphic analysis and Yates' Chi-square analysis for both Q5.3.1 and Q5.3.2.

Analytical Rules:

- This is a monitoring indicator that will be used to support management decisions.
- Type I Error of 0.05.

Objective 6: Determine if the recipient stray rate of hatchery fish is below the acceptable levels to maintain genetic variation among stocks.

Maintaining locally adapted traits among independent fish populations requires that returning hatchery fish have a high rate of site fidelity to the target population or stream. Hatchery practices (e.g., imprinting on water sources at key life history stages, release methodology, release location, age at return, and environmental conditions) are the main variables thought to affect stray rates. Regardless of the magnitude of homing of adult returns, if adult hatchery fish do not contribute to the natural population, the program will not meet the basic condition of a supplementation program.

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Independent populations are populations that are genetically differentiated from other populations. In some cases, genetic differentiation may be assumed based on phenotypic traits or geographic isolation when molecular genetics analyses are not available. When populations are not independent, straying among them does not pose a risk of genetic homogenization. In addition, stray rates of hatchery-origin fish cannot be expected to be lower than for natural-origin fish. When estimates of stray rates for natural-origin fish are available and if they exceed the 5% among population stray rate or 10% within population stray rate thresholds identified in this plan, analysis and interpretation of stray rates must take into account the concept that hatchery programs may be held to unattainable standards based on the natural stray rate. Current criteria established by the ICBTRT (2005) and the Upper Columbia Spring Chinook Salmon and Steelhead Recovery Plan (2007) indicate that fish that do stray to other non-target populations

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should not comprise greater than 5% of the non-target spawning population. Likewise, fish that stray into non-target spawning areas within an independent population should not comprise greater than 10% of the non-target spawning aggregate (see Tables 6.1 and 6.2).

This plan identifies three stray rate metrics; brood-year stray rate, among population return-year stray rate, and within population return-year stray rate. The return-year stray rates have specific targets that are from the ICBTRT (2005) and Upper Columbia Spring Chinook Salmon and Steelhead Recovery Plan (2007), and are linked to extinction risk. That is, hatchery strays from other populations cannot make up more than 5% of the spawning escapement within a non-target, recipient population. In addition, hatchery strays from other spawning aggregations within a population (e.g., Chiwawa spring Chinook) cannot make up more than 10% of the spawning escapement within a non-target, recipient spawning aggregate (e.g., Peshastin Creek). Brood-year stray rate, on the other hand, is not discussed in the Upper Columbia Spring Chinook Salmon and Steelhead Recovery Plan (2007) or ICBTRT (2005) and therefore has no specific target. Nevertheless, it is important to track brood-year stray rates to determine if hatchery operations affect the homing and straying of specific brood years. These data support the return-year stray metrics and are used to explain possible changes in genetic variation among stocks.

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6.1.1 Brood-Year Stray Rates (*Monitoring Indicator*)

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Monitoring Questions:

Q6.1.1: What is the brood-year stray rate of hatchery fish?

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Target Species/Populations:

- Q6.1.1 applies to all hatchery stocks.

Statistical Hypothesis 6.1.1:

- $Ho_{6.1.1.1}$: None.

Deleted: Stray rate of hatchery fish ≥ 5% of total hatchery brood return

Measured Variables:

- Number of hatchery carcasses found in non-target and target spawning areas or number of returning spawners counted via PIT-tag detection or at weirs in close temporal proximity to spawning areas.
- Number of hatchery fish collected for broodstock.
- Number of hatchery fish taken in fishery.
- Locations of live and dead strays (used to tease out overshoot).

Derived Variables:

- Total number of hatchery carcasses and take in fishery estimated from expansion analysis.
- Percent of the total brood return that strays.
- Appendix 5: Reciprocal stray rates

Spatial/Temporal Scale:

- Calculate annually based on brood year.
- Time series.

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Possible Statistical Analysis:
- Use graphical analysis to track brood-year stray rates over time.

Deleted: and one-sample quantile tests to compare the estimated stray rate with the target (5%) stray rate.

Analytical Rules:
- This is a monitoring indicator that will be used to support management decisions.

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6.2 Among Population Return-Year Stray Rates (*Monitoring Indicator*)

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Monitoring Questions:

Q6.2.1: Do hatchery strays make up less than 5% of the spawning escapement within other non-target independent populations?

Target Species/Populations:
- Q6.2.1 applies to all hatchery stocks.

Statistical Hypothesis 6.2.1:
- $Ho_{6.2.1.1}$: Stray hatchery fish make up ≥ 5% of the spawning escapement (based on run year) within other independent populations [9]

Measured Variables:
- Number of hatchery carcasses (PIT-tagged steelhead) found in non-target and target spawning areas or number of returning spawners counted via PIT-tag detection or at weirs in close temporal proximity to spawning areas.

Derived Variables:
- Total number of hatchery salmon carcasses (PIT-tagged steelhead, spawners counted at weirs) estimated from expansion analysis.
- Percent of the non-target population that is made up of hatchery strays.
- Appendix 5: Reciprocal stray rates

Spatial/Temporal Scale:
- Calculate annually based on return year.
- Time series.

Possible Statistical Analysis:
- Use graphical analysis and one-sample quantile tests to compare the estimated stray rate with the target (5%) stray rate.

[9] This stray rate is suggested based on a literature review and recommendations by the ICBTRT (2005) and is identified in the Upper Columbia Spring Chinook Salmon and Steelhead Recovery Plan (2007). It can be re-evaluated as more information on naturally-produced Upper Columbia salmonids becomes available. This will be evaluated on a species and program specific basis and decisions made by the HCP HC. It is important to understand the actual spawner composition of the population to determine the potential effect of straying.

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Analytical Rules:
- This is a monitoring indicator that will be used to support management decisions.
- Type I Error of 0.05.

6.3 Within Population Return-Year Stray Rates (*Monitoring Indicator*)

Deleted: among Spawning Areas within the Population

Monitoring Questions:

Q6.3.1: Do hatchery strays make up less than 10% of the spawning aggregate within non-target spawning areas within the target population?[10]

Target Species/Populations:
- Q6.3.1 applies to all hatchery stocks.

Statistical Hypothesis 6.3.1:
- $Ho_{6.3.1}$: Stray hatchery fish make up ≥ 10% of spawning escapement (based on run year) within non-target spawning areas within the target population

Measured Variables:
- Number of hatchery carcasses (possibly PIT-tagged steelhead) found in non-target and target spawning aggregates or number of returning spawners counted via PIT-tag detection or at weirs in close temporal proximity to spawning areas.

Derived Variables:
- Total number of hatchery salmon carcasses (possibly PIT-tagged steelhead or spawners counted at weirs) estimated from expansion analysis.
- Percent of the non-target spawning aggregate that is made up of hatchery strays.
- Appendix 5: Reciprocal stray rates

Spatial/Temporal Scale:
- Calculate annually based on return year.
- Time series.

Possible Statistical Analysis:
- Use graphical analysis and one-sample quantile tests to compare the estimated stray rate with the target (10%) stray rate.

Analytical Rules:
- This is a monitoring indicator that will be used to support management decisions.
- Type I Error of 0.05.

[10] The value of 10% should be reviewed by the Hatchery Committee. See footnote 3 for additional information.

Monitoring Indicators: Population Genetics

Objective 7: Determine if genetic diversity, population structure, and effective population size have changed in natural spawning populations as a result of the hatchery program.

The genetic component of the M&E Plan specifically addresses the potential for changes in genetic diversity in natural populations as a result of a hatchery program(s). The long-term fitness of populations is assumed to be related to maintaining the genetic diversity of natural populations. However, hatchery programs select a subset of individuals from the population to pass on genetic material to the next generation. This is often a relatively small number of individuals that produce a large number of offspring, and can result in changes in allele frequencies and reductions of effective population size. Therefore, it is important to monitor the genetic status of the natural populations to determine if there are signs of changes in genetic distance among populations, changes in allele frequencies, and to estimate effective population size. Assessing the genetic effects of the hatchery program does not require annual sampling. Meeting stray-rate targets (hypotheses tested under Objective 5) should reduce significant changes in population genetics. Stray rates may inform population genetic analyses. Testing statistical hypotheses associated with genetic components (Hypotheses 3.1, 3.2, and 3.3) should be conducted every ten years or two generations.

7.1 Allele Frequency (*Monitoring Indicator*)

Monitoring Questions:

Q7.1.1: Is the allele frequency of hatchery fish similar to the allele frequency of naturally produced and donor fish?

Target Species/Populations:

- Q7.1.1 applies to all conservation stocks.

Statiscial Hypotheses 7.1.1:

- $Ho_{7.1.1}$: Allele frequency $_{\text{Hatchery}}$ = Allele frequency $_{\text{Naturally produced}}$ = Allele frequency $_{\text{Donor pop.}}$
- $Ha_{7.1.1}$: Allele frequency $_{\text{Hatchery}}$ ≠ Allele frequency $_{\text{Naturally produced}}$ = Allele frequency $_{\text{Donor pop.}}$ or
- $Ha_{7.1.1}$: Allele frequency $_{\text{Hatchery}}$ = Allele frequency $_{\text{Naturally produced}}$ ≠ Allele frequency $_{\text{Donor pop.}}$ or
- $Ha_{7.1.1}$: Allele frequency $_{\text{Hatchery}}$ ≠ Allele frequency $_{\text{Naturally produced}}$ ≠ Allele frequency $_{\text{Donor pop.}}$

Measured Variables:

- Microsatellite genotypes or SNP genotypes, as appropriate

Derived Variables:

- Allele frequency

Spatial/Temporal Scale:
- Analyze as a time series, initially comparing pre- and post-hatchery samples and thereafter every 10 years.
- Compare samples within drainages.

Possible Statistical Analysis:
- Population differentiation tests, analysis of molecular variance (AMOVA), and relative genetic distances.

Analytical Rules:
- This is a monitoring indicator that will be used to support management decisions.
- Type I Error of 0.05.

7.2 Genetic Distances Between Populations (*Monitoring Indicator*)

Monitoring Questions:

Q7.2.1: Does the genetic distance among subpopulations within a supplemented population remain the same over time?

Target Species/Populations:
- Q7.2.1 applies to all conservation and safety-net stocks.

Statistical Hypothesis 7.2.1:
- $Ho_{7.2.1.1}$: Genetic distance between subpopulations $_{\text{Year } x}$ = Genetic distance between subpopulations $_{\text{Year } y}$

Measured Variables:
- Microsatellite genotypes or SNP genotypes

Derived Variables:
- Allele frequencies

Spatial/Temporal Scale:
- Analyze as a time series, initially comparing pre- and post-hatchery samples and thereafter every 10 years.
- Compare samples among spawning aggregates.

Possible Statistical Analysis:
- Population differentiation tests, AMOVA, and relative genetic distances.

Analytical Rules:
- This is a monitoring indicator that will be used to support management decisions.
- Type I Error of 0.05.

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7.3 Effective Spawning Population (*Monitoring Indicator*)

Monitoring Questions:

Q7.3.1: Is the ratio of effective population size (N_e) to spawning population size (N) constant over time?

Target Species/Populations:

- Q7.3.1 applies to all supplemented stocks.

Statistical Hypothesis 3.3:

- $Ho_{7.3.1.1}$: $(N_e/N)_{t0} = (N_e/N)_{t1}$ for each population

Measured Variables:

- Microsatellite genotypes or SNP genotypes

Derived Variables:

- Allele frequencies

Spatial/Temporal Scale:

- Analyze as a time series, initially comparing pre- and post-hatchery samples and thereafter every 10 years.

Possible Statistical Analysis:

- Population differentiation tests, relative genetic distances, statistics to calculate effective population size (e.g., harmonic means).

Analytical Rules:

- This is a monitoring indicator that will be used to support management decisions.
- Type I Error of 0.05.

Monitoring Indicators: Phenotypic Traits

Objective 8: Determine if hatchery programs have caused changes in phenotypic characteristics of natural populations.

Fitness, or the ability of individuals to survive and pass on their genes to the next generation in a given environment, includes genetic, physiological, and behavioral components.[11] Maintaining the long-term fitness of supplemented populations requires a comprehensive evaluation of genetic and phenotypic characteristics. Evaluation of some phenotypic traits (i.e., run timing, spawn timing, spawning location, and stray rates) is addressed under Objective 5. Objective 8 assess the potential effects of domestication, including size at maturity, age at maturity, sex ratio, and fecundity. Age and size at maturity shall be assessed for both fish arriving in the Columbia system, and those recovered on the spawning grounds. Size (or age) selective mortality during migration through the Columbia system, such as through fisheries, could alter the age and size of fish on the spawning grounds.

8.1 Age at Maturity (*Monitoring Indicator*)

Monitoring Questions:

Q8.1.1: Is the age at maturity of hatchery and naturally produced fish similar at the time they enter the Columbia River and when they spawn?

Target Species/Populations:

- Q8.1.1 applies to all conservation program stocks.

Statistical Hypotheses 8.1.1:

- $Ho_{8.1.1.1}$: Age at Maturity $_{\text{Hatchery produced spawners Gender X}}$ = Age at Maturity $_{\text{Naturally produced spawners Gender X}}$
- $Ho_{8.1.1.2}$: Age at Maturity $_{\text{All hatchery produced adults Gender X}}$ = Age at Maturity $_{\text{All naturally produced adults Gender X}}$

Measured Variables:

- Total and salt (ocean) age of hatchery and naturally produced salmon carcasses collected on spawning grounds.
- Total and salt age of broodstock.
- Total and salt age of fish at stock assessment locations (e.g., Dryden, Tumwater, Wells, Priest Rapids).
- Whenever possible, age at maturity will be measured at weirs or dams near the spawning stream to avoid the size-related carcass recovery bias on spawning grounds (carcass sampling).
- Assess age of fish, including harvested fish.

[11] These metrics are difficult to measure, and phenotypic expression of these traits may be all we can measure and evaluate.

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Derived Variables:
- Total age and saltwater age
- Age of fish entering the Columbia River.

Spatial/Temporal Scale:
- Calculate annually based on brood year.
- Time series.

Possible Statistical Analysis:
- Use graphic analysis and Yates' Chi-square.

Analytical Rules:
- This is a monitoring indicator that will be used to support management decisions.
- Type I Error of 0.05.

8.2 Size at Maturity (*Monitoring Indicator*)

Monitoring Questions:

Q8.2.1: Is the size (length) at maturity of a given age and sex of hatchery fish similar to the size at maturity of a given age and sex of naturally produced fish?

Target Species/Populations:
- Q8.2.1 applies to all conservation and safety-net stocks.

Statistical Hypothesis 8.2.1:
- $Ho_{8.2.1.1}$: Size (length) at Maturity $_{\text{Hatchery Age X and Gender Y}}$ = Size (length) at Maturity $_{\text{Naturally produced Age X and Gender Y}}$
- $Ho_{8.2.1.2}$: Size (length) at Maturity $_{\text{All hatchery adults Gender X}}$ = Size (length) at Maturity $_{\text{All naturally produced adults Gender X}}$

Measured Variables:
- Size (length), age, and gender of hatchery and naturally produced salmon carcasses collected on spawning grounds.
- Size (length), age, and gender of broodstock.
- Size (length), age, and gender of fish at stock assessment locations (e.g., Priest Rapids, Dryden, Tumwater, Wells, Twisp Weir).
- Whenever possible size at maturity will be measured at weirs or dams near the spawning stream to avoid the size-related carcass recovery bias on spawning grounds (carcass sampling).

Derived Variables:
- Total age and saltwater age

Spatial/Temporal Scale:

- Calculate annually based on brood year.
- Time series.

Possible Statistical Analysis:
- Use graphic analysis and three-way ANOVA by origin, gender, and age

Analytical Rules:
- This is a monitoring indicator that will be used to support management decisions.
- Type I Error of 0.05.

8.3 Fecundity at Size (*Monitoring Indicator*)[12]

Monitoring Questions:

Q8.3.1: Is the fecundity vs. size relationship of hatchery and naturally produced fish similar?

Q8.3.2: Is the gonadal mass vs. size relationship of hatchery and naturally produced fish similar?

Target Species/Populations:
- Both Q8.3.1 and Q8.3.2 apply to all conservation stocks using both natural- and hatchery-origin broodstock.

Statistical Hypothesis 8.3.1:
- $Ho_{8.3.1.1}$: Slope of Fecundity vs. Size $_{Hatchery}$ = Slope of Fecundity vs. Size $_{Naturally\ produced}$

Statistical Hypothesis 8.3.2:
- $Ho_{8.3.2.1}$: Gonadal Mass vs. Size $_{Hatchery}$ = Gonadal Mass vs. Size $_{Naturally\ produced}$

Measured Variables:
- Length, weight, and age (covariate) of hatchery and natural-origin broodstock after eggs have been removed.
- Number and weight of eggs

Derived Variables:
- Total age and saltwater age.
- Mean weight per egg.

Spatial/Temporal Scale:
- Calculate annually based on brood year.
- Time series.

Possible Statistical Analysis:

[12] May not apply to all programs.

- Use graphic analysis, regression, t-test, and ANCOVA.

Analytical Rules:
- This is a monitoring indicator that will be used to support management decisions.
- Type I Error of 0.05.

8.4 Sex Ratio (*Monitoring Indicator*)

Monitoring Questions:

Q8.4.1: Is the sex ratio of hatchery and naturally produced fish similar?

Target Species/Populations:
- Q8.4.1 applies to all conservation stocks.

Statistical Hypothesis 8.4.1:
- $Ho_{8.4.1.1}$: Sex Ratio $_{\text{Hatchery}}$ = Sex Ratio $_{\text{Naturally produced}}$

Measured Variables:
- Age and sex of hatchery and naturally produced salmon carcasses collected on spawning grounds or sampled at dams or weirs.
- Whenever possible sex ratio will be measured at weirs or dams near the spawning stream to avoid the size-related carcass recovery bias on spawning grounds (carcass sampling or ultrasound on live fish).

Derived Variables:
- Ratio of sexes based on brood year returns

Spatial/Temporal Scale:
- Calculate annually based on brood year.
- Time series.

Possible Statistical Analysis:
- Use graphic analysis and Yates'Chi-square.

Analytical Rules:
- This is a monitoring indicator that will be used to support management decisions.
- Type I Error of 0.05.

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Monitoring Indicators: Hatchery Environment

<u>Objective 9</u>: Determine if hatchery fish were released at the programmed size and number.

The HCP outlines the number and size of fish that are to be released to meet NNI and inundation compensation levels. The size of the fish at release may be altered according to an adaptive management process in the Hatchery Committee(s), and the number of fish can be altered by survival study results and adjustment of hatchery production for population dynamics. Size of fish at release can affect survival, sex ratios, age at return, stray rate, and fecundity. In addition, the variation in size at release may affect performance of the fish.

The coefficient of variation (CV) will be evaluated to ascertain if program performance is related to variation in size at release. Note also that variation in a population is a natural condition and striving to control this variation could result in directional or stabilizing artificial selection that could have unforeseen long-term consequences. Attaining uniform or multi-modal growth in a hatchery environment may not be adaptive for fitness in the wild. Therefore, pursuit of a CV target should be seen as an informative exercise, but is not in itself indicative of success or failure of a hatchery program. Furthermore, growth regimes may prove to be important in affecting adult returns and age structure. Although many factors can influence both the size and number of fish released, past hatchery cultural experience with these stocks should assist in meeting program production levels. Appendix 5 presents the target size at release and CVs for the programs. These targets shall be assessed annually to ensure they are optimized to inform management decisions.

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9.1 Size at Release of Hatchery Fish (*Monitoring Indicator*)

Monitoring Questions:

Q9.1.1: Is the size (length and weight) of hatchery fish released equal to the program goal?

Commented [TH1]: Do we need to add these to Appendix 5?

Target Species/Populations:

- Q9.1.1 applies to all hatchery stocks.

Statistical Hypothesis 9.1.1:

- $Ho_{9.1.1.1}$: Hatchery fish $_{\text{Size at release}}$ = Programmed $_{\text{Size at release}}$

Measured Variables:

- Fork length and weights of random samples of hatchery juveniles at release.

Derived Variables:

- Mean length (FL) and mean weight
- Appendix 6: Rearing targets

Spatial/Temporal Scale:

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- Calculate annually.
- Time series.

Possible Statistical Analysis:

- Use graphic analysis and descriptive statistics to compare the estimated size of hatchery fish at time of release with the program goal.

Analytical Rules:

- This is a monitoring indicator that will be used to support management decisions.

9.2 Coefficient of Variation (CV) of Hatchery Fish Released (*Monitoring Indicator*)

Monitoring Questions:

Q9.2.1: Is the CV of hatchery fish released equal to the program target identified in Appendix 5?

Target Species/Populations:

- Q9.2.1 applies to all hatchery stocks.

Statistical Hypothesis 9.2.1:

- $Ho_{9.2.1.1}$: Hatchery fish CV $_{\text{at release}}$ = Programmed CV in Appendix 5

Measured Variables:

- Length and weights of random samples of hatchery smolts.

Derived Variables:

- Coefficient of Variation: $cv = (1 + 1/4n) \times (s/x)$ (where s = standard deviation, x = estimated mean, n = sample size)
- Appendix 5: Rearing targets

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Spatial/Temporal Scale:

- Calculate annually.
- Time series.

Possible Statistical Analysis:

- Use graphic analysis and descriptive statistics to compare the estimated CV of size of hatchery fish released with the program goal.

Analytical Rules:

- This is a monitoring indicator that will be used to support management decisions.

9.3 Condition Factor (K) of Hatchery Fish Released (*Monitoring Indicator*)

Monitoring Questions:

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Q9.3.1: Is the K of hatchery fish released equal to the program target identified in Appendix 5?

Commented [TH2]: At this time there is no program target for K.

Target Species/Populations:
- Q9.3.1 applies to all hatchery stocks.

Statistical Hypothesis 9.3.1:
- $Ho_{9.3.1.1}$: Hatchery fish $K_{\text{at release}}$ = Programmed K identified in Appendix 5

Measured Variables:
- Monthly individual lengths and weights of random samples of hatchery juveniles.

Derived Variables:
- Condition Factor: $K = W/L^3 \times 10^5$

Spatial/Temporal Scale:
- Calculate annually.
- Time series.

Possible Statistical Analysis:
- Use graphic analysis and descriptive statistics to compare the estimated K of released hatchery fish with the program goal.

Analytical Rules:
- This is a monitoring indicator that will be used to support management decisions.
- Type I Error of 0.05.

9.4 Number of Hatchery Fish (*Monitoring Indicator*)

Monitoring Questions:

Q9.4.1: Is the number of hatchery fish released equal to the program goal identified in Appendix 2?

Commented [TH3]: Suggest putting the release targets in Appendix 5

Target Species/Populations:
- Q9.4.1 applies to all hatchery stocks.

Statistical Hypothesis 9.4.1:
- $Ho_{9.4.1.1}$: Hatchery Fish Number = Programmed Number identified in Appendix 2

Measured Variables:
- Numbers of smolts released from the hatchery.

Derived Variables:
- Appendix 2: Rearing targets

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Spatial/Temporal Scale:

- Calculate annually.
- Time series.

Possible Statistical Analysis:

- Use graphic analysis and one-sample quantile tests to compare the estimated number of hatchery fish released with the program goal.

Analytical Rules:

- This is a monitoring indicator that will be used to support management decisions.
- Type I Error of 0.05.

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Monitoring Indicators: Harvest

Objective 10: Determine if appropriate harvest rates have been applied to conservation, safety-net, and segregated harvest programs to meet the HCP/SSSA goal of providing harvest opportunities while also contributing to population management and minimizing risk to natural populations.

Harvest will be applied to different types of programs in an effort to achieve the management objectives of those programs. Programs designed to augment harvest should routinely contribute to harvest at a rate that greatly reduces the incidence of straying to natural spawning grounds, but also allows the program to be sustained. Safety-net programs may be harvested as part of an adult management strategy to minimize excessive escapement of hatchery-origin fish to spawning grounds. Similarly, conservation programs may undergo harvest to manage returning adults, but the emphasis for these programs should be to achieve escapement goals. In all cases, harvest effort should not have the unintended consequence of removing excessive numbers of conservation or natural-origin fish. In years when the expected returns of hatchery adults are above the level required to meet program goals (i.e., supplementation of spawning populations and/or brood stock requirements), surplus fish may be available for harvest. The M&E Plan specifically addresses harvest and harvest opportunities upstream of Priest Rapids Dam. Harvest or removal of surplus hatchery fish from the spawning grounds may assist in reducing potential adverse ecological and genetic impacts to natural populations (e.g., loss of genetic variation within and between populations, loss of fitness, reduced effective population size, and density-dependent effects).

10.1 Harvest Rates (*Monitoring Indicator*)

Monitoring Questions:

Q10.1.1: Conservation Programs: Is the harvest on conservation hatchery fish at an appropriate level to manage natural spawning of conservation hatchery fish but low enough to sustain the hatchery program?

Q10.1.2: Safety-Net Programs: Is the harvest on conservation hatchery fish at an appropriate level to manage natural spawning of safety-net hatchery fish but low enough to sustain the hatchery program?

Q10.1.3: Is the harvest on hatchery fish produced from harvest-augmentation programs high enough to manage natural spawning but low enough to sustain the hatchery program?

Q10.1.4: Is the escapement of fish from conservation and safety-net programs in excess of broodstock and natural production[13] needs to provide opportunities for terminal harvest?

Target Species/Populations:

- Q10.1.1 applies to conservation programs.
- Q10.1.2 applies to safety-net programs.
- Q10.1.3 applies harvest augmentation programs.

[13] The current best estimates of carrying capacity (maximum recruits) will be used, as available.

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- Q10.1.4 applies to conservation and safety-net programs.

Statistical Hypothesis 10.1.1:
- $Ho_{10.1.1.1}$: Harvest rate ≤ Maximum level to meet program goals

Statistical Hypothesis 10.1.2:
- $Ho_{10.1.2.1}$: Harvest rate ≤ Maximum level to meet program goals

Statistical Hypothesis 10.1.3:
- $Ho_{10.1.3.1}$: Escapement ≤ Maximum level to meet supplementation goals

Statistical Hypothesis 10.1.4:
- $Ho_{10.1.4.1}$: Harvest rate ≤ Maximum level to meet program goals

Measured Variables:
- Numbers of hatchery fish taken in harvest.
- Numbers of natural-origin fish taken in harvest.

Derived Variables:
- Total harvest by fishery estimated from expansion analysis.

Spatial/Temporal Scale:
- Calculated annually.
- Time series.

Possible Statistical Analysis:
- Use graphic analysis and one-sample quantile tests to compare the estimated harvest of hatchery fish with the program goal.

Analytical Rules:
- This is a monitoring indicator that will be used to support management decisions.
- Type I Error of 0.05.

Regional Objectives

Hatchery programs have the potential to increase diseases that typically occur at low levels in the natural environment (Objective 9). In addition, hatchery fish can reduce the abundance, size, or distribution of non-target taxa through ecological interactions (Objective 10). These are important objectives that will be monitored at a later time. Analytical rules will be established for these objectives before monitoring activities begin.

Objective 11: Determine if the incidence of disease has increased in the natural and hatchery populations.

The hatchery environment has the potential to amplify diseases that are typically found at low levels in the natural environment. Amplification could occur within the hatchery population (i.e., vertical and horizontal transmission) or indirectly from the hatchery effluent or commingling between infected and non-infected fish (i.e., horizontal transmission). Potential impacts to natural populations have not been extensively studied, but should be considered for programs in which the hatchery fish are expected to commingle with natural fish. This is particularly important for supplementation type programs. Specifically, the causative agent of bacterial kidney disease (BKD), *Renibacterium salmoninarum* (Rs), could be monitored at selected acclimation ponds, both in the water and fish, in which the risk and potential for transmission from the hatchery is highest. Although it is technologically possible to measure the amount of Rs in water or Rs DNA in smolts and adults non-lethally sampled, the biological meaning of these data are uncertain. Currently, the only metric available for M & E purposes is measuring the antigen level from kidney/spleen samples (i.e., ELISA, PCR). When available, non-lethal sampling may replace or be used in concert with lethal sampling.

Implementation of this objective will be conducted in a coordinated approach within the hatchery and natural environment. BKD management within the hatchery population (e.g., broodstock or juveniles) has the potential to reduce the prevalence of disease through various actions (e.g., culling or reduced rearing densities). BKD management must also take into account and support other relevant objectives of the M & E program (e.g., Hatchery Return Rate [HRR], number of smolts released). Hence, the goal of BKD management is to decrease the prevalence of disease and maintain hatchery production objectives (i.e., number and HRR).

As previously discussed, disease transmission from hatchery to naturally produced fish may occur at various life stages and locations. Of these, horizontal transmission from hatchery effluent, vertical transmission on the spawning grounds, and horizontal transmission in the migration corridor have been identified as disease interactions that could be examined under this objective, although others may also be relevant. Experimental designs addressing this objective may require technology not yet available, although in some instances samples may be collected, but not analyzed until a link can be established between bacteria levels in samples and disease prevalence.

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Developing a complete set of questions and hypotheses statements for this objective may not be practical at this time, because there is currently no BKD Management Plan. However, while developing experimental designs for this objective, it may be feasible to incorporate both hatchery and natural environment monitoring under a single study design. Integration of the different aspects of the objective would likely result in a more robust approach into understanding the effectiveness of disease management strategies.

Proposed Tasks:

T1: Assemble fish health data for fish used as brood (e.g., ELISA results).

T2: Conduct data exploration exercise to identify potential relationships between pathogen profiles and likely causative variables (e.g., rearing conditions and management actions).

T3: Develop hypotheses for potential testing to meet objective.

Objective 12: Determine if the release of hatchery fish affects non-target taxa of concern (NTTOC) within acceptable limits.

Ecological risks of Pacific salmon (spring, summer, and fall run Chinook, coho, and sockeye salmon) and steelhead trout hatchery programs operated between 2013 and 2023 in the Upper Columbia Watershed will be assessed using Delphi and modeling approaches. Committees composed of resource managers and public utility districts identified non-target taxa of concern (i.e., taxa that are not the target of supplementation), and acceptable hatchery impacts (i.e., change in population status) to those taxa. Biologists assembled information about hatchery programs, non-target taxa, and ecological interactions and this information will be provided to expert panelists in the Delphi process to facilitate assessment of risks and also used to populate the Predation, Competition, and Disease (PCD) Risk 1 model. Delphi panelists will independently estimate the proportion of a non-target taxa population that will be affected by each individual hatchery program. Estimates from each of the two approaches will be independently averaged, a measure of dispersion calculated (e.g., standard deviation), and subsequently compared to the acceptable hatchery impact levels that were determined previously by committees of resource managers and public utility districts. Measures of dispersion will be used to estimate the scientific uncertainty associated with risk estimates. Delphi and model results will be compared to evaluate the qualities of the two approaches. Furthermore, estimates of impacts from each hatchery program will be combined together to generate an estimate of cumulative impact to each non-target taxa.

The Hatchery Evaluation Technical Team (HETT) is currently addressing this objective. Work has been underway for several years. The study is expected to provide risk assessment using both an ecological modeling approach and a panel of expert opinion. These two methods will be compared to establish the potential to use modeling in place of expert panels to conduct such risk assessments in the future.

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Adaptively Managing Using Monitoring and Evaluation Results

Because of naturally large variation in productivity indicators, several years of data may be required before statistical inferences can be made regarding the effects of hatchery fish on productivity of naturally produced fish. Furthermore, given the large natural variation of productivity indicators, productivity could increase or decrease as a result of the hatchery programs before a difference is detected statistically. In the interim, risk associated with supplementation programs and the productivity of naturally produced fish can be quantified based on observed natural variation in the indicator of interest (Table 1). If large differences in rates of change between supplemented and reference populations are observed, management actions may be required.

Assuming hatchery programs do not negatively affect the productivity of naturally produced fish, the observed difference in rates of change between the supplemented and reference populations should decrease over time as more of the natural variation within and between populations is incorporated into these data. More simply, as the number of years increases, the acceptable observed difference in the indicator(s) decreases. The value of the difference at any point in time would determine if management actions are warranted.

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Glossary

Term	Definition
Adult-to-Adult survival (Ratio)	The number of parent broodstock relative to the number of returning adults.
Age at maturity	The age of fish at the time of spawning (hatchery or naturally)
Augmentation	A hatchery strategy where fish are released for the sole purpose of providing harvest opportunities.
Broodstock	Adult salmon and steelhead collected for hatchery fish egg harvest and fertilization.
Donor population	The source population for supplementation programs before hatchery fish spawned naturally.
Effective population size (Ne)	The number of reproducing individuals in an ideal population (i.e., Ne = N) that would lose genetic variation due to genetic drift or inbreeding at the same rate as the number of reproducing adults in the real population under consideration (Hallerman 2003).
ESA	Endangered Species Act passed in 1973. The ESA-listed species refers to fish species added to the ESA list of endangered or threatened species and are covered by the ESA.
Expected value	A number of smolts or adults derived from survival rates agreed to in the Biological Assessment and Management Plan (BAMP 1998).
Extraction rate	The proportion of the spawning population collected for broodstock.
Genetic diversity	All the genetic variation within a species of interest, including both within and between population components.
Genetic stock structure	A type of assortative mating, in which the gene pool of a species is composed of a group of subpopulations, or stocks, that mate panmictically within themselves.
Genetic variation	All the variation due to different alleles and genes in an individual, population, or species.
HCP	Habitat Conservation Plan is a plan that enables an individual or organization to obtain a Section 10 Permit which outlines what will be done to “minimize and mitigate” the impact of the permitted take on a listed species.
HCP-HC	Habitat Conservation Plan Hatchery Committee is the committee that directs actions under the hatchery program section of the HCP’s for Chelan and Douglas PUDs.
HRR	Hatchery Replacement Rate is the ratio of the number of returning hatchery adults relative to the number of adults taken as broodstock, both hatchery and naturally produced fish (i.e., adult-to-adult replacement rate).
Long-term fitness	Long-term fitness is the ability of a population to self-perpetuate over successive generation.
Naturally produced	Progeny of fish that spawned in the natural environment, regardless of the origin of the parents.
Mean Ratio	The ratio between a treatment and control population, with the mean taken across a time period, such as years. Used in analysis in Before-After-Control-Impact studies.
Ne	Effective population size

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Non-target taxa of concern (NTTOC)	Species, stocks, or components of a stock with high value (e.g., stewardship or utilization) that may suffer negative impacts as a result of a hatchery program.
NRR	Natural replacement rate is the ratio of the number of returning naturally produced adults relative to the number of adults that naturally spawned, both hatchery and naturally produced.
NTTOC	Non-target taxa of concern.
pHOS	Proportion of Hatchery Origin Spawners
PNI	Proportionate Natural Influence
pNOB	Proportion of Natural Origin Broodstock
Productivity	The capacity in which juvenile fish or adults can be produced.
Reference population	A population in which no directed artificial propagation is currently directed, although may have occurred in the past. Reference populations are used to monitor the natural variability in survival rates and out of basin impacts on survival.
SAR	Smolt-to-adult survival rate
SAR Smolt-to-adult survival rate (SAR)	Smolt-to-adult survival rate is a measure of the number of adults that return from a given smolt population.
Segregated	A type of hatchery program in which returning adults are spatially or temporally isolated from other populations.
Size-at-maturity	The length or weight of a fish at a point in time during the year in which spawning will occur.
Smolts per redd	The total number of smolts produced from a stream divided by the total number of redds from which they were produced.
Spawning Escapement	The number of adult fish that survive to spawn.
Stray rate	The rate at which fish spawn outside of natal rivers or the stream in which they were released.
Supplementation	A hatchery strategy where the main purpose is to increase the relative abundance of natural spawning fish without reducing the long-term fitness of the population.
Target population	A specific population in which management actions are directed (e.g., artificial propagation, harvest, or conservation).

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Appendices

Appendix 1: **Spawning escapement objectives for steelhead, spring- and summer-Chinook in the mid-Columbia River.**

Appendix 2: **HRR Targets**

Appendix 3: **PNI and pHOS Management Targets or Sliding Scales.**

Appendix 4: **Management Targets for the Spatial Distribution of Spawners or Redds.**

Appendix 5: **Rearing Targets for PUD-Funded Hatchery Programs.**

Deleted: Reciprocal stray rate objectives for UCR summer steelhead and spring Chinook.

Appendix 6: **Methods for Identifying Reference Populations and Testing Differences between Reference and Supplemented Populations.**

Deleted: Rearing Targets for PUD-Funded Hatchery Programs.

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Methods for Identifying Reference Populations and Testing Differences in Abundance and Productivity between Reference Populations and Supplemented Populations: Chiwawa Spring Chinook Case Study

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September 2011

An important goal of supplementation is to increase spawning abundance and natural-origin recruitment of the supplemented population, and not reduce the productivity of the supplemented population. Indeed, a successful supplementation program must increase spawning abundance and natural-origin recruitment to levels above those that would have occurred without supplementation. There are several methods that can be used to test the effects of supplementation programs on these population metrics. One important method is to compare the performance of population metrics (e.g., spawning abundance, natural-origin recruitment, and productivity) in the supplemented population to those in un-supplemented (reference) populations. By comparing supplemented populations to reference populations, one can determine if the supplementation programs benefit, harm, or have no effect on the supplemented populations. These comparisons, however, are only valid if the performance of the reference populations is similar to the performance of the supplemented population prior to the period of supplementation. If the performance of the two populations differs significantly before any supplementation occurs, then any results from comparing the two populations after supplementation will be suspect. It is therefore important to select reference populations that are as similar as possible to the supplemented populations.

One of the goals of the Conceptual Approach to Monitoring and Evaluating the Chelan County PUD Hatchery Programs (Murdoch and Peven 2005) is to use reference populations to analyze the potential effects of hatchery supplementation programs on natural-origin salmon and steelhead spawner abundance and productivity[14]. Murdoch and Peven (2005) identified specific objectives to evaluate the performance of the program. For example, Objective 1 determines if the supplementation programs have increased the number of naturally spawning and naturally produced adults of the target population (supplemented population) relative to a reference population. Objective 7 determines if the proportion of hatchery fish on the spawning grounds affects the freshwater productivity (e.g., number of juveniles per redd) of supplemented streams when compared to reference streams. The relevant questions tested under each objective are as follows:

[14] Productivity is defined as adult recruits per spawner, where recruits are the number of adults produced from a given brood year (i.e., spawners plus adults harvested).

Objective 1:

- Is the annual change in the number of natural-origin recruits produced from the supplemented populations greater than or equal to the annual change in natural-origin recruits in an un-supplemented population?
- Is the change in natural replacement rates within the supplemented population greater than or equal to the change in natural replacement rates in an un-supplemented population?

Objective 7:

- Is the change in numbers of juveniles (smolts, parr, or emigrants) per redd in the supplemented population greater than or equal to that in an un-supplemented population?[15]

In this paper, we describe methods used to identify suitable reference streams and statistical techniques that can be used to compare reference populations with supplemented populations. Although we apply the methods described in this paper to Chiwawa spring Chinook salmon (hereafter referred to as Chinook), the methods should also apply to steelhead and other supplemented salmon stocks in the Upper Columbia Basin.

Identification of Reference Populations

Reference populations are an important component of an effectiveness monitoring design because they provide the standard by which treatment conditions are compared (ISRP and ISAB 2005; Murdoch and Peven 2005; Galbreath et al. 2008). Selecting appropriate reference areas and maintaining them over long periods of time is needed to establish the effectiveness of supplementation programs.

We developed a three-step process for identifying suitable reference populations (Figure 1). Each step serves as a filter. That is, potential reference populations are evaluated based on specific criteria under each step. Populations that pass through each step are considered suitable reference populations for a specific supplemented population.

[15] In this paper we only address adult recruits, not juvenile recruits. This is because we were unable to find suitable reference populations for analysis of juveniles. However, the methods described in this paper would also apply to juveniles.

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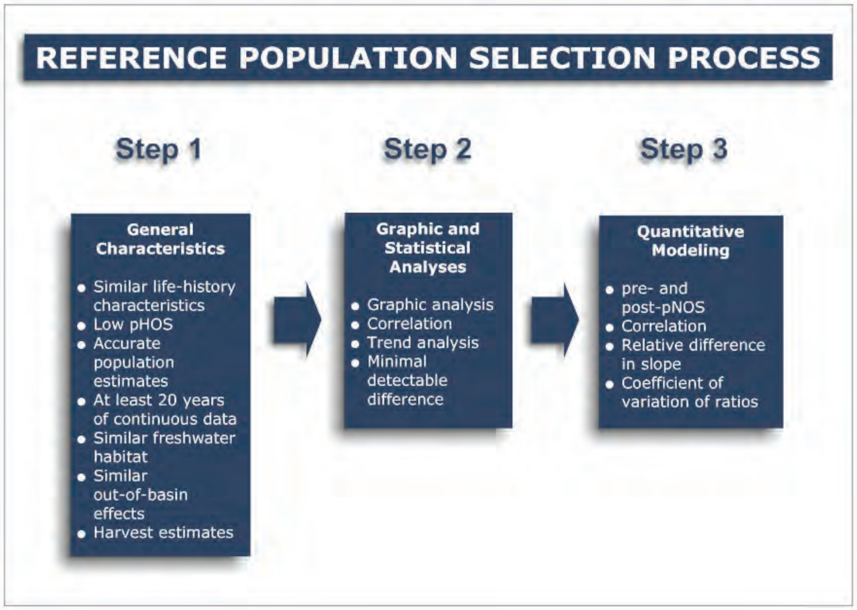

Figure 1. Criteria evaluated during each step in the process of identifying suitable reference populations.

Step 1: General Characteristics

Under step 1, potential reference populations are evaluated based on several general criteria. When compared to the supplemented population, potential reference populations should have:

- Similar life-history characteristics (e.g., run timing, migration characteristics, etc.).
- No or few hatchery fish in the reference area (pHOS < 10%).
- Accurate abundance estimates.
- Long time series of natural-origin abundance and productivity estimates (at least 20 years of continuous data).
- Similar trends in freshwater habitat.
- Similar out-of-basin effects (i.e., similar migration and ocean survivals).
- Harvest estimates for adjusting escapement estimates.

We used these criteria to begin the process of selecting suitable reference populations for the Chiwawa spring Chinook program. We began by identifying stream-type Chinook populations within the Columbia Basin. Galbreath et al. (2008; their Table 1) identified stream-type Chinook populations within the Columbia River Basin that may serve as suitable reference populations for hatchery programs. Supplementing their work with data from the NOAA Fisheries Salmon Population Summary Database, we identified 18 candidate stream-type Chinook populations that may serve as reference populations for the Chiwawa supplementation program (Table 1).

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Table 1. Populations of stream-type Chinook salmon and their comparison to Chiwawa spring Chinook.

Population	Similar life-history	No or few hatchery fish	Accurate abundance estimates	Long time series (at least 20 years)	Similar freshwater habitat impairments	Similar out-of-basin effects	Comments
Deschutes River	Yes	Yes	Yes	Yes	No	No	
John Day mainstem	Yes	Yes	Yes	Yes	No	No	
Middle Fk John Day	Yes	Yes	Yes	Yes	No	No	
North Fk John Day	Yes	Yes	Yes	Yes	No	No	
Granite Creek	Yes	Yes	Yes	Yes	No	No	
Wenaha River	Yes	No	Yes	Yes	Yes	No	Hatchery strays (>10%)
Minam River	Yes	No	Yes	Yes	Yes	No	Hatchery strays (>10%)
Slate Creek	Yes	Yes	Yes	No	No	No	
Secesh River	Yes	Yes	Yes	Yes	Yes	No	
Middle Fk Salmon River	Yes	Yes	Yes	No	No	No	Fair productivity est.
Big Creek	Yes	Yes	Yes	Yes	No	No	
Camas Creek	Yes	Yes	Yes	Yes	No	No	Fair productivity est.
Loon Creek	Yes	Yes	Yes	Yes	No	No	Fair productivity est.
Sulphur Creek	Yes	Yes	Yes	Yes	No	No	
Bear Valley Creek	Yes	Yes	Yes	Yes	No	No	
Marsh Creek	Yes	Yes	Yes	Yes	Yes	No	
North Fk Salmon River	Yes	Yes	No	No	Yes	No	
Lemhi River	Yes	Yes	Yes	Yes	No	No	
East Fk Salmon River	Yes	No	Yes	Yes	No	No	Hatchery strays (>10%)
Valley Creek	Yes	No	Yes	Yes	No	No	Hatchery strays (>10%)
Chamberlain Creek	Yes	Yes	Yes	No	Yes	No	
Naches River	Yes	Yes	Yes	Yes	Yes	No	
Little Wenatchee River	Yes	No	Yes	Yes	Yes	Yes	Hatchery strays (>10%)
Entiat River	Yes	No	Yes	Yes	No	No	Hatchery release ending

We then assessed the accuracy and length of the series of abundance estimates. We assumed that abundance estimates generated from expanded redd counts or adjusted weir counts would compare well with estimates in the Chiwawa Basin, which were based on expanded redd counts. In addition, we looked for populations that had an abundance data series that extended from at least 1981 to present. Based on this analysis, we identified 18 populations with abundance estimates that could be compared to those from the Chiwawa Basin (Table 1).

Next, we determined if the potential reference populations came from watersheds with habitat conditions similar to those in the Chiwawa Basin. For this exercise, we searched recovery plans and draft recovery plans to identify tributary factors that limit Chinook abundance, productivity, and survival within the reference populations. We compared these factors with those limiting

Chinook salmon in the Chiwawa Basin. Based on this analysis, we identified eight populations with habitat impairments similar to those in the Chiwawa Basin (Table 1).

Finally, we examined the potential reference populations to see if they experienced out-of-basin effects similar to spring Chinook from the Chiwawa Basin. In this case, we compared the number of mainstem dams that each potential reference population passes during migration. Six of the potential reference populations pass less than six mainstem dams; the other populations pass eight mainstem dams (Table 1). Only the Little Wenatchee population passes seven dams, similar to the Chiwawa population.

In sum, there were no reference populations that matched the Chiwawa spring Chinook population on all the criteria identified above. Differential out-of-basin effects and freshwater habitat conditions prevented most reference populations from matching with Chiwawa spring Chinook. However, some of the potential reference populations were similar to the Chiwawa population on several criteria and warranted further investigation. We selected the following populations for further investigation: Sesech River, Marsh Creek, Naches River, Little Wenatchee, and Entiat River.

We included the Little Wenatchee because it is within the Wenatchee River basin and experiences similar out-of-basin effects and has the same climatic and environmental conditions as the Chiwawa. A confounding effect with the Little Wenatchee is that Chiwawa hatchery fish have strayed into the Little Wenatchee. However, straying of Chiwawa hatchery fish should decrease with the change in source water to the Chiwawa acclimation ponds in 2006. We also included the Entiat River because it is an adjacent basin to the Chiwawa and experiences similar climatic and environmental conditions. The spring Chinook hatchery program that has operated in the Entiat since 1975 has been discontinued. Therefore, this population offers a unique opportunity to compare the Chiwawa population to a population in which the hatchery program has been discontinued.

Step 2: Graphic and Statistical Analysis

Graphic Analysis

Although we were unable to find potential reference populations that matched with the Chiwawa population on all criteria considered under Step 1, spawner abundance, natural-origin recruits (NORs), and productivity of some of the potential reference populations may nevertheless track closely with the Chiwawa population. If the time series of abundance, NORs, and productivity of a potential reference population tracks closely with the abundance, NORs, and productivity of the Chiwawa population, the reference population may provide a reasonable reference condition for testing the effects of supplementation on the Chiwawa population.

Under Step 2, we used graphing techniques to examine the relationship of abundance, NORs, and productivity between the Chiwawa population and the five reference populations (Sesech River, Marsh Creek, Naches River, Little Wenatchee, and Entiat River). We compiled spawner abundance, NORs, and productivity data from local biologists and the NOAA Fisheries Salmon Population Summary Database. We then compared time series plots of spawner abundance, NORs, and productivity data of potential reference populations with the Chiwawa population (Figures 2, 3, and 4; plots on the left side of figures). The time series only included the period 1981 to 1992, which represented the period before supplementation of the Chiwawa population (pre-treatment period). We also plotted the relationship between the abundance, NORs, and productivity of each

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potential reference population to the Chiwawa population (Figures 2, 3, and 4; plots on right side of figures). These plots show whether the reference populations closely tracked the Chiwawa population. As a point of reference, data points that fall along the dashed line would represent a perfect relationship between the two populations (i.e., both populations have identical abundance, NORs, and productivity estimates). While a perfect relationship between two independent populations is unrealistic, a strong linear relationship between the two populations indicates populations with similar trends.

Based on analysis of spawner abundance, the Naches River time series tracked more closely with the abundance of Chiwawa spring Chinook than did the other potential reference populations. The poor relationship with the other potential reference streams was largely because of the relatively high abundance of Chiwawa spring Chinook during the mid-1980s. As with spawner abundance, analyses of NORs indicated a close relationship between the Naches and Chiwawa populations. The other potential reference populations tracked poorly with the Chiwawa. The analyses of productivity indicated close relationships between potential reference populations and the Chiwawa population. The Naches, Sesech, and Little Wenatchee populations tracked the closest with the Chiwawa population.

When analyzing the potential effects of a supplementation program on fish performance, it is common to transform the data to meet various assumptions of statistical analysis. The most common transformation used to adjust abundance, NORs, and productivity data is the natural logarithm (LN or $\log_e$). We therefore transformed the spawner abundance, NORs, and productivity data using LN and re-plotted the relationships between the potential reference populations and the Chiwawa population (Figures 5, 6, and 7). We added 1 to each observation before taking its logarithm to avoid taking the logarithm of 0, which is undefined (note that the LN of 1 is 0).

By transforming spawner abundance, NORs, and productivity data, most of the potential reference populations tracked more closely with the Chiwawa population. The Naches, Entiat, and Little Wenatchee abundance data tracked the closest with the Chiwawa abundance data (Figure 5). For NORs, Marsh Creek and the Little Wenatchee populations tracked the closest with the Chiwawa (Figure 6). For productivity, the Naches, Sesech, and Little Wenatchee tracked the closest with the Chiwawa (Figure 7).

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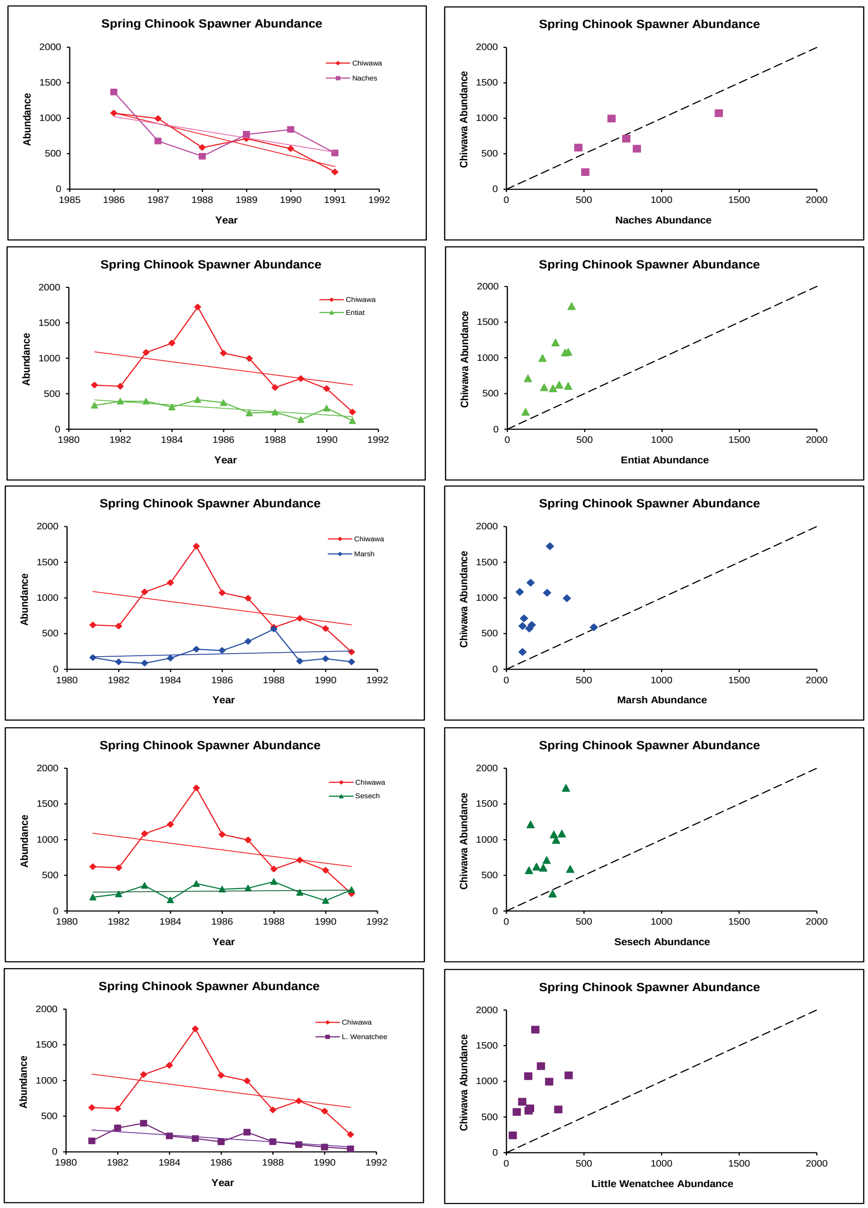

Figure 2. Time series of spawner abundance of potential reference populations and the Chiwawa spring Chinook population before the Chiwawa population was supplemented with hatchery fish.

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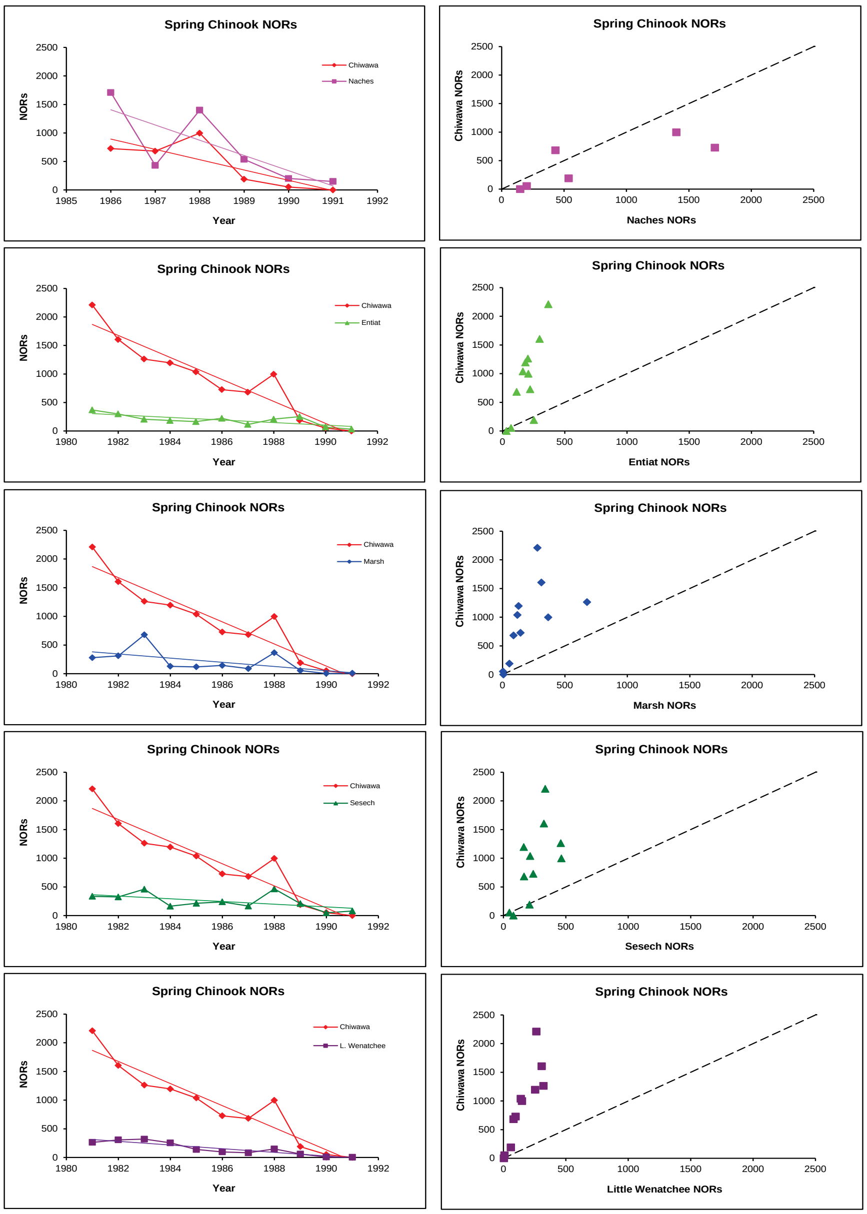

Figure 3. Time series of natural-origin recruits (NORs) of potential reference populations and the Chiwawa spring Chinook population before the Chiwawa population was supplemented with hatchery fish.

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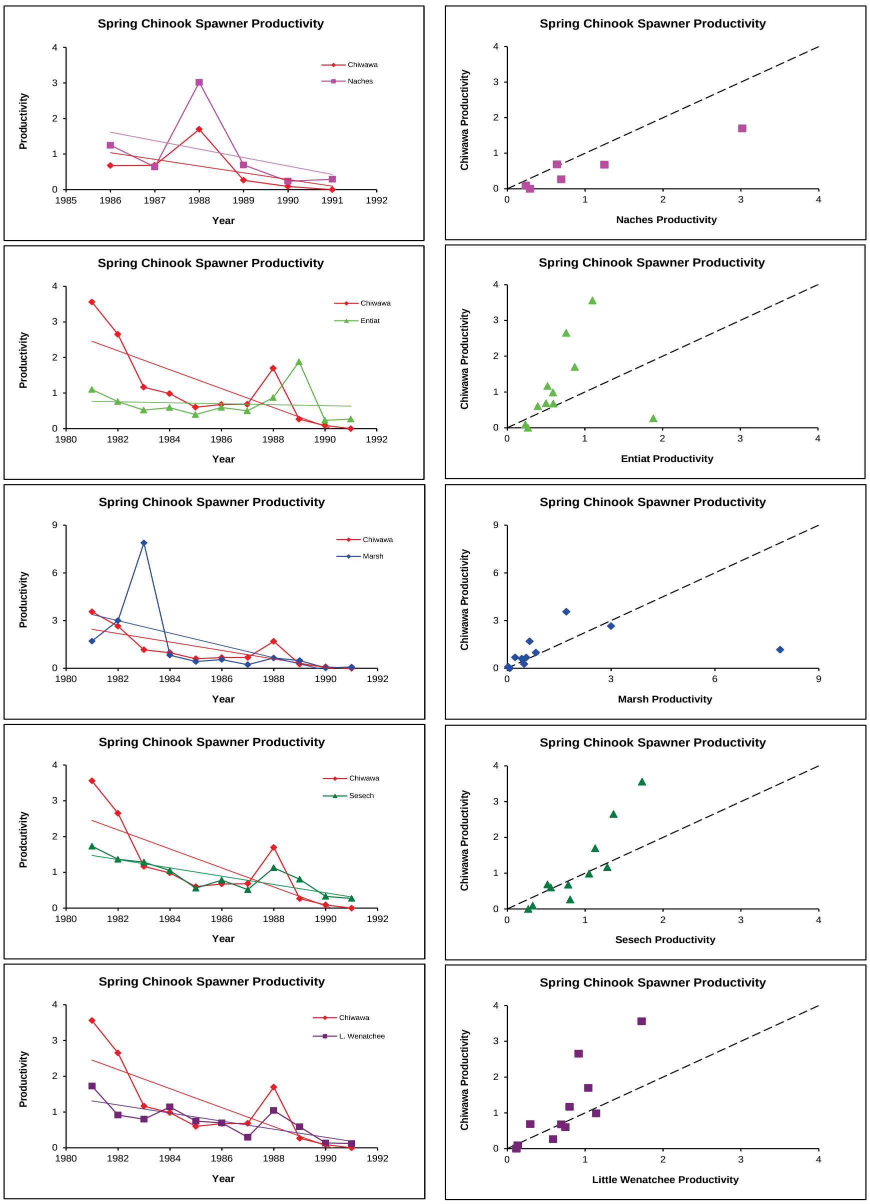

Figure 4. Time series of adult productivity of potential reference populations and the Chiwawa spring Chinook population before the Chiwawa population was supplemented with hatchery fish.

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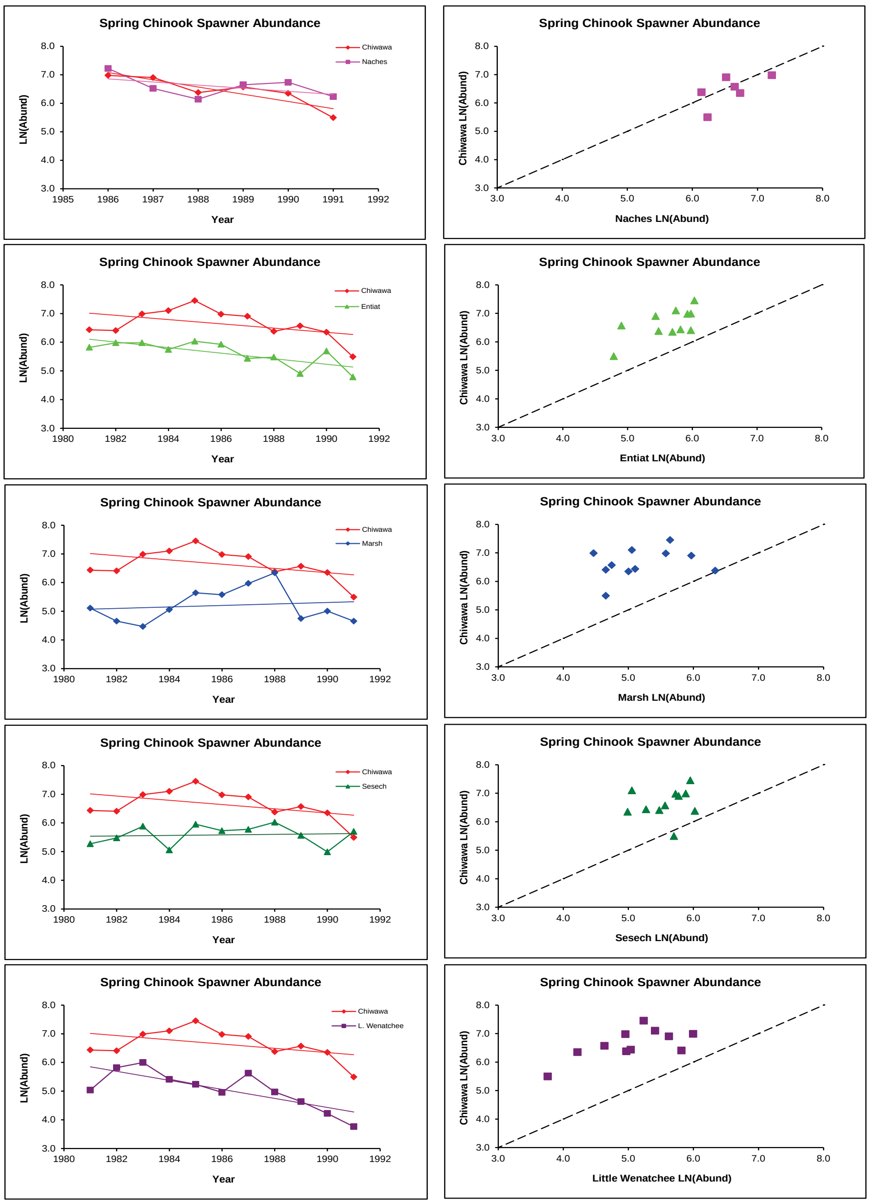

Figure 5. Time series of natural log spawner abundance of potential reference populations and the Chiwawa spring Chinook population before the Chiwawa population was supplemented with hatchery fish.

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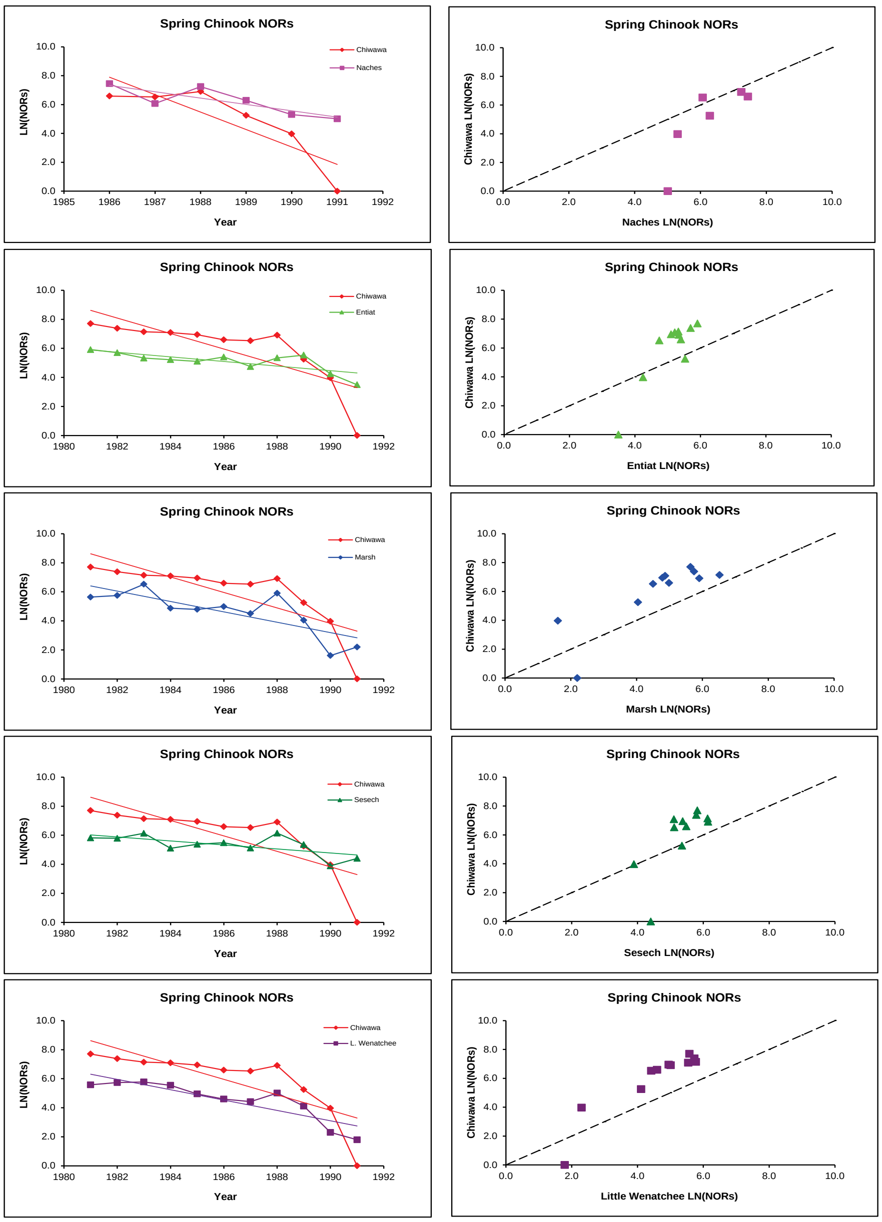

Figure 6. Time series of natural log natural-origin recruits (NORs) of potential reference populations and the Chiwawa spring Chinook population before the Chiwawa population was supplemented with hatchery fish.

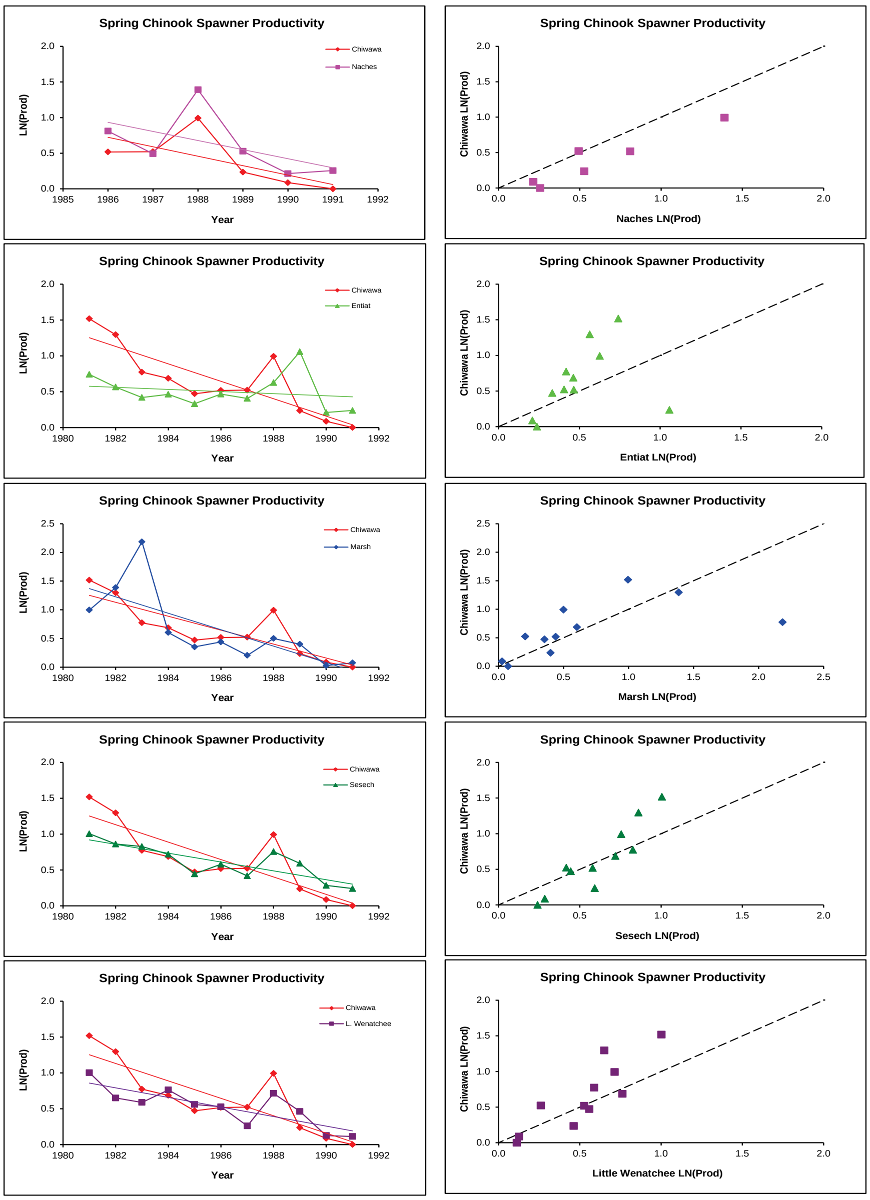

Figure 7. Time series of natural log adult productivity of potential reference populations and the Chiwawa spring Chinook population before the Chiwawa population was supplemented with hatchery fish.

Correlations and Trends

Other methods for evaluating the suitability of potential reference populations under Step 2 include correlation and trend analyses. For correlation analysis, we simply calculated the Pearson correlation coefficient, which is an index of the strength of the association between the potential reference populations and the Chiwawa population. The coefficient ranges from -1 to 1, where a value near 1 or -1 represents that strongest association between the populations. A value of 0 means no association. We used only spawner abundance, NORs, and productivity data during the pre-treatment period (1981-1992). We assumed that populations with coefficients greater than 0.6 represented reasonable reference conditions.

For trend analyses, we used least squares techniques to compute a straight-line trend through the spawner abundance and productivity data for the potential reference populations and the Chiwawa population. Trends were fit to the pre-treatment time series data (1981-1992). We then used t-tests to determine if the slopes of the trends between potential reference populations and the Chiwawa population differed significantly.

It is important to note that time-series trend analyses are susceptible to temporal correlations in the data. Autoregressive integrated moving average (ARIMA) models can be used to describe the correlation structure in temporal data (Gotelli and Ellison 2004). However, these models require a long time series (N > 40) and therefore we could not use them to model the spring Chinook data. As such, we were unable to correct for any temporal correlation that may exist within the time series.

Tests of correlation with spawner abundance data indicated that the Naches River closely correlated with the Chiwawa population (Table 2). There was no difference in abundance trends between the potential reference populations and the Chiwawa population (Table 2; Figure 2). For NORs, all potential reference populations correlated with the Chiwawa population (Table 2). However, trends in NORs of all reference populations, except Naches, differed significantly from the Chiwawa population (Table 2; Figure 3). For productivity, the Naches, Sesech, and Little Wenatchee correlated with the Chiwawa population (Table 2). Only the Entiat productivity trend differed significantly from the Chiwawa population trend (Table 2; Figure 4).

Table 2. Pearson correlation coefficients and t-test results comparing slopes of trends between potential reference populations and the Chiwawa spring Chinook population; d.f. = degrees of freedom and for correlation coefficients, an asterisk (*) indicates significance at P < 0.05.

Reference populations	Pearson correlation coefficient	t-test on slopes		
		t-value	d.f.	P-value
Spawner Abundance Data				
Naches	0.684*	-0.659	8	0.528
Entiat	0.598*	-0.596	18	0.559
Marsh	0.147	-1.341	18	0.197
Sesech	0.274	-1.265	18	0.222
Little Wenatchee	0.399	-0.591	18	0.562
Natural-Origin Recruits				
Naches	0.803*	0.666	8	0.524
Entiat	0.795*	-7.495	18	0.000
Marsh	0.605*	-5.786	18	0.000

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Reference populations	Pearson correlation coefficient	t-test on slopes		
		t-value	d.f.	P-value
Sesech	0.648*	-6.874	18	0.000
Little Wenatchee	0.880*	-7.206	18	0.000
Productivity Data				
Naches	0.960*	0.169	8	0.870
Entiat	0.272	-3.057	18	0.007
Marsh	0.320	0.605	18	0.553
Sesech	0.903*	-2.059	18	0.054
Little Wenatchee	0.848*	-2.065	18	0.054

We also ran correlation and trend analyses on natural-log transformed spawner abundance, NORs, and productivity data. These analyses indicated that the Naches, Entiat, and Little Wenatchee abundance data correlated with the Chiwawa population data (Table 3). None of the abundance trends of the potential reference populations differed significantly from the Chiwawa population trend (Table 3; Figure 5). For NORs, all potential reference populations correlated with the Chiwawa population (Table 3). Only trends in NORs of the Entiat and Sesech differed significantly from the Chiwawa population (Table 2; Figure 6). For productivity, the Naches, Marsh, Sesech, and Little Wenatchee correlated with the Chiwawa population data (Table 3). Only the Entiat productivity trend differed significantly from the Chiwawa population trend (Table 3; Figure 7).

Table 3. Pearson correlation coefficients and t-test results comparing slopes of trends between potential reference populations and the Chiwawa spring Chinook population; d.f. = degrees of freedom and for correlation coefficients, an asterisk (*) indicates significance at $P < 0.05$. Analyses were conducted on natural-log transformed abundance and productivity data.

Reference populations	Pearson correlation coefficient	t-test on slopes		
		t-value	d.f.	P-value
LN Spawner Abundance Data				
Naches	0.642*	-1.323	8	0.222
Entiat	0.652*	0.412	18	0.685
Marsh	0.294	-1.324	18	0.202
Sesech	0.149	-1.431	18	0.170
Little Wenatchee	0.670*	1.325	18	0.202
LN Natural-Origin Recruits				
Naches	0.824*	-1.985	8	0.082
Entiat	0.886*	-2.563	18	0.019
Marsh	0.830*	-1.038	18	0.313
Sesech	0.730*	-2.664	18	0.016
Little Wenatchee	0.927*	-1.150	18	0.265
LN Productivity Data				
Naches	0.944*	-0.042	8	0.968

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Reference populations	Pearson correlation coefficient	t-test on slopes		
		t-value	d.f.	P-value
Entiat	0.373	-3.043	18	0.007
Marsh	0.610*	0.428	18	0.674
Sesech	0.913*	-2.050	18	0.055
Little Wenatchee	0.862*	-1.811	18	0.087

In summary, based on correlation, trend, and graphic analyses, the Naches, Entiat, and Little Wenatchee populations appear to be reasonable reference populations for comparing spawner abundance data with Chiwawa data. For NORs, the Naches, Marsh, and Little Wenatchee appear to be reasonable reference populations. For productivity, the Naches, Marsh, Sesech, and Little Wenatchee populations appear to be reasonable reference populations for the Chiwawa population.

Minimal Detectable Differences (MDD)

Given a suite of potential reference populations, it is important to conduct power analyses to determine the minimum differences that can be detected when comparing the reference populations to the supplemented population. As a final exercise under Step 2, we examined potential reference populations for the smallest minimal detectable differences. Before conducting power analyses, several decisions needed to be made, including what statistical procedures will be used to analyze the data, the desired level of statistical power (probability of rejecting a false null hypothesis), the size of the type-I error (the probability of rejecting a true null hypothesis of no difference), and the number of samples (i.e., years) included in the analysis. In this case, the number of samples represents the number of treatment (supplementation) years. The number of pre-treatment years (1981-1992) was based on the number of years of quality data available for Chiwawa spring Chinook and potential reference populations.

We designed the study as a modified BACI (Before-After, Control-Impact) design, which includes replication before and after supplementation in both the treated (T) population and the reference (R) populations. A common approach used to analyze data from BACI designs includes analysis of difference scores (Stewart-Oaten et al. 1992; Smith et al. 1993). Differences are calculated between paired treatment and reference population scores (i.e., T-R). Another approach is to calculate ratios (treatment/reference; T/R) for paired treatment and reference population scores (Skalski and Robson 1992). Finally, differences in annual changes in paired treatment and reference population scores can be calculated (i.e., ΔT-ΔR) (Murdoch and Peven 2005; Hays et al. 2006).[16] These derived difference and ratio scores are then analyzed for a before-after treatment effect with a two-sample t-test, Aspin-Welch modification of the t-test, or a randomization test. For power analyses, we calculated minimal detectable differences assuming the use of an independent two-sample t-test with a type-I error rate of 0.05, power of 0.80 (beta or type-II error rate of 0.20), and sample sizes (treatment years) of 5, 10, 15, 20, 25, and 50 years.

[16] The difference of annual difference scores was estimated by first subtracting the population parameter (e.g., spawner abundance) in year 2 from year 1. This continues for all years in the data series for both treatment ($T_{t+1} – T_t$) and reference populations ($R_{t+1} – R_t$). We then calculated differences between paired treatment and reference annual difference scores $[(T_{t+1} – T_t) - (R_{t+1} – R_t) = \Delta T\text{-}\Delta R]$.

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The power analysis calculated the minimal detectable difference between mean difference or ratio scores before and during supplementation. We used existing data to calculate variances for the pre-supplementation and supplementation periods. Thus, variances were known and unequal. For both spawner abundance and NORs, the null hypothesis tested was that the mean difference or ratio before supplementation equaled the mean difference or ratio during supplementation. The alternative hypothesis was that the mean difference or ratio before supplementation was less than the mean difference during supplementation (one-tail test; Difference < 0). For productivity, the null hypothesis tested was that the mean difference or ratio before supplementation equaled the mean difference or ratio during supplementation. The alternative hypothesis was that the mean difference or ratio before supplementation was greater than the mean difference during supplementation (one-tail test; Difference > 0).

Based on spawner abundance data, power analysis indicated that the Sesech-Chiwawa pairing consistently produced the smallest detectable differences (Table 4). However, when the abundance data were transformed using natural logs, the Entiat-Chiwawa pairing produced the smallest detectable difference (Table 5). Minimal detectable differences, based on mean difference scores on untransformed data and a treatment period of 20 years, ranged from 334 to 394 adult spawners; transformed data ranged from 0.479 to 1.010. These analyses indicate that the Naches, Entiat, Sesech, and Little Wenatchee populations appear to be reasonable reference populations for comparing spawner abundance data with Chiwawa data. The Marsh Creek population produced some of the largest detectable differences and based on these analyses may not be a reasonable reference population.

Table 4. Minimal detectable differences between mean difference and ratio scores before and during supplementation. Analyses were conducted on spawner abundance data.

Response variable	Treatment years	Minimal detectable differences by reference population				
		Naches	Entiat	Marsh	Sesech	Little Wenatchee
T-R	5	638	604	560	396	652
	10	464	448	444	354	481
	15	405	395	406	341	424
	20	376	368	387	334	394
	25	358	352	376	331	376
	50	322	319	354	323	340
T/R	5	0.600	2.084	39.251	1.569	5.498
	10	0.506	1.548	24.729	1.508	3.828
	15	0.478	1.367	19.646	1.490	3.256
	20	0.465	1.275	16.828	1.481	2.954
	25	0.458	1.219	14.974	1.475	2.765
	50	0.447	1.105	10.573	1.465	2.366
ΔT-ΔR	5	1,049	761	717	518	766
	10	750	542	539	411	547
	15	650	467	480	376	473
	20	598	429	450	359	434

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Response variable	Treatment years	Minimal detectable differences by reference population				
		Naches	Entiat	Marsh	Sesech	Little Wenatchee
	25	567	405	431	348	410
	50	506	355	395	329	361

Table 5. Minimal detectable differences between mean difference and ratio scores before and during supplementation. Analyses were conducted on natural-log transformed spawner abundance data.

Response variable	Treatment years	Minimal detectable differences by reference population				
		Naches	Entiat	Marsh	Sesech	Little Wenatchee
T-R	5	0.975	0.871	2.061	0.828	1.013
	10	0.721	0.613	1.375	0.648	0.722
	15	0.637	0.525	1.138	0.588	0.623
	20	0.595	0.479	1.010	0.559	0.571
	25	0.569	0.450	0.928	0.541	0.539
	50	0.521	0.390	0.749	0.505	0.473
T/R	5	0.157	0.162	2.343	0.160	0.368
	10	0.116	0.115	1.474	0.125	0.247
	15	0.102	0.099	1.170	0.114	0.206
	20	0.095	0.090	1.001	0.108	0.183
	25	0.091	0.085	0.890	0.104	0.169
	50	0.082	0.075	0.625	0.098	0.138
ΔT-ΔR	5	1.261	1.288	3.076	1.160	1.467
	10	0.898	0.900	2.020	0.887	1.001
	15	0.776	0.768	1.653	0.797	0.840
	20	0.713	0.698	1.463	0.751	0.755
	25	0.675	0.655	1.325	0.724	0.701
	50	0.600	0.564	1.038	0.670	0.585

Based on NORs, power analysis indicated that the Entiat-Chiwawa, Marsh-Chiwawa, and Little Wenatchee-Chiwawa pairings produced the smallest detectable differences (Table 6). When NORs were transformed using natural logs, the Little Wenatchee-Chiwawa pairing produced the smallest detectable difference (Table 7). Minimal detectable differences, based on mean difference scores on untransformed data and a treatment period of 20 years, ranged from 483 to 640 NORs; transformed data ranged from 0.958 to 2.262. These analyses indicate that the Entiat, Marsh, and Little Wenatchee populations appear to be reasonable reference populations for comparing NORs with Chiwawa data.

Table 6. Minimal detectable differences between mean difference and ratio scores before and during supplementation. Analyses were conducted on natural-origin recruits.

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Response variable	Treatment years	Minimal detectable differences by reference population				
		Naches	Entiat	Marsh	Sesech	Little Wenatchee
T-R	5	1,139	541	573	630	546
	10	809	511	515	550	503
	15	698	502	498	526	489
	20	640	497	489	514	483
	25	604	494	484	507	479
	50	534	489	474	493	472
T/R	5	0.469	2.538	5.196	1.976	6.973
	10	0.451	2.183	4.183	1.894	5.118
	15	0.446	2.072	3.854	1.869	4.492
	20	0.445	2.017	3.691	1.857	4.170
	25	0.444	1.986	3.594	1.850	3.973
	50	0.443	1.924	3.405	1.836	3.572
ΔT-ΔR	5	1,639	500	519	609	531
	10	1,239	386	409	433	396
	15	1,109	348	374	372	351
	20	1,046	329	356	341	328
	25	1,009	318	346	321	314
	50	943	295	325	281	285

Table 7. Minimal detectable differences between mean difference and ratio scores before and during supplementation. Analyses were conducted on natural-log transformed natural-origin recruits.

Response variable	Treatment years	Minimal detectable differences by reference population				
		Naches	Entiat	Marsh	Sesech	Little Wenatchee
T-R	5	2.380	1.646	1.967	2.247	1.174
	10	2.291	1.479	1.505	1.835	1.026
	15	2.270	1.428	1.351	1.702	0.980
	20	2.262	1.403	1.273	1.636	0.958
	25	2.258	1.389	1.227	1.597	0.945
	50	2.253	1.361	1.133	1.522	0.920
T/R	5	0.322	0.332	0.739	0.398	0.356
	10	0.301	0.289	0.581	0.334	0.322
	15	0.296	0.275	0.530	0.314	0.312
	20	0.294	0.269	0.504	0.305	0.307
	25	0.293	0.265	0.488	0.299	0.304
	50	0.291	0.258	0.458	0.288	0.298
ΔT-ΔR	5	2.858	2.400	2.355	3.283	2.109

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Response variable	Treatment years	Minimal detectable differences by reference population				
		Naches	Entiat	Marsh	Sesech	Little Wenatchee
	10	2.560	1.714	1.881	2.311	1.552
	15	2.485	1.481	1.728	1.979	1.365
	20	2.456	1.360	1.652	1.805	1.269
	25	2.443	1.285	1.607	1.697	1.210
	50	2.430	1.130	1.519	1.471	1.092

Using untransformed productivity data, power analysis indicated that the Little Wenatchee-Chiwawa pairing consistently produced the smallest detectable differences (Table 8). The Marsh-Chiwawa pairings produced the largest detectable differences. When we analyzed natural-log transformed productivity data, the Naches-Chiwawa and Little Wenatchee-Chiwawa pairings produced the smallest detectable differences (Table 9). Minimal detectable differences, based on mean difference scores on untransformed data and a treatment period of 20 years, ranged from 0.754 to 1.839; transformed data ranged from 0.277 to 0.477. These analyses indicate that the Naches, Entiat, Sesech, and Little Wenatchee populations appear to be reasonable reference populations for comparing productivity data with Chiwawa data. The Marsh Creek population produced some of the largest detectable differences and based on these analyses may not be a reasonable reference population.

Table 8. Minimal detectable differences between mean difference and ratio scores before and during supplementation. Analyses were conducted on productivity data.

Response variable	Treatment years	Minimal detectable differences by reference population				
		Naches	Entiat	Marsh	Sesech	Little Wenatchee
T-R	5	2.181	1.382	2.033	3.517	1.192
	10	1.442	1.119	1.900	2.265	0.901
	15	1.186	1.033	1.859	1.828	0.804
	20	1.047	0.991	1.839	1.588	0.754
	25	0.959	0.966	1.828	1.432	0.724
	50	0.764	0.917	1.806	1.074	0.664
T/R	5	1.364	1.773	0.863	0.876	2.167
	10	1.095	1.359	0.831	0.687	1.587
	15	1.011	1.221	0.822	0.625	1.391
	20	0.971	1.152	0.817	0.594	1.290
	25	0.949	1.110	0.814	0.575	1.228
	50	0.910	1.027	0.908	0.538	1.102
ΔT-ΔR	5	3.298	1.864	3.211	4.420	1.942
	10	2.263	1.382	2.968	2.811	1.291
	15	1.909	1.220	2.894	2.248	1.066
	20	1.723	1.137	2.859	1.938	0.944

Response variable	Treatment years	Minimal detectable differences by reference population				
		Naches	Entiat	Marsh	Sesech	Little Wenatchee
	25	1.606	1.087	2.839	1.735	0.866
	50	1.365	0.986	2.800	1.259	0.695

Table 9. Minimal detectable differences between mean difference and ratio scores before and during supplementation. Analyses were conducted on natural-log transformed productivity data.

Response variable	Treatment years	Minimal detectable differences by reference population				
		Naches	Entiat	Marsh	Sesech	Little Wenatchee
T-R	5	0.540	0.551	0.674	0.890	0.585
	10	0.367	0.452	0.542	0.590	0.413
	15	0.308	0.421	0.499	0.486	0.355
	20	0.277	0.405	0.477	0.430	0.324
	25	0.257	0.396	0.465	0.393	0.305
	50	0.215	0.378	0.440	0.314	0.265
T/R	5	0.915	1.286	0.743	0.697	1.685
	10	0.744	0.973	0.704	0.541	1.227
	15	0.691	0.868	0.692	0.489	1.072
	20	0.666	0.815	0.687	0.463	0.993
	25	0.652	0.783	0.683	0.447	0.943
	50	0.628	0.719	0.677	0.416	0.843
ΔT-ΔR	5	0.885	0.810	1.028	1.252	0.971
	10	0.631	0.609	0.822	0.809	0.640
	15	0.546	0.542	0.755	0.655	0.525
	20	0.502	0.508	0.722	0.570	0.463
	25	0.475	0.487	0.702	0.516	0.423
	50	0.423	0.446	0.664	0.391	0.333

Step 3: Quantitative Method for Ranking Selection Criteria

Not surprisingly, different selection criteria produced different results (Table 10). Determining whether a given population is or is not a suitable reference population based on selection criteria such as graphic analysis can be subjective. In addition, treating each selection criterion as equally important may not be appropriate. For example, using the information in Table 10, is it appropriate to select a reference population that has two or three "Yes" entries, or should only populations with four "Yes" entries be selected as suitable reference populations? This approach does not allow certain selection criteria to carry more weight in the overall selection process. That is, correlation may be more important than graphic analysis in the overall selection process. In order to reduce subjectivity, we developed a method of scoring and weighting each selection criterion. This method allows a more quantitative process for selecting suitable reference populations.

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Table 10. Summary of results from graphic analysis, correlations, trend analysis, and power analysis (minimal detectable differences). "Yes" indicates that the population is a suitable reference population for the Chiwawa population; "No" indicates that it may not be a suitable reference population.

Potential reference populations	Graphic analysis	Correlation	Trends	Minimal detectable differences
Spawner Abundance				
Naches	Yes	Yes	Yes	Yes
Entiat	Yes	Yes	Yes	Yes
Marsh	No	No	Yes	No
Sesech	No	No	Yes	Yes
Little Wenatchee	Yes	Yes	Yes	Yes
Natural-Origin Recruits				
Naches	Yes	Yes	Yes	No
Entiat	No	Yes	No	Yes
Marsh	Yes	Yes	Yes	Yes
Sesech	No	Yes	No	No
Little Wenatchee	Yes	Yes	Yes	Yes
Productivity				
Naches	Yes	Yes	Yes	Yes
Entiat	No	No	No	Yes
Marsh	No	Yes	Yes	No
Sesech	Yes	Yes	Yes	Yes
Little Wenatchee	Yes	Yes	Yes	Yes

We developed scoring methods for each of the following five selection criteria:

(1) The proportion of natural-origin spawners (pNOS) in the reference population for the period before supplementation (pre-pNOS);

(2) pNOS in the reference population for the period following supplementation (post-pNOS);

(3) The correlation between the reference and supplemented populations before supplementation;

(4) The relative difference in slopes between the reference and supplemented populations before supplementation; and

(5) The coefficient of variation (CV) of the ratio of supplemented to reference populations before the period of supplementation.

Each selection criteria was scored from 0 to 1, with 0 being the worst possible score and 1 being the best.

The pre- and post-pNOS values were calculated as the average pNOS values before and after supplementation, respectively. Because pNOS values range from 0-1, we did not need to rescale these values. When using reference populations to evaluate the effects of supplementation programs, it is important that the reference populations maintain high values of pNOS throughout

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the life of the monitoring program. Therefore, we heavily weighted the mean pNOS scores. We assigned weights of 30 and 40 to the mean pre- and post-pNOS scores, respectively. The relatively larger weight for the post-supplementation period is to reduce the likelihood of retaining a reference population that becomes influenced by hatchery fish during the supplementation period.

We assessed the association between the reference and supplemented populations during the pre-supplementation period by calculating the Pearson correlation coefficient, which ranges from -1 to 1. To scale the coefficient between 0 and 1, we took the absolute value of the coefficient. Thus, a coefficient of -0.92 would be reported as 0.92. For our analyses, we were not concerned with the direction of the relationship, only the strength of the relationship. The correlation coefficient was given a weight of 12.5.

As noted earlier, we used least squares to fit a linear trend to each of the reference populations and the supplemented population during the pre-supplementation period. Using the slope estimates for each trend line, we calculated the relative difference in slopes as the slope of the supplemented population minus the slope of the reference population, divided by the slope of the reference population. To scale this value between 0 and 1, we used absolute values, and depending on the direction of the slopes, we subtracted the relative difference from 1. The latter was needed to make sure a larger relative difference value indicated a small difference in slopes between the supplemented and reference populations. The relative difference score was given a weight of 7.5.

Finally, as a means to score effect size, we calculated the CV of the ratio of supplemented to reference population parameters (i.e., T/R). The CV was calculated as the standard deviation of the ratios divided by the absolute value of the mean ratios. The CV was subtracted from 1. This scaled the value from 0 to 1 with larger values representing the best condition. The CV was given a weight of 10, which is greater than the weight for trend, but less than the weight for correlation.

The total score for a reference population was calculated by multiplying the estimated value, which ranged from 0 to 1, by its weight. The sum of the five weighted values provided a total score, which ranged from 0 to 100. Based on several simulations, we set the cut-off score at 81. That is, if the total score for a given reference population equaled or exceeded 81, the population was included as a suitable reference population. If the total score fell below 81, the population was not considered a suitable reference. Based on the distribution of all scores possible, a score of 81 or greater represented only 3% of the total distribution. Thus, a cut-off of 81 is quite conservative.

Under Step 3, we used this method to select the final suite of suitable reference populations. Table 11 shows results from scoring each of the reference populations using the quantitative method. Using the cut-off criterion of 81, only the Naches, Marsh, and Sesech populations would be considered suitable reference populations for the Chiwawa supplementation program. Both the Entiat and Little Wenatchee populations failed to meet the minimum score, largely because of the influence of hatchery fish within those populations (i.e., relatively low pNOS values).

Table 11. Results from scoring potential reference populations using the selection criteria (pNOS, correlation, trend, and effect size). Populations with scores less than 81 were considered unsuitable as reference populations. Populations with scores equal to or greater than 81 were considered suitable references. These results were based on natural-log transformed data.

Potential reference populations	Population metric		
	Abundance	NORs	Productivity
Naches	85	88	91

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Potential reference populations	Population metric		
	Abundance	NORs	Productivity
Entiat	23	21	16
Marsh	79	91	87
Sesech	84	85	88
Little Wenatchee	51	53	49

An important benefit from scoring the different selection criteria is that the total scores can be used to weight the outcome of differing statistical results. For example, analyses may show that when three suitable reference populations are compared to the supplemented population, two of the reference populations may indicate a significant treatment effect, while the third indicates no effect. Under this scenario it is not clear if the supplementation program has or has not affected the abundance or productivity of the supplemented population. If, however, the two reference populations that produced a significant result had higher total scores than the reference population that did not indicate a significant result, one can place more weight on the results from populations with higher total scores.

Conclusions

The purpose of this exercise was to develop a method for selecting suitable reference populations that could be used to assess the effects of supplementation programs on spawner abundance, NORs, and productivity. The selection process included a three-step process (Figure 8). Step 1 identified populations with similar life-history characteristics, few or no hatchery spawners, a long time series of accurate abundance and productivity estimates, and similar freshwater habitat impairments and out-of-basin effects. Populations that met these criteria were then examined for their graphical and statistical relationship with the supplemented population (Step 2). The statistical analysis under Step 2 were converted to a quantitative model (Step 3) that was used to generate a weighted score for pNOS, correlation, trends, and effect sizes for each potential reference population. Reference populations with total scores of 81 or greater were selected as suitable reference populations.

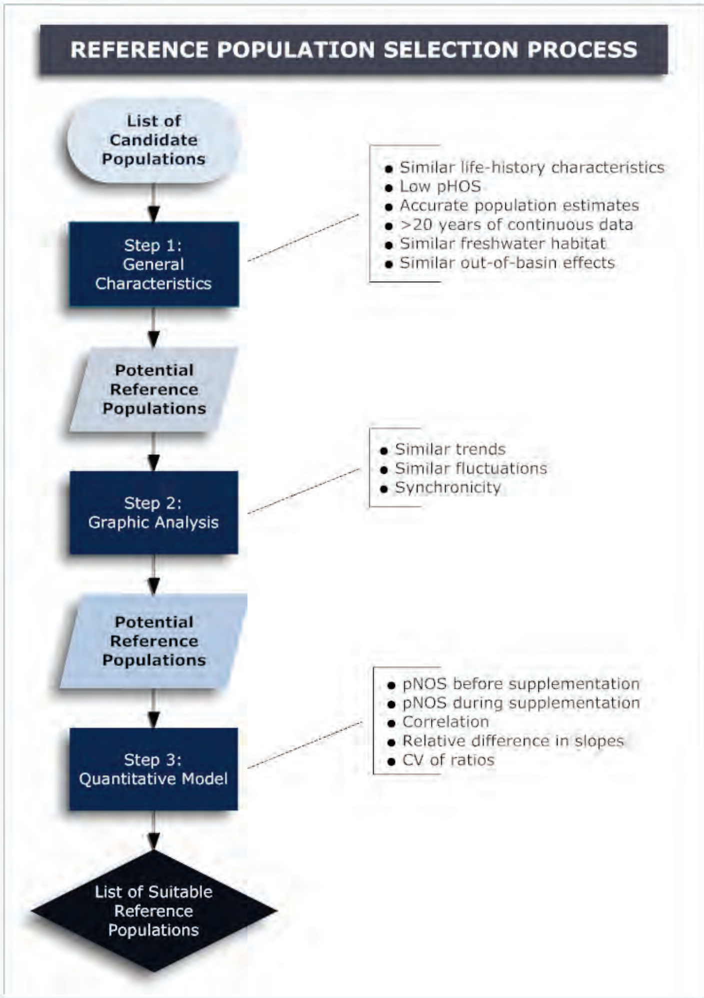

Figure 8. Three-step process for selecting suitable reference populations for supplemented populations.

We used this approach to select suitable reference populations for analyzing the effects of the Chiwawa spring Chinook supplementation program on fish abundance and productivity. The method indicated that the Naches, Marsh, and Sesech populations would serve as suitable reference populations for the Chiwawa spring Chinook supplementation program. Both the Entiat and Little Wenatchee populations failed to meet the minimum score, largely because of the influence of hatchery fish within those populations (i.e., relatively low pNOS values). However, because the presence of hatchery spring Chinook within those populations should decrease, they may serve as unique reference populations in which the comparisons change from all populations receiving

hatchery fish to only the Chiwawa population receiving hatchery fish. Therefore, we will continue to include both the Little Wenatchee and Entiat populations in future analyses.

An important assumption in the use of reference populations is that the supplemented and reference populations that tracked each other before supplementation would continue to track each other in the absence of supplementation. Given that the reference populations did not match the Chiwawa population on all criteria examined (Table 1) and some reference populations tracked the Chiwawa population more poorly than others (Figures 2-7; Tables 2-4), there may be some uncertainty as to whether differences observed between the Chiwawa and reference populations during the supplementation period are associated with the hatchery program, "nuisance" factors[17], or a combination of both. In addition, we have no ability to regulate or control activities in reference areas. Any large-scale change (man-made or natural) in reference areas could affect our ability to assess the effectiveness of the supplementation program.

Because we have no ability to maintain reference areas for long periods of time and may not be able to control all activities even within the supplemented populations, we propose the use of a "causal-comparative" approach to strengthen the certainty of our inferences (Pearsons and Temple 2010). The causal-comparative approach relies on correlative data to try and make a case for causal inference.[18] Correlation is used to rule out alternative hypotheses (note that we make our case as much if not more by disproving plausible alternatives as we do by showing that the data are consistent with a hypothesis). For example, large scale land-use activities or natural events can affect stream flows, fine sediment recruitment, and water temperatures. Changes in these factors can affect the freshwater survival and productivity of fish independently of supplementation programs. If changes in habitat, migratory, and ocean conditions do not affect reference and treatment populations similarly, inferences associated with supplementation programs may be confounded. By measuring and tracking these extraneous factors within reference and treatment areas, we can assess the effects of these state variables on population conditions independent of the supplementation programs. This allows us to more effectively assess the influence of supplementation programs on populations.

To that end, we recommend that the following state variables be measured and tracked within the Chiwawa Basin and each of the reference areas: mean annual precipitation, total and riparian forest cover, road density, impervious surface, and alluvium. These variables can be used to describe differences in water temperatures at different life stages (pre-spawning, egg incubation, and summer rearing) and substrate characteristics, including fine sediments and embeddedness (Jorgensen et al. 2009). They can be used to assess possible changes in spawner abundance, NORs, and productivity that are independent of supplementation.

[17] A "nuisance" factor is any factor that is outside the control of the experimenter and can affect the response variable (spawner abundance or productivity). In this case, nuisance factors may include differences in freshwater habitat trends and conditions, out-of-basin effects (e.g., migration and ocean survival), and hatchery strays that affect the Chiwawa and reference populations differently.

[18] It is important to point out that correlation does not demonstrate cause-and-effect. It only suggests a relationship between variables. Thus, inferences based on correlation lack the certainty that is associated with a design-based approach.

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Analyses with Reference Populations

Once suitable reference populations are selected, methods for analyzing the supplemented and reference populations need to be identified. What follows is a description of different analyses that can be used to assess the effects of supplementation programs on spawner abundance, NORs, and productivity using reference populations. Later in this report we describe methods for assessing supplementation effects when reference populations are not available.

We used some of the reference populations selected for the Chiwawa program to illustrate the different methods for evaluating the effects of the supplementation program on spawner abundance, NORs, and productivity. For abundance, we selected the Naches, Entiat, Little Wenatchee, and Sesech populations as suitable references for the Chiwawa population. For NORs, we selected the Naches, Entiat, Marsh, and Little Wenatchee populations as suitable references. For productivity, we selected the Naches, Sesech, Little Wenatchee, and Marsh Creek as suitable references for the Chiwawa. As noted earlier, we included the Little Wenatchee and Entiat populations, even though they did not meet all the criteria for suitable reference populations.

Analysis of Trends

As a first step, we used trend analyses to assess the effects of the Chiwawa supplementation program on spring Chinook spawner abundance, NORs, and productivity. Here, we compared the slopes of the trends between each treatment/reference pair before and during supplementation using t-tests. If the hatchery program is successfully supplementing the natural spring Chinook population, trends in spawner abundance and NORs should deviate significantly (i.e., the slope of the supplemented population should be greater than the slopes of the reference populations during the supplementation period). For productivity, the slope of the supplemented population, relative to the reference population, should increase or remain the same.

Trend analysis indicated that the relationship of slopes of spawner abundance between the Chiwawa and reference populations did not change significantly after the initiation of supplementation (Figure 9; Table 12). This was true for both transformed and untransformed abundance data. Before supplementation, spawner abundances trended down in both the Chiwawa and reference populations (Figure 9). During the period of supplementation, abundances in both the Chiwawa and reference populations trended upward. Interestingly, in nearly all treatment/reference comparisons, the Pearson correlation coefficient was greater in the supplementation period than in the pre-supplementation period (Table 12). This was most evident in the transformed abundance data (Figure 9).

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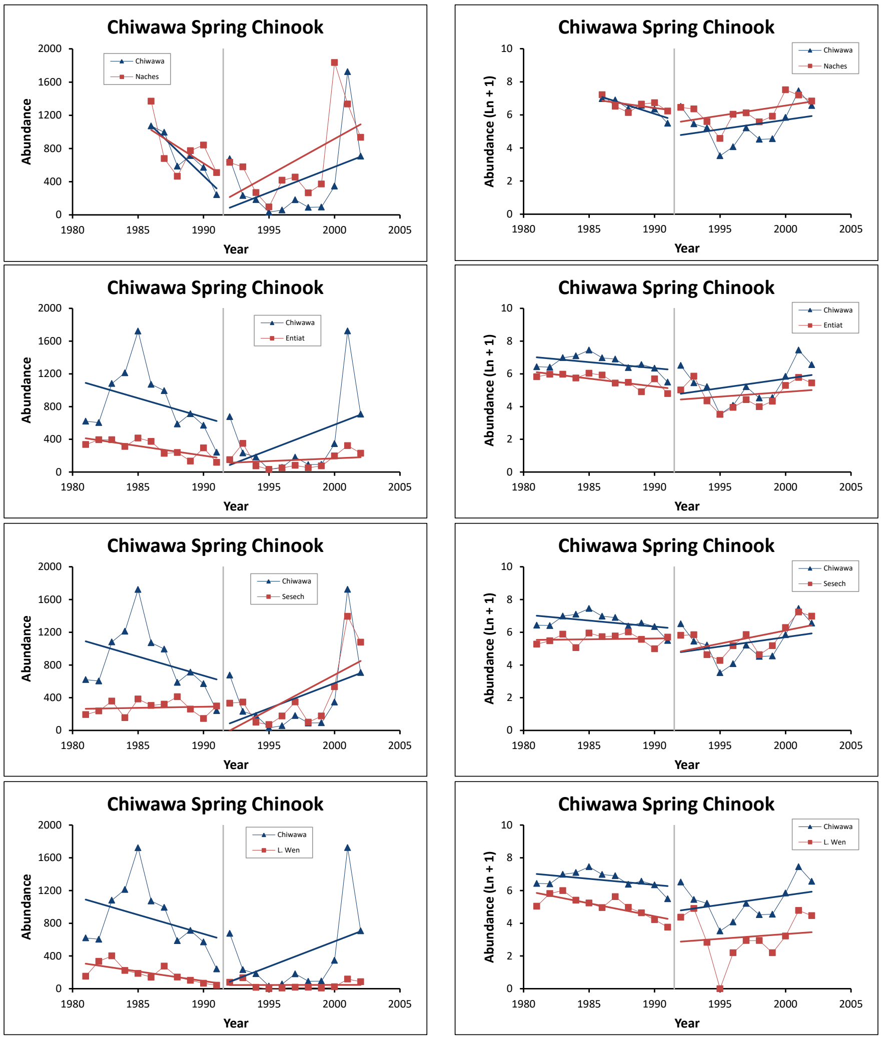

Figure 9. Trends in spring Chinook spawner abundance in the Chiwawa and reference populations. The vertical lines in the figures separate the pre- and post-supplementation periods. Figures on the left include untransformed spawner abundance data; those on the right include natural-log transformed data.

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Table 12. Pearson correlation coefficients and t-test results comparing slopes of spawner abundance trends between reference populations and the Chiwawa spring Chinook population before and during the supplementation periods; for correlation coefficients, an asterisk (*) indicates significance at P < 0.05. Analyses include both untransformed and natural-log transformed spawner abundance data.

Reference population	Pearson correlation coefficient		Test on slopes			
			t-value		P-value	
	Before	During	Before	During	Before	During
Spawner Abundance						
Naches	0.684*	0.595	-0.659	-0.414	0.528	0.684
Entiat	0.598*	0.672*	-0.596	1.162	0.559	0.260
Sesech	0.274	0.904*	-1.265	-0.418	0.222	0.681
Little Wenatchee	0.399	0.685*	-0.591	1.330	0.562	0.200
LN Spawner Abundance						
Naches	0.642*	0.813*	-1.323	-0.047	0.222	0.963
Entiat	0.652*	0.860*	0.412	0.422	0.685	0.678
Sesech	0.149	0.878*	-1.431	-0.333	0.170	0.743
Little Wenatchee	0.670*	0.861*	1.325	0.316	0.202	0.756

Trend analysis indicated that the relationship of slopes of NORs between the Chiwawa and reference populations did not change significantly after the initiation of supplementation (Figure 10; Table 13). Before supplementation, Chiwawa NORs trended downward more strongly than the reference populations (Figure 10). However, during the supplementation period, both the Chiwawa and reference population NORs trended upward in parallel. In nearly all treatment/reference comparisons, the Pearson correlation coefficient was greater in the pre-supplementation period than in the supplementation period (Table 13).

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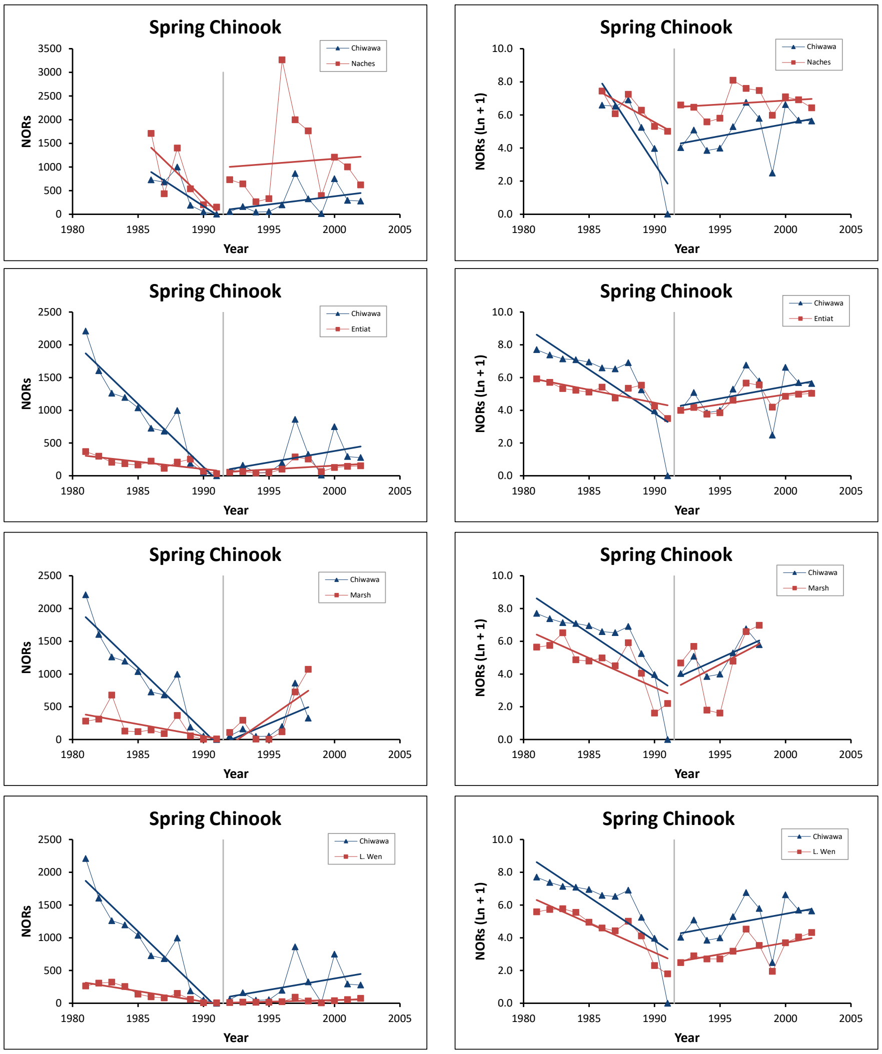

Figure 10. Trends in spring Chinook natural-origin recruits (NORs) in the Chiwawa and reference populations. The vertical lines in the figures separate the pre- and post-supplementation periods. Figures on the left include untransformed NORs; those on the right include natural-log transformed data.

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Table 13. Pearson correlation coefficients and t-test results comparing slopes of natural-origin recruits trends between reference populations and the Chiwawa spring Chinook population before and during the supplementation periods; for correlation coefficients, an asterisk (*) indicates significance at P < 0.05. Analyses include both untransformed and natural-log transformed natural-origin recruits.

Reference population	Pearson correlation coefficient		Test on slopes			
			t-value		P-value	
	Before	During	Before	During	Before	During
Natural-Origin Recruits						
Naches	0.803*	0.432	0.666	0.140	0.524	0.890
Entiat	0.795*	0.754*	-7.495	0.847	0.000	0.408
Marsh	0.605*	0.677*	-5.786	-0.718	0.000	0.489
Little Wenatchee	0.880*	0.758*	-7.206	1.128	0.000	0.274
LN Natural-Origin Recruits						
Naches	0.824*	0.710*	-1.985	0.693	0.082	0.497
Entiat	0.886*	0.796*	-2.563	0.202	0.019	0.842
Marsh	0.830*	0.835*	-1.038	-0.134	0.313	0.896
Little Wenatchee	0.927*	0.898*	-1.150	0.046	0.265	0.964

As with NORs and spawner abundance data, trend analysis indicated that the relationship of slopes of productivity (recruits/spawner) between the Chiwawa and reference populations did not change significantly after the initiation of supplementation (Figure 11; Table 14). This was true for both transformed and untransformed productivity data. Before supplementation, productivities trended down in both the Chiwawa and reference populations (Figure 11). During the period of supplementation, productivities fluctuated widely in both the Chiwawa and reference populations. Nevertheless, during the supplementation period, productivities generally increased in both the reference and Chiwawa populations. Unlike with spawner abundance, the Pearson correlation coefficients resulting from analysis of productivity data were generally higher in the pre-supplementation period than during the supplementation period (Table 14).

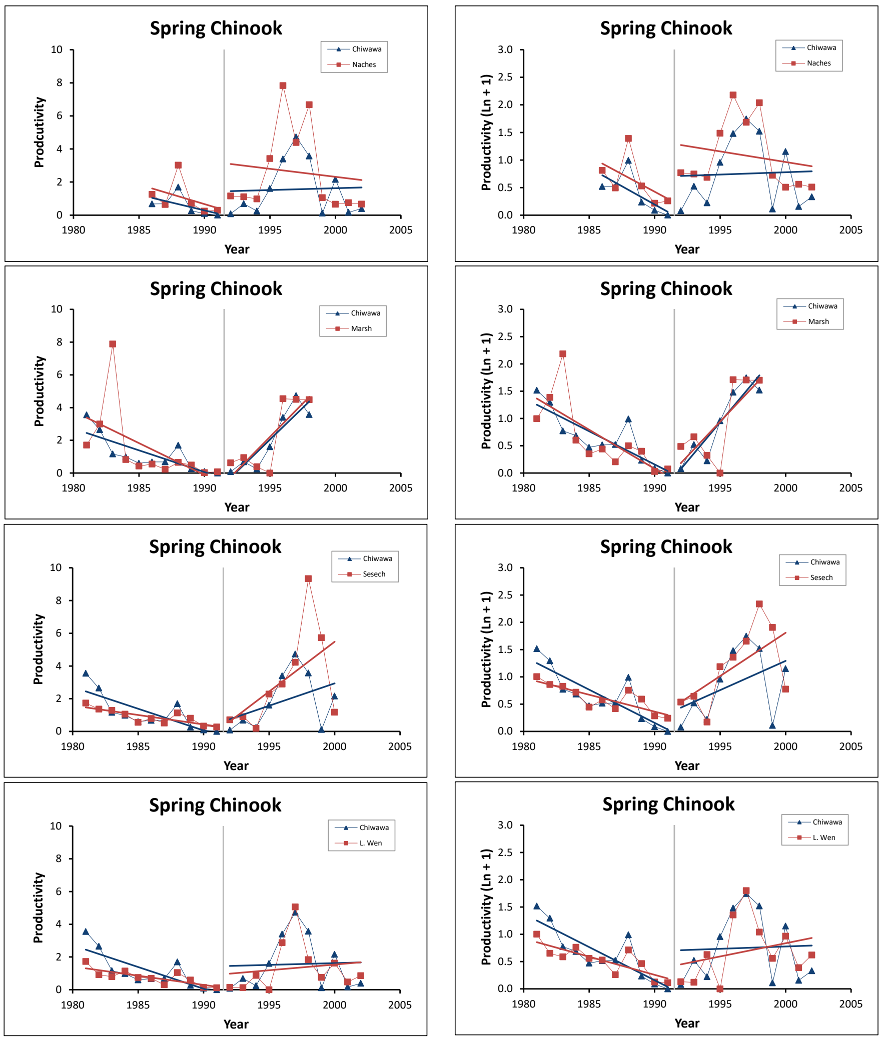

Figure 11. Trends in spring Chinook productivity (recruits/spawner) in the Chiwawa (supplemented) and reference populations. The vertical lines in the figures separate the pre- and post-supplementation periods. Figures on the left include untransformed productivity data; those on the right include natural-log transformed data.

Table 14. Pearson correlation coefficients and t-test results comparing slopes of productivity (recruits/spawner) trends between reference populations and the Chiwawa spring Chinook population before and during the supplementation periods; for correlation coefficients, an asterisk (*) indicates significance at P < 0.05. Analyses include both untransformed and natural-log transformed productivity data.

Reference population	Pearson correlation coefficient		Test on slopes			
			t-value		P-value	
	Before	During	Before	During	Before	During
Productivity						
Naches	0.960*	0.802*	0.169	0.387	0.870	0.703
Marsh	0.320	0.910*	0.605	-0.132	0.553	0.898
Sesech	0.903*	0.491	-2.059	-0.837	0.054	0.417
Little Wenatchee	0.848*	0.864*	-2.065	-0.213	0.054	0.834
LN Productivity						
Naches	0.944*	0.805*	-0.042	0.526	0.968	0.605
Marsh	0.610*	0.804*	0.428	0.281	0.674	0.784
Sesech	0.913*	0.531	-2.050	-0.463	0.055	0.651
Little Wenatchee	0.862*	0.751*	-1.811	-0.480	0.087	0.637

Using trend analysis, we found no evidence that the supplementation program has significantly increased the spawner abundance and NORs of spring Chinook in the Chiwawa Basin. Even though we documented an increasing trend in spawner abundance and NORs during the supplementation period, a similar increase in spawner abundance and NORs was observed in the reference populations. In addition, we found no evidence that the supplementation program has increased the productivity of spring Chinook in the Chiwawa Basin. Importantly, the productivity of spring Chinook in the Chiwawa Basin did not trend downward during the supplementation period. Thus, based on trend analysis, it appears that the supplementation program has not increased or decreased the abundance and productivity of spring Chinook in the Chiwawa Basin.

We note that this exercise only tests the slopes of the trend lines. It does not test for differences in elevations of the trend lines. A supplementation program could increase spawner abundance, NORs, and productivity of the target population without changing the slopes of the trend lines. That is, supplementation could cause the elevation of the trend line to be greater during the supplementation period than during the pre-supplementation period. In the next section we evaluate elevation differences by testing mean differences before and after supplementation.

Analysis of Mean Differences, Ratios, and Rates

For assessing mean differences between supplemented and reference populations, we derived three different response variables using transformed and untransformed spawner abundance, NORs, and productivity data. The first included difference scores, which were calculated as the difference between paired treatment and reference data (T-R). The second included ratios, which were calculated as the ratio of paired treatment and reference data (T/R). Finally, we calculated the differences in annual changes in paired treatment and reference population data (ΔT-ΔR; see footnote #2).

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If the hatchery program is successfully supplementing the natural spring Chinook population, the mean difference or ratio score of paired spawner abundance data and NORs during the supplementation period should be greater than the pre-supplementation period. For productivity, the mean difference or ratio score during the supplementation period should be equal to or higher than the pre-supplementation period. We tested the following statistical hypotheses.

Spawner Abundance and NORs:

Ho: Mean Difference (or Ratio) before supplementation ≥ Mean Difference (or Ratio) during supplementation.

Ha: Mean Difference (or Ratio) before supplementation < Mean Difference (or Ratio) during supplementation (i.e., $\mu_{pre} - \mu_{post} < 0$).

Productivity (Recruits/Spawner):

Ho: Mean Difference (or Ratio) before supplementation ≤ Mean Difference (or Ratio) during supplementation.

Ha: Mean Difference (or Ratio) before supplementation > Mean Difference (or Ratio) during supplementation (i.e., $\mu_{pre} - \mu_{post} > 0$).[19]

For each set of response variables, we tested before/after supplementation effects using a one-tailed Aspin-Welch unequal-variance test. We used the Aspin-Welch unequal-variance test instead of Student's t-test, because in nearly every case, the variances of response variables in the pre-treatment and supplementation periods were unequal.[20] This was true even for natural-log transformed variables. We used the modified Levene equal-variance test to assess the equality of variance. In some cases, the distributions of response variables were not normal (based on the Omnibus Normality test and examination of histograms, normal probability plots, and box plots). Therefore, we also used a randomization test, based on 10,000 Monte Carlo simulations, to assess differences in response variables before and during supplementation. The randomization procedure only allowed the testing of two-tailed hypotheses. Therefore, we generated 95% confidence intervals on the mean difference ($\mu_{pre} - \mu_{post}$) using bootstrapping methods to determine the direction of the difference. We generated 5,000 bootstrap samples to calculate confidence intervals.

All these statistical methods assume that the samples of derived difference or ratio scores from the pre-supplementation and supplementation periods were independent. However, BACI designs, like time-series trend analysis, are repeated-measures designs and therefore are susceptible to temporal correlations in the data. This means that the two samples of difference or ratio scores may not be independent. Under this scenario, ARIMA models can be used to describe the correlation structure in temporal data (Gotelli and Ellison 2004). ARIMA models can be fit individually to the reference and supplemented time series data, or to a derived data series created by taking the ratio or difference of the supplemented/reference data at each time step. ARIMA models, however, require a long time series (N > 40) and therefore we could not use them to model

[19] Because of the logic of null hypothesis testing, the rejection of the null hypothesis of no difference in productivity would mean that the supplementation program has reduced the productivity of the target population (here rejection of the null indicates "harm"). Notice that the rejection of the null hypothesis of no difference in spawner abundance means that the supplementation program has improved the spawner abundance in the target population (here rejection of the null indicates "benefit").

[20] In cases in which the variances were equal, both the Aspin-Welch test and Student's t-test gave the same result.

the spring Chinook data. Thus, we acknowledge that our analyses may be confounded if the samples are not independent.

Difference Scores (T-R)

Analysis of supplementation effects on spawner abundance using difference scores indicated that supplementation did not significantly increase spawning abundance in the Chiwawa Basin (Table 15; Figure 12). Only the Little Wenatchee-Chiwawa pairing using transformed abundance data indicated a significant increase in spawning abundance following supplementation. The randomization test indicated significant differences in several of the treatment-reference pairs; however, the bootstrap CIs indicated that those differences were in the wrong direction (i.e., CIs > 0). That is, compared to the reference populations, spawner abundance decreased in the Chiwawa Basin during the supplementation period (Figure 12).

Table 15. Results of the Aspin-Welch unequal-variance test, randomization test (based on 10,000 Monte Carlo samples), and 95% CI (based on 5,000 bootstrap samples) on transformed and untransformed spawner abundance data. Tests determined if the mean difference scores during the supplementation period were greater than mean difference scores during the pre-supplementation period.

Reference population	Aspin-Welch unequal-variance test			Randomization test P-value	Bootstrap 95% CI
	t-value	P-value	Effect size		
		Spawner Abundance			
Naches	1.066	0.848	184	0.322	-162 – 472
Entiat	1.872	0.962	316	0.078	17 – 633
Sesech	4.502	0.999	607	0.000	349 – 851
Little Wenatchee	1.773	0.954	321	0.093	0 – 690
		LN Spawner Abundance			
Naches	2.603	0.990	0.701	0.026	0.210 – 1.214
Entiat	1.701	0.946	0.388	0.108	-0.033 – 0.811
Sesech	5.394	0.999	1.327	0.000	0.891 – 1.805
Little Wenatchee	-2.259	0.018	0.609	0.034	-1.125 – -0.097

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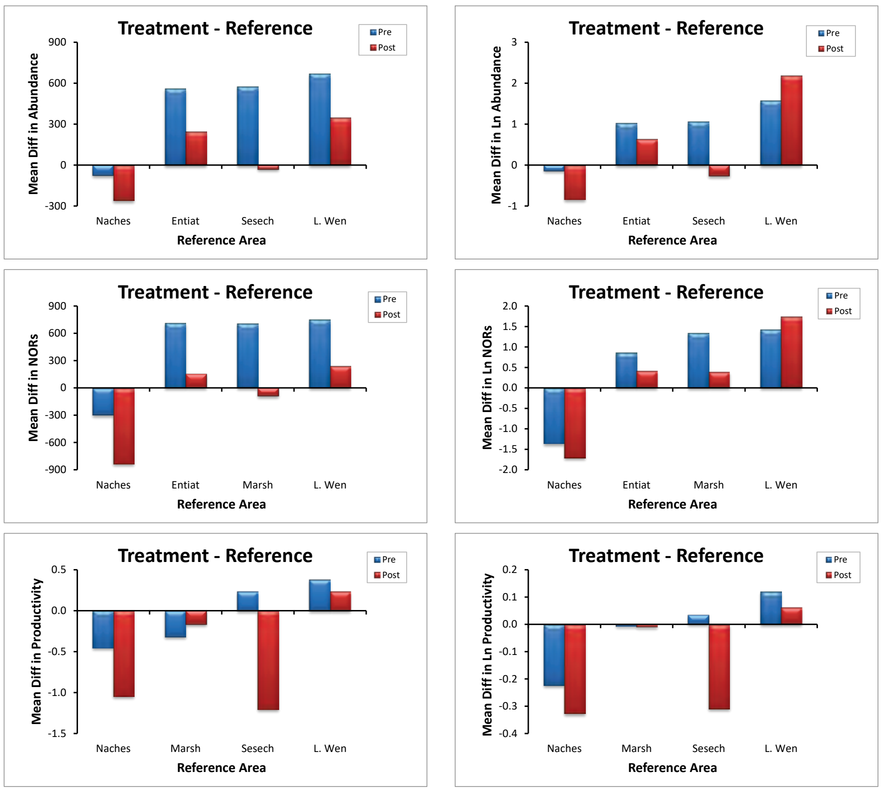

Figure 12. Mean difference (Treatment – Reference) scores of untransformed (figures on the left) and transformed (figures on the right) spawner abundance, natural-origin recruits (NORs), and productivity data before (pre) and after (post) spring Chinook supplementation in the Chiwawa Basin. Positive effects of supplementation on spawner abundance and NORs are indicated when the post-supplementation (red) bars are greater than their corresponding pre-supplementation (blue) bars. Negative effects of supplementation on productivity are indicated when the pre-supplementation (blue) bars are greater than their corresponding post-supplementation (red) bars.

Analysis of supplementation effects on NORs using difference scores indicated that supplementation did not significantly increase NORs in the Chiwawa Basin (Table 16; Figure 12). The randomization test indicated significant differences in several of the treatment-reference pairs; however, the bootstrap CIs indicated that those differences were in the wrong direction. That is, compared to the reference populations, NORs decreased in the Chiwawa Basin during the supplementation period (Figure 12).

Table 16. Results of the Aspin-Welch unequal-variance test, randomization test (based on 10,000 Monte Carlo samples), and 95% CI (based on 5,000 bootstrap samples) on transformed and untransformed natural-origin recruits. Tests determined if the mean difference scores during the supplementation period were greater than mean difference scores during the pre-supplementation period.

Reference population	Aspin-Welch unequal-variance test			Randomization test P-value	Bootstrap 95% CI
	t-value	P-value	Effect size		
Natural-Origin Recruits					
Naches	1.787	0.953	537	0.081	-60 – 1039
Entiat	2.879	0.993	558	0.007	201 – 916
Marsh	3.817	0.999	795	0.001	381 – 1153
Little Wenatchee	2.668	0.991	510	0.013	145 – 863
LN Natural-Origin Recruits					
Naches	0.430	0.659	0.354	0.686	-0.948 – 1.975
Entiat	0.788	0.779	0.445	0.465	-0.504 – 1.583
Marsh	1.45	0.916	0.953	0.168	-0.169 – 2.243
Little Wenatchee	-0.813	0.214	-0.319	0.506	-0.948 – 0.484

Analysis of supplementation effects on productivity (adult recruits/spawner) using difference scores indicated that supplementation did not significantly decrease productivity in the Chiwawa Basin (Table 17; Figure 12). All tests, regardless of treatment-reference pairs, indicated that productivity did not change significantly during the supplementation period. These tests indicate that supplementation has not negatively affected the productivity of spring Chinook salmon in the Chiwawa Basin.

Table 17. Results of the Aspin-Welch unequal-variance test, randomization test (based on 10,000 Monte Carlo samples), and 95% CI (based on 5,000 bootstrap samples) on transformed and untransformed productivity data. Tests determined if the mean difference scores during the supplementation period were less than mean difference scores during the pre-supplementation period.

Reference population	Aspin-Welch unequal-variance test			Randomization test P-value	Bootstrap 95% CI
	t-value	P-value	Effect size		
Productivity					
Naches	1.134	0.139	0.594	0.296	-0.427 – 1.540
Marsh	-0.203	0.579	0.152	0.932	-0.304 – 1.381
Sesech	1.607	0.071	1.435	0.151	-0.403 – 2.917
Little Wenatchee	0.431	0.335	0.147	0.665	-0.498 – 0.762
LN Productivity					
Naches	0.770	0.227	0.104	0.480	-0.125 – 0.378
Marsh	0.012	0.495	0.003	0.992	-0.375 – 0.493
Sesech	1.463	0.087	0.343	0.161	-0.135 – 0.732
Little Wenatchee	0.390	0.351	0.060	0.701	-0.229 – 0.347

Ratio Scores (T/R)

As with difference scores, analysis of supplementation effects on spawner abundance using ratios indicated that supplementation did not significantly increase spawning abundance in the Chiwawa Basin (Table 18; Figure 13). Only the Little Wenatchee-Chiwawa pairing indicated a significant increase in spawning abundance following supplementation. Analysis with both transformed and untransformed Little Wenatchee-Chiwawa data indicated a significant effect. In contrast, only difference scores derived from transformed data indicated a significant effect. The randomization test indicated significant differences in several of the treatment-reference pairs; however, the bootstrap CIs indicated that those differences were in the wrong direction. That is, compared to the reference populations, spawner abundance decreased in the Chiwawa Basin during the supplementation period (Figure 13).

Table 18. Results of the Aspin-Welch unequal-variance test, randomization test (based on 10,000 Monte Carlo samples), and 95% CI (based on 5,000 bootstrap samples) on transformed and untransformed spawner abundance data. Tests determined if the mean ratios during the supplementation period were greater than mean ratios during the pre-supplementation period.

Reference population	Aspin-Welch unequal-variance test			Randomization test P-value	Bootstrap 95% CI
	t-value	P-value	Effect size		
Spawner Abundance					
Naches	2.110	0.970	0.398	0.065	0.056 – 0.737
Entiat	1.254	0.888	0.731	0.223	-0.365 – 1.834
Sesech	4.251	0.999	2.428	0.000	1.278 – 3.435
Little Wenatchee	-2.649	0.009	3.897	0.018	-6.579 – -1.202
LN Spawner Abundance					
Naches	2.783	0.993	0.120	0.021	0.045 – 0.199
Entiat	1.273	0.890	0.055	0.220	-0.026 – 0.135
Sesech	5.143	0.999	0.244	0.000	0.160 – 0.335
Little Wenatchee	-3.462	0.002	0.327	0.003	-0.516 – -0.154

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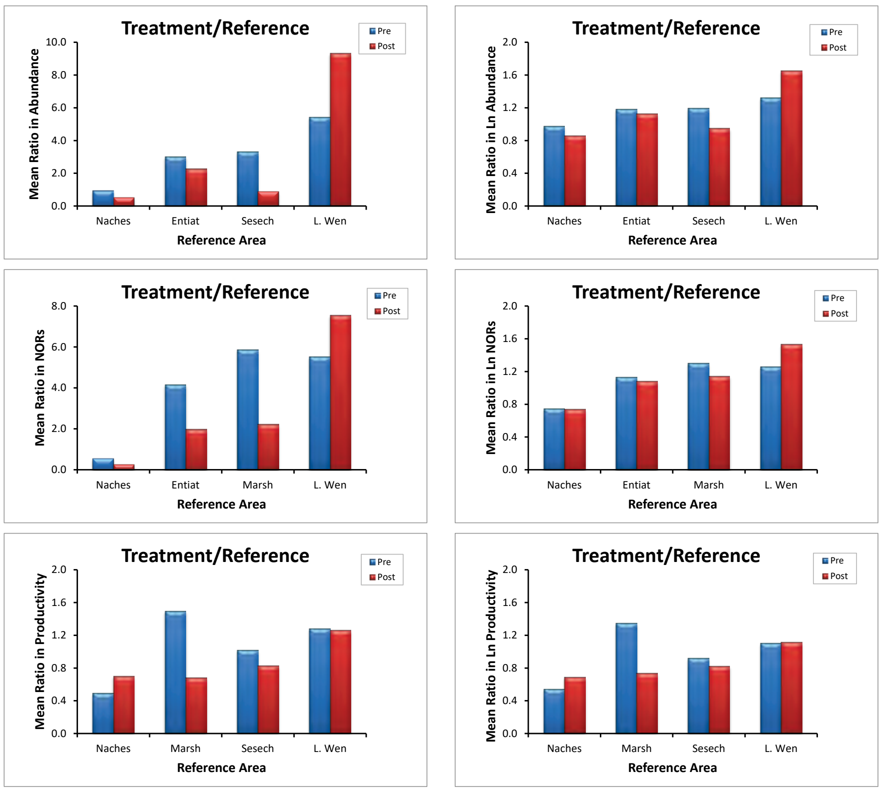

Figure 13. Mean ratios (Treatment/Reference) scores of untransformed (figures on the left) and transformed (figures on the right) spawner abundance, natural-origin recruits (NORs), and productivity data before (pre) and after (post) spring Chinook supplementation in the Chiwawa Basin. Positive effects of supplementation on spawner abundance and NORs are indicated when the post-supplementation (red) bars are greater than their corresponding pre-supplementation (blue) bars. Negative effects of supplementation on productivity are indicated when the pre-supplementation (blue) bars are greater than their corresponding post-supplementation (red) bars.

Analysis of supplementation effects on NORs using ratios indicated that supplementation did not significantly increase NORs in the Chiwawa Basin (Table 19; Figure 13). Only the Little Wenatchee-Chiwawa pairing indicated a significant increase in transformed NORs following supplementation. The randomization test indicated significant differences in several of the treatment-reference pairs; however, the bootstrap CIs indicated that those differences were in the wrong direction. That is, compared to the reference populations, NORs decreased in the Chiwawa Basin during the supplementation period (Figure 13).

Table 19. Results of the Aspin-Welch unequal-variance test, randomization test (based on 10,000 Monte Carlo samples), and 95% CI (based on 5,000 bootstrap samples) on transformed and untransformed natural-origin recruits. Tests determined if the mean ratios during the supplementation period were greater than mean ratios during the pre-supplementation period.

Reference population	Aspin-Welch unequal-variance test			Randomization test P-value	Bootstrap 95% CI
	t-value	P-value	Effect size		
Natural-Origin Recruits					
Naches	1.318	0.881	0.306	0.219	-0.157 – 0.670
Entiat	2.447	0.987	2.172	0.028	0.593 – 3.871
Marsh	2.001	0.965	3.638	0.075	0.532 – 7.201
Little Wenatchee	-1.148	0.136	2.020	0.284	-5.055 – 1.516
LN Natural-Origin Recruits					
Naches	0.057	0.522	0.009	0.967	-0.230 – 0.351
Entiat	0.359	0.638	0.049	0.759	-0.173 – 0.336
Marsh	0.603	0.721	0.161	0.579	-0.272 – 0.681
Little Wenatchee	-1.914	0.038	0.277	0.027	-0.504 – 0.031

Analysis of supplementation effects on productivity (adult recruits/spawner) using ratios indicated that supplementation did not significantly decrease productivity in the Chiwawa Basin (Table 20; Figure 13). Although the Aspin-Welch test indicated a significant effect when comparing the Chiwawa to the Marsh Creek population, both the randomization test and the bootstrap CI did not indicate a significant effect. These tests indicate that supplementation has probably not negatively affected the productivity of spring Chinook salmon in the Chiwawa Basin.

Table 20. Results of the Aspin-Welch unequal-variance test, randomization test (based on 10,000 Monte Carlo samples), and 95% CI (based on 5,000 bootstrap samples) on transformed and untransformed productivity data. Tests determined if the mean ratios during the supplementation period were less than mean ratios during the pre-supplementation period.

Reference population	Aspin-Welch unequal-variance test			Randomization test P-value	Bootstrap 95% CI
	t-value	P-value	Effect size		
Productivity					
Naches	-0.677	0.745	0.209	0.688	-0.700 – 0.425
Marsh	2.236	0.022	0.814	0.054	0.112 – 1.459
Sesech	0.677	0.253	0.191	0.515	-0.356 – 0.718
Little Wenatchee	0.033	0.487	0.018	0.979	-0.879 – 1.162
LN Productivity					
Naches	-0.639	0.734	0.148	0.616	-0.548 – 0.316
Marsh	1.952	0.036	0.613	0.081	-0.003 – 1.170
Sesech	0.447	0.330	0.098	0.663	-0.301 – 0.515
Little Wenatchee	-0.034	0.513	0.015	0.982	-0.692 – 0.861

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Difference of Annual Difference Scores (ΔT-ΔR)

Analysis of supplementation effects on spawner abundance using difference scores of annual changes indicated that supplementation did not significantly increase spawning abundance in the Chiwawa Basin (Table 21; Figure 14). None of the statistical analyses detected a significant increase in annual change in the Chiwawa Basin relative to the reference populations.

Table 21. Results of the Aspin-Welch unequal-variance test, randomization test (based on 10,000 Monte Carlo samples), and 95% CI (based on 5,000 bootstrap samples) on transformed and untransformed spawner abundance data. Tests determined if mean difference scores of annual change during the supplementation period were greater than mean difference scores of annual change during the pre-supplementation period.

Reference population	Aspin-Welch unequal-variance test			Randomization test P-value	Bootstrap 95% CI
	t-value	P-value	Effect size		
Spawner Abundance					
Naches	0.009	0.503	2	0.995	-502 – 539
Entiat	-0.239	0.407	48	0.826	-414 – 327
Sesech	-0.126	0.451	20	0.902	-311 – 266
Little Wenatchee	-0.318	0.377	65	0.761	-452 – 311
LN Spawner Abundance					
Naches	-0.425	0.339	0.142	0.698	-0.744 – 0.466
Entiat	-0.084	0.467	0.028	0.933	-0.681 – 0.593
Sesech	-0.349	0.366	0.117	0.740	-0.741 – 0.515
Little Wenatchee	0.001	0.500	0.000	0.999	-0.663 – 0.687

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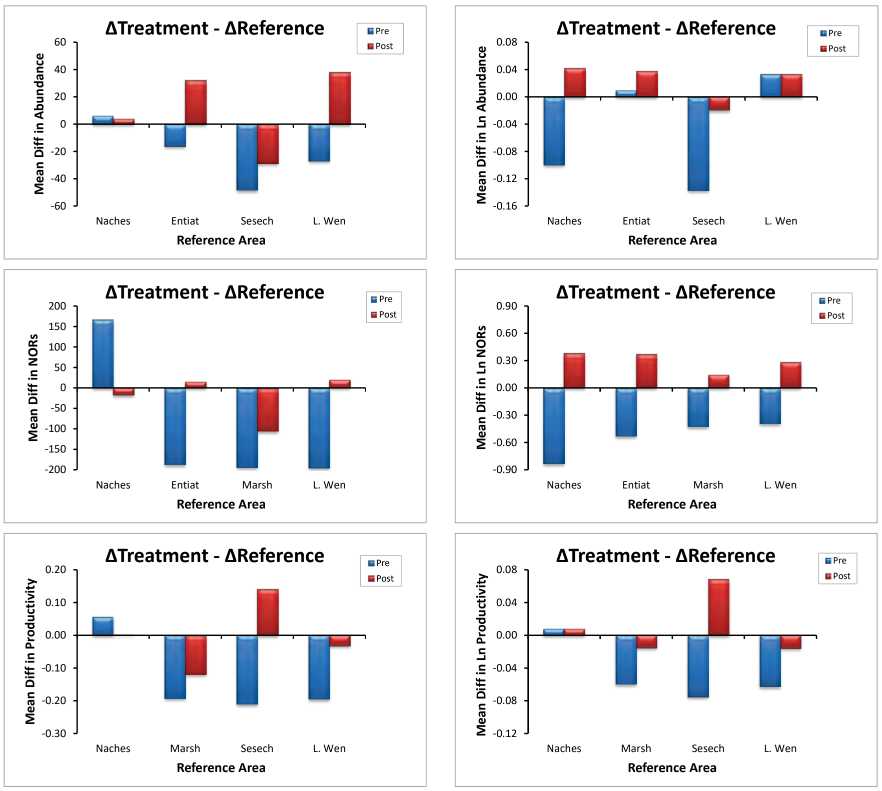

Figure 14. Mean difference scores of annual changes (ΔTreatment – ΔReference) of untransformed (figures on the left) and transformed (figures on the right) spawner abundance and productivity data before (pre) and after (post) spring Chinook supplementation in the Chiwawa Basin.

Analysis of supplementation effects on NORs using difference scores of annual changes indicated that supplementation did not significantly increase NORs in the Chiwawa Basin (Table 22; Figure 14). None of the statistical analyses detected a significant increase in annual change in the Chiwawa Basin relative to the reference populations.

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Table 22. Results of the Aspin-Welch unequal-variance test, randomization test (based on 10,000 Monte Carlo samples), and 95% CI (based on 5,000 bootstrap samples) on transformed and untransformed natural-origin recruits. Tests determined if mean difference scores of annual change during the supplementation period were greater than mean difference scores of annual change during the pre-supplementation period.

Reference population	Aspin-Welch unequal-variance test			Randomization test P-value	Bootstrap 95% CI
	t-value	P-value	Effect size		
Natural-Origin Recruits					
Naches	0.399	0.652	184	0.741	-699 – 989
Entiat	-1.381	0.092	202	0.194	-471 – 86
Marsh	-0.505	0.311	88	0.624	-425 – 206
Little Wenatchee	-1.437	0.084	214	0.179	-481 – 64
LN Natural-Origin Recruits					
Naches	-1.301	0.118	1.214	0.224	-2.783 – 0.531
Entiat	-1.408	0.088	0.901	0.188	-1.977 – 0.387
Marsh	-0.712	0.244	0.570	0.517	-1.952 – 0.975
Little Wenatchee	-1.154	0.132	0.674	0.274	-1.706 – 0.497

Analysis of supplementation effects on productivity (adult recruits/spawner) using difference scores of annual changes indicated that supplementation did not significantly decrease productivity in the Chiwawa Basin (Table 23; Figure 14). All tests, regardless of treatment-reference pairs, indicated that productivity did not change significantly during the supplementation period.

Table 23. Results of the Aspin-Welch unequal-variance test, randomization test (based on 10,000 Monte Carlo samples), and 95% CI (based on 5,000 bootstrap samples) on transformed and untransformed productivity data. Tests determined if the mean difference scores of annual change during the supplementation period were less than mean difference scores of annual change during the pre-supplementation period.

Reference population	Aspin-Welch unequal-variance test			Randomization test P-value	Bootstrap 95% CI
	t-value	P-value	Effect size		
Productivity					
Naches	0.002	0.475	0.054	0.952	-1.464 – 1.583
Marsh	-0.063	0.525	0.074	0.948	-2.395 – 2.031
Sesech	-0.317	0.621	0.350	0.628	-2.387 – 1.695
Little Wenatchee	-0.347	0.633	0.163	0.728	-1.023 – 0.725
LN Productivity					
Naches	0.000	0.500	0.000	0.999	-0.408 – 0.445
Marsh	-0.126	0.549	0.044	0.904	-0.715 – 0.595
Sesech	-0.449	0.668	0.144	0.727	-0.685 – 0.509
Little Wenatchee	-0.200	0.578	0.047	0.842	-0.466 – 0.391

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We believe results from analysis of mean differences of annual change (ΔT-ΔR) in spawning abundance, NORs, and productivity are difficult to interpret and may be insensitive to treatment effects. A simpler analysis, which is also easier to interpret, is the use of trend analysis. Therefore, we recommend that analyses using differences of annual change be replaced with trend analysis.

Corrections for Density Dependence and Carrying Capacity

The analyses described above assume that the density of spawners or recruits does not affect the survival and productivity of fish. However, it is well known that the density of fish can affect the number of recruits as well as the productivity of the population. This occurs through the relationship between density and mortality. Mortality of fish can be generally classified as density independent and density dependent. In general, when densities are low, the mortality is density independent, but as densities increase, the amount of density-dependent mortality increases. Monitoring programs can make use of this information to derive density-corrected estimates of productivity. In this section, we describe two different methods for deriving density-corrected estimates of productivity.

The first method controlled the effects of density on productivity (adult recruits/spawner; R/S) by partitioning observed productivities into density-independent and density-dependent productivity. When abundance is below the minimum number of spawners (S) needed to produce the maximum number of recruits (K_{sp}), the observed productivity is used in statistical tests. However, when the abundance is equal to or above K_{sp}, the modeled value of productivity (R/K_{sp}) is used in statistical tests.

$$\boldsymbol{Adj\ R/S} = \begin{cases} \boldsymbol{R/S}, & \boldsymbol{if\ S < K_{sp}} \\ \boldsymbol{R/K_{sp}}, & \boldsymbol{if\ S \geq K_{sp}} \end{cases}$$

The density-independent and density-dependent productivities were then combined in a single test.

The second method was based on one of the goals of supplementation, which is to fill the capacity of the environment with fish. This method corrects for differences in carrying capacities between the supplemented and reference populations. We did this by calculating the percent saturation of NORs. That is, we calculated the fraction of the habitat (τ) that was filled with NORs by dividing the observed NOR by the modeled maximum number of NORs (K_R) that the habitat could support.

$$\boldsymbol{\tau} = \frac{\boldsymbol{NOR_{obs}}}{\boldsymbol{K_R}}$$

Note that 1-τ represents the unused portion of the carrying capacity and is the term that is multiplied by the exponential growth equation to derive the logistic growth equation. We included τ in the statistical analyses.

These two methods require the estimation of carrying capacity (K_R) and the spawning abundance that produces the maximum number of recruits (K_{sp}). We estimated these parameters for both reference populations and the supplemented population using Ricker, Beverton-Holt, and smooth hockey stick stock-recruitment models. We used only spawner abundance as a predictor of subsequent brood recruitment. We made the following assumptions in proceeding with the analysis:

- *Density-dependent mortality*—For some time period before recruitment, the brood instantaneous mortality rate is proportional to the number of parent spawners (Ricker 1954).
- *Lognormal variation*—At any particular spawning stock size, the variation in recruitment is log-normally distributed about its average, and acts multiplicatively (Quinn and Deriso 1999).
- *Measurement error*—Error in spawning stock size estimates (measurement error) is small relative to the range of spawning stock sizes observed (Hilborn and Walters 1992). Variation in realized recruitment at any particular spawning stock size (process error) dominates recruitment measurement error.
- *Stationarity*—The average stock-recruitment relationship is constant over time (Hilborn and Walters 1992). That is, environmental conditions randomly affect survival independent of stock size or time.

In general, the methods we used to fit the models to the data followed those outlined in Hilborn and Walters (1992) and Froese (2008). The Ricker model, which assumes that the number of recruits increases to a maximum and then declines as the number of spawners increases, takes the form:

$$\boldsymbol{E(R) = \alpha S e^{-\beta S}}$$

where E(R) is the expected recruitment, S is spawner abundance, α is the number of recruits per spawner at low spawning levels, and β describes how quickly the recruits per spawner drop as the number of spawners increases. We estimated K_R as:

$$\boldsymbol{K_R = \left(\frac{\alpha}{\beta}\right) e^{-1}}$$

and K_{sp} as:

$$\boldsymbol{K_{sp} = \frac{1}{\beta}}$$

The Beverton-Holt model assumes that the number of recruits increases constantly toward an asymptote as the number of spawners increases. After the asymptote is reached, the number of recruits neither increases nor decreases. The asymptote represents the maximum number of recruits the system can support (i.e., carrying capacity for the system; K_R). The Beverton-Holt curve takes the form:

$$\boldsymbol{E(R) = \frac{(\alpha S)}{(\beta + S)}}$$

where E(R) and S are as above, α is the maximum number of recruits produced (K_R), and β is the number of spawners needed to produce (on average) recruits equal to one-half the maximum number of recruits. Because $K_{sp} = \infty$ in the Beverton-Holt model, we estimated K_{sp} as the number of spawners needed to produce 0.99(K_R).

Like the Beverton-Holt model, the smooth hockey stick model assumes that the number of recruits increases toward an asymptote (carrying capacity; K_R) as the number of spawners increases. After the carrying capacity is reached, the number of recruits neither increases nor decreases. The carrying capacity represents the maximum number of recruits the system can support. This curve

takes the form (Froese 2008):

$$E(R) = R_{\infty}\left(1 - e^{-\left(\frac{\alpha}{R\infty}\right)S}\right)$$

where E(R) and S are as above, α is the slope at the origin of the spawner-recruitment curve, and R_{∞} is the carrying capacity of recruits (note that $R_{\infty} = K_R$). As with the Beverton-Holt model, we estimated K_{sp} as the number of spawners needed to produce $0.99(K_R)$.

We used non-linear regression to fit the three models to spawner-recruitment data. Before fitting the models, we transformed recruitment data using natural logs. We estimated bias and uncertainty measures (95% CI) for the model parameters using bootstrap procedures, which assumed that the {R, S} sample represented or approximated the population. The number of bootstrap samples was 3,000. We computed and stored the non-linear regression results for each bootstrap sample. We then calculated the bootstrap 95% CI by arranging the 3,000 bootstrap parameter values in sorted order and selected the 2.5 and 97.5 percentiles from the list.

We used Akaike's Information Criterion for small sample size (AIC_c) to determine which model(s) best explained the relationship between spawners and recruitment in the supplemented and reference populations. AIC_c was estimated as:

$$AIC_c = -2log(£(\theta|data)) + 2K + \left(\frac{2K(K+1)}{n-K-1}\right)$$

where $log(£(\theta|data))$ is the maximum likelihood estimate, K is the number of estimable parameters (structural parameters plus the residual variance parameter), and n is the sample size (Burnham and Anderson 2002). We used least-squares methods to estimate $log(£(\theta|data))$, which was calculated as $log(\sigma^2)$, where σ^2 = residual sum of squares divided by the sample size ($\sigma^2 = RSS/n$). AIC_c assessed model fit in relation to model complexity (number of parameters). The model with the smallest AIC_c value represented the "best approximating" model within the model set. Remaining models were ranked relative to the best model using AIC_c difference scores (ΔAIC_c), Akaike weights (w_i), and evidence ratios. Models with ΔAIC_c values less than 2 indicated that there is substantial support for these models as being the best-fitting models within the set (Burnham and Anderson 2002). Models with values greater than 2 had less support. Akaike weights are probabilities estimating the strength of the evidence supporting a particular model as being the best model within the model set. Models with small w_i values are less plausible as competing models (Burnham and Anderson 2002). If no single model could be specified as the best model, a "best subset" of competing models was identified using (1) AIC_c differences to indicate the level of empirical support each model had as being the best model, (2) evidence ratios based on Akaike weights to indicate the relative probability that any model is the best model, and (3) coefficients of determination (R^2) assessing the explanatory power of each model.

Stock-Recruitment Analysis

We successfully fit stock-recruitment models to the Chiwawa and reference population data. The span of spawner data for the Chiwawa and reference populations was greater than 14 times the minimum observed spawners, which should provide sufficient contrast for estimation of model parameters. In addition, the span of recruitment data was greater than 12 times the minimum observed recruitment, again providing sufficient contrast for estimation of parameters. The relationship between natural log R/S and spawners indicated that some of the highest productivities occurred at the lower spawner levels and the lowest productivities generally occurred at the highest spawner levels (Figure 15). This is consistent with the assumption of density-dependent mortality.

Although model fits were generally poor, explaining less than 40% of the residual variation in natural-log recruitment data, we were able to estimate average maximum recruitment levels (K_R) and the spawning levels needed to produce maximum recruitment (K_{sp}) (Table 24; Figure 15). For all populations examined, Akaike information criterion was unable to identify a best approximating model (i.e., ΔAIC_c values were less than 2, indicating support for all three models). However, evaluation of 95% CIs and the asymptotic correlation coefficients indicated that the smooth hockey stick model may be the best approximating model for each population. Therefore, we used estimates of K_R and K_{sp} derived from the smooth hockey stick model to correct for density dependence and different carrying capacities in treatment-reference comparisons.

As part of the regression diagnostics, we examined the dependence of the model residuals on time and found a significant ($P < 0.05$), positive, one-year-lag autocorrelation for the Entiat (0.562), Marsh (0.551), Sesech (0.564), and Little Wenatchee (0.629) populations. For the purposes of our work here, we did not attempt to correct for this one-year-lag correlation in the residuals. Future analyses will explore the use of autoregressive models (e.g., AR1; Noakes et al. 1987) to correct for autocorrelation.

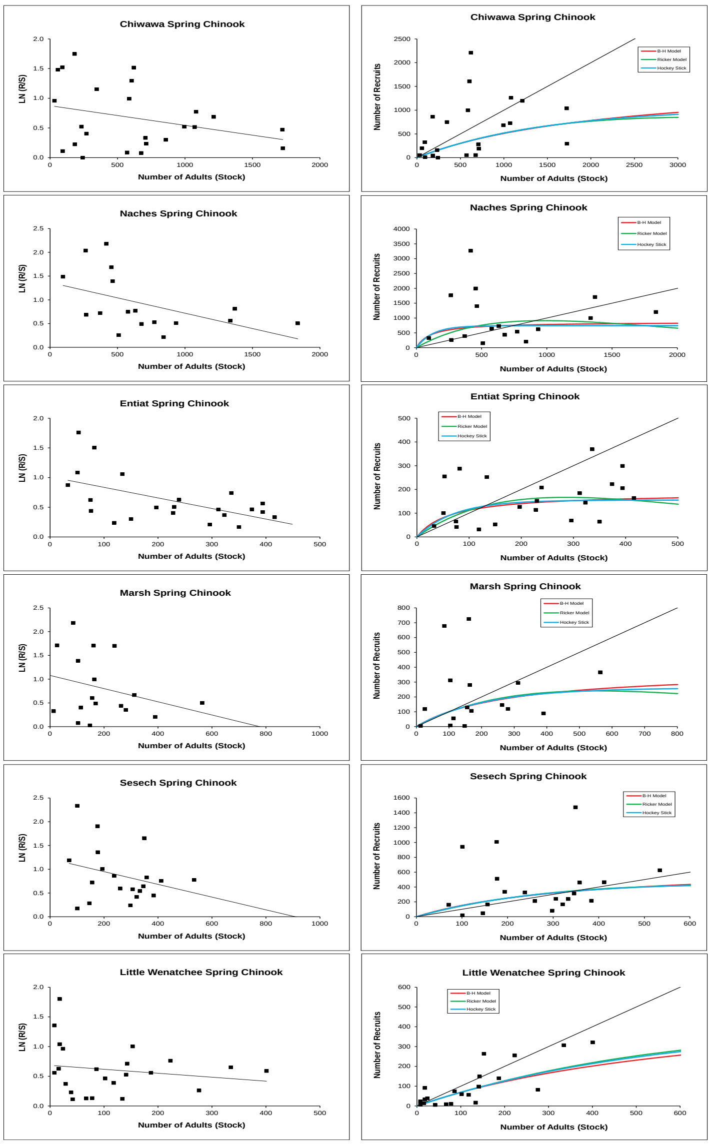

Figure 15. Relationships between natural log recruits/spawner (LN R/S) and spawners (Stock) in the Chiwawa and reference populations (figures on the left) and relationships between numbers of untransformed recruits and spawners in the Chiwawa and reference populations (figures on the right). Figures on the right also show the fit of the Ricker, Beverton-Holt, and the smooth hockey stick models to the data (black straight line represents R=S).

Table 24. Results from fitting Ricker, Beverton-Holt, and smooth hockey stick models to stock-recruitment data from the Chiwawa and reference populations. 95% CI on parameter estimates are based on 3,000 bootstrap trials; Corr coef = asymptotic correlation of the parameter estimates; K_R = maximum natural origin recruits (recruits at carrying capacity); K_{sp} = number of spawners needed to produce K_R; AICc = Akaike's Information Criterion for small sample size; Adj R^2 = coefficient of determination that is adjusted for the number of parameters in the model.

Model	Parameter	Parameter value	Bootstrap 95% CI	Corr coef	K_R	K_{sp}	AICc	Adj R^2
Chiwawa Population								
Ricker	α	0.7048	-0.6197 1.1055	0.791	852	3,285	-47.949	0.125
	β	0.000304	-0.000668 0.000609					
Beverton-Holt	α	1687.4	-65654539 3062.1	0.989	1,687	43,760	-47.962	0.125
	β	2308.5	-99999538 4526.1					
Smooth hockey stick	α	6.956	-41.313 8.2270	-0.708	1,049	6,847	-47.949	0.125
	β	0.7118	-2.397 1.122					
Naches Population								
Ricker	α	2.5223	-2.0003 3.9672	0.844	912	983	-45.063	-0.143
	β	0.001018	-0.000752 0.001717					
Beverton-Holt	α	869.4	97.4 1641.4	0.858	869	11,455	-46.801	-0.097
	β	111.8	-346.2 569.8					
Smooth hockey stick	α	6.612	5.9223 7.006	-0.399	744	565	-46.831	-0.095
	β	6.013	-89.071 12.026					
Entiat Population								
Ricker	α	1.5843	0.1609 2.4178	0.867	167	286	-68.365	-0.049
	β	0.003496	0.001141 0.005906					
Beverton-Holt	α	186.1	67.9 304.3	0.880	186	1,277	-69.895	0.029
	β	65.0	-59.1 189.2					
Smooth hockey stick	α	5.045	4.381 5.378	-0.450	155	344	-69.379	0.003
	β	2.180	-89.369 3.704					
Marsh Creek Population								
Ricker	α	1.1852	-1.8268 1.9269	0.823	241	552	-32.237	0.218

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Model	Parameter	Parameter value	Bootstrap 95% CI	Corr coef	K_R	K_{sp}	AICc	Adj R^2
	β	0.001810	-0.003063 0.003625					
Beverton-Holt	α	383.3	-85109314 665.4	0.970	383	5,310	-32.291	0.234
	β	282.4	-99999944 564.9					
Smooth hockey stick	α	5.565	-22.631 6.584	-0.694	261	984	-32.264	0.227
	β	1.265	-108.574 2.531					
Sesech Population								
Ricker	α	1.6835	-2.9253 2.5951	0.912	421	680	-54.589	-0.005
	β	0.001470	-0.002951 0.002941					
Beverton-Holt	α	689.9	-986.8 2366.7	0.981	690	6,591	-54.678	0.000
	β	351.7	-1059.0 1762.5					
Smooth hockey stick	α	6.1528	-22.851 6.815	-0.821	470	1,185	-54.633	-0.002
	β	0.8000	-119.370 2.909					
Little Wenatchee Population								
Ricker	α	0.7447	0.0828 1.0280	0.735	356	1,298	-66.978	0.357
	β	0.000770	-0.003052 0.001541					
Beverton-Holt	α	564.7	-74423355 1067.6	0.994	565	13,400	-67.055	0.358
	β	719.7	-99999856 1413.4					
Smooth hockey stick	α	6.0181	-49.5620 8.1122	-0.683	411	2,544	-67.000	0.357
	β	0.7550	-0.9539 1.0452					

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Method 1: Productivity Data Adjusted for Density Dependence

Analysis of supplementation effects on productivity (adult recruits/spawner adjusted for density-dependent effects based on the smooth hockey stick model) using difference scores indicated that supplementation did not significantly decrease productivity in the Chiwawa Basin (Table 25; Figure 16). All tests, regardless of treatment-reference pairs, indicated that productivity did not change significantly during the supplementation period, even though productivity did decrease during the supplementation period (Figure 16). These results are consistent with those based on unadjusted productivity data (Table 17). This is because most abundance estimates were below the level of assumed density dependence.

Table 25. Results of the Aspin-Welch unequal-variance test, randomization test (based on 10,000 Monte Carlo samples), and 95% CI (based on 5,000 bootstrap samples) on transformed and untransformed productivity data corrected for density dependence. Tests determined if the mean difference scores during the supplementation period were greater than mean difference scores during the pre-supplementation period.

Reference population	Aspin-Welch unequal-variance test			Randomization test P-value	Bootstrap 95% CI
	t-value	P-value	Effect size		
Productivity					
Naches	0.904	0.190	0.496	0.412	-0.511 – 1.497
Marsh	-0.203	0.579	0.152	0.927	-1.298 – 1.372
Sesech	1.607	0.071	1.435	0.146	-0.359 – 2.911
Little Wenatchee	0.431	0.335	0.147	0.668	-0.487 – 0.781
LN Productivity					
Naches	0.570	0.290	0.083	0.568	-0.168 – 0.362
Marsh	0.012	0.495	0.003	0.991	-0.373 – 0.480
Sesech	1.463	0.087	0.343	0.171	-0.125 – 0.732
Little Wenatchee	0.390	0.351	0.060	0.709	-0.218 – 0.365

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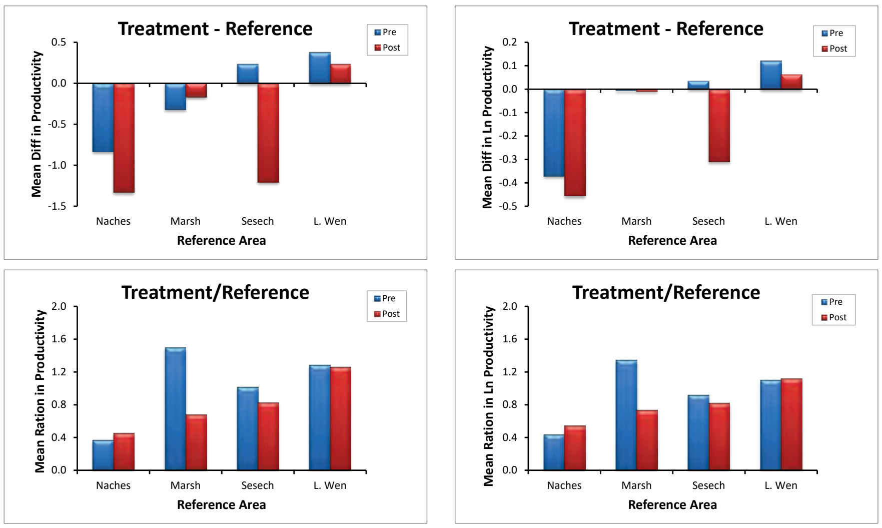

Figure 16. Mean differences (Treatment – Reference; figures on the top) and mean ratios (Treatment/Reference; figures on the bottom) of transformed and untransformed productivity data (adjusted for density dependence) before (pre) and after (post) spring Chinook supplementation in the Chiwawa Basin. Negative effects of supplementation on productivity are indicated when the pre-supplementation (blue) bars are greater than their corresponding post-supplementation (red) bars.

Analysis of supplementation effects on productivity (adult recruits/spawner adjusted for density-dependent effects) using ratios indicated that supplementation did not significantly decrease productivity in the Chiwawa Basin (Table 26; Figure 16). The Aspin-Welch test and the 95% CIs did indicate a significant effect when comparing the Chiwawa to the Marsh Creek population. These results are consistent with those using unadjusted productivity data (Table 20). Again, this is because most abundance estimates were below the level of assumed density dependence.

Table 26. Results of the Aspin-Welch unequal-variance test, randomization test (based on 10,000 Monte Carlo samples), and 95% CI (based on 5,000 bootstrap samples) on transformed and untransformed productivity data corrected for density dependence. Tests determined if the mean ratios during the supplementation period were less than mean ratios during the pre-supplementation period.

Reference population	Aspin-Welch unequal-variance test			Randomization test P-value	Bootstrap 95% CI
	t-value	P-value	Effect size		
			Productivity		
Naches	-0.529	0.696	0.087	0.597	-0.394 – 0.214
Marsh	2.236	0.022	0.814	0.056	0.140 – 1.470
Sesech	0.677	0.253	0.191	0.496	-0.343 – 0.727
Little Wenatchee	0.033	0.487	0.018	0.978	-0.902 – 1.181
			LN Productivity		
Naches	-0.621	0.726	0.104	0.536	-0.406 – 0.191

Reference population	Aspin-Welch unequal-variance test			Randomization test P-value	Bootstrap 95% CI
	t-value	P-value	Effect size		
Marsh	1.952	0.036	0.613	0.076	0.005 – 1.163
Sesech	0.447	0.330	0.098	0.649	-0.312 – 0.498
Little Wenatchee	-0.034	0.513	0.015	0.980	-0.697 – 0.852

Our analyses assume that there is a spawner abundance (K_{sp}) at which density-independent effects end and density-dependent effects begin. In reality, density-dependent effects occur at low spawning abundance and intensify as spawning abundance increases (evident in the changing slope of the three stock-recruitment curves used in our analyses). We did not account for these increasing density-dependent effects at spawner abundances less than K_{sp}. If we accounted for the increasing effects of density dependence at spawning abundances less than K_{sp}, the analysis with and without productivity adjustments may give different results.

Method 2: Fraction of Carrying Capacity Filled with NORs

We analyzed the effects of supplementation on filling the capacity of the habitat with natural-origin recruits. The smooth hockey stick model derived the carrying capacity (K_R) estimates for the Chiwawa and reference populations. The fraction of the carrying capacity filled with Chinook recruits before and during supplementation for the Chiwawa and reference populations is provided in Table 27. These data indicate that for the Chiwawa population, the mean fraction of the K_R filled with fish decreased significantly from the pre-supplementation period through the supplementation period (Table 27). Likewise, the Entiat and Little Wenatchee populations showed a significant decline in the mean fraction of K_R filled with adult recruits. In contrast, the mean fraction of K_R in the Naches and Marsh Creek populations increased during the same period (Table 27).[21] Interestingly, the fraction of K_R filled with adult recruits for all populations trended downward during the pre-supplementation period (Figure 17). During the supplementation period, however, the fraction of K_R filled with adult recruits trended upward for all populations. These results suggest that agents of mortality outside the Chiwawa and reference populations were reducing recruitment to the populations.

[21] Although we do not show the results here, statistical analysis of the mean fraction of carrying capacity filled by adult recruits using natural-log transformed data produced the same result as using untransformed data. This was true for all populations.

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Table 27. Fraction of the carrying capacity that was filled with Chinook salmon adult recruits in the Chiwawa and reference populations before (pre) and during (post) supplementation in Chiwawa Basin. The smooth hockey stick model estimated carrying capacity for each population. Statistical results from comparing the pre and post mean scores using the Aspin-Welch unequal-variance test are provided at the bottom of the table.

Supplementation period	Chiwawa	Reference populations			
		Naches	Entiat	Marsh	L. Wenatchee
Pre-supplementation period (1981-1992)	2.11		2.38	1.07	0.64
	1.53		1.93	1.20	0.75
	1.20		1.32	2.60	0.78
	1.14		1.19	0.49	0.62
	0.99		1.06	0.46	0.34
	0.70	2.30	1.43	0.56	0.24
	0.65	0.58	0.74	0.34	0.20
	0.95	1.88	1.34	1.40	0.36
	0.18	0.72	1.63	0.22	0.15
	0.05	0.27	0.45	0.02	0.02
	0.00	0.20	0.21	0.03	0.01
Pre-Mean:	0.86	0.99	1.24	0.76	0.37
Pre-Range:	0.00 – 2.11	0.20 – 2.30	0.21 – 2.38	0.02 – 2.60	0.01 – 0.78
Post-supplementation period (1992-2002)	0.05	0.98	0.34	0.41	0.03
	0.15	0.86	0.41	1.13	0.04
	0.04	0.35	0.27	0.02	0.03
	0.05	0.44	0.30	0.02	0.03
	0.19	4.39	0.65	0.45	0.06
	0.82	2.68	1.85	2.78	0.22
	0.31	2.37	1.65	4.10	0.08
	0.01	0.53	0.42		0.02
	0.71	1.62	0.82		0.10
	0.28	1.35	0.93		0.14
	0.27	0.83	0.98		0.18
Post-Mean:	0.26	1.49	0.78	1.27	0.08
Post-Range:	0.04 – 0.82	0.35 – 4.39	0.30 – 1.85	0.02 – 4.10	0.02 – 0.22
One-sided Aspin-Welch t-test of pre and post means	t = 2.846; P = 0.007	t = -0.967; P = 0.825	t = 1.833; P = 0.041	t = -0.799; P = 0.776	t = 3.321; P = 0.003

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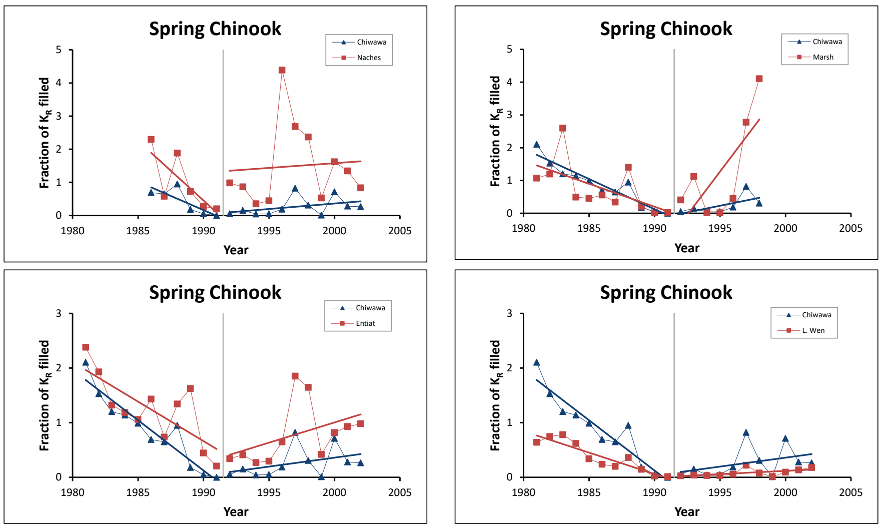

Figure 17. Trends in the fraction of the carrying capacity that was filled with Chinook salmon adult recruits in the Chiwawa and reference populations before (pre) and during (post) supplementation in Chiwawa Basin. The vertical lines in the figures separate the pre- and post-supplementation periods. The smooth hockey stick model estimated carrying capacity for each population.

We then compared the mean difference scores and ratios between the Chiwawa and reference populations before and during supplementation using data representing the fraction of K_R filled with adult recruits. In most of the Chiwawa-reference population comparisons, the absolute value of the mean difference between the fraction of K_R filled with recruits was greater in the supplementation period than during the pre-supplementation period; two of the four pairings were significant (Table 28; Figure 18). Analysis of difference scores using natural-log transformed data indicated that three of the four pairings were significant (Table 28).

Results from analyses using ratios were similar to results using difference scores. Mean ratio scores were generally smaller during the supplementation period than during the pre-supplementation period (Figure 18). This indicated that the mean fraction of K_R filled by adult recruits in most reference populations was greater during the supplementation period than during the pre-supplementation period (i.e., the denominator in the ratio increased between the pre- and post-supplementation periods). In contrast, the fraction of K_R filled by adult recruits in the Chiwawa decreased from the pre- to post-supplementation period (i.e., the numerator in the ratio decreased between the pre- and post-supplementation periods). Thus, unlike the Chiwawa population, the capacity of most reference populations was becoming more saturated during the period when the Chiwawa was being supplemented. Statistical analysis with mean ratios indicated that two of the four pairings were significant (Table 29).

Analyses comparing the Little Wenatchee with the Chiwawa indicate that adult recruits to the Little Wenatchee have been well below its carrying capacity. During the pre-supplementation period, the capacity of the Little Wenatchee was on average 37% saturated with adult recruits. During the supplementation period, the capacity of the Little Wenatchee declined to 8% saturation

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with adult recruits (a 22% decline). The Chiwawa, during the pre-supplementation period, was on average 86% saturated. During the supplementation period, percent saturation in the Chiwawa decreased to 26% (a 30% decrease). During the same time periods, the capacity of the Entiat population, which until recently has been supplemented, declined from 124% to 78% saturation (a 63% decline).

Table 28. Results of the Aspin-Welch unequal-variance test, randomization test (based on 10,000 Monte Carlo samples), and 95% CI (based on 5,000 bootstrap samples) on the fraction of the habitat capacity (K_R) that is filled with natural origin recruits. Analyses include both transformed and untransformed data. Tests determined if the mean difference scores during the supplementation period were greater than mean difference scores during the pre-supplementation period.

Reference population	Aspin-Welch unequal-variance test			Randomization test	Bootstrap 95% CI
	t-value	P-value	Effect size	P-value	
Fraction of Capacity Filled					
Naches	1.550	0.071	0.657	0.145	-0.173 – 1.378
Entiat	0.835	0.207	0.141	0.422	-0.167 – 0.475
Marsh	2.026	0.040	1.141	0.055	0.064 – 2.054
Little Wenatchee	2.166	0.023	0.310	0.031	0.035 – 0.569
LN Fraction of Capacity Filled					
Naches	2.123	0.026	0.311	0.039	0.031 – 0.575
Entiat	1.405	0.087	0.122	0.176	-0.034 – 0.289
Marsh	2.547	0.017	0.519	0.017	0.125 – 0.864
Little Wenatchee	1.744	0.049	0.130	0.100	-0.004 – 0.273

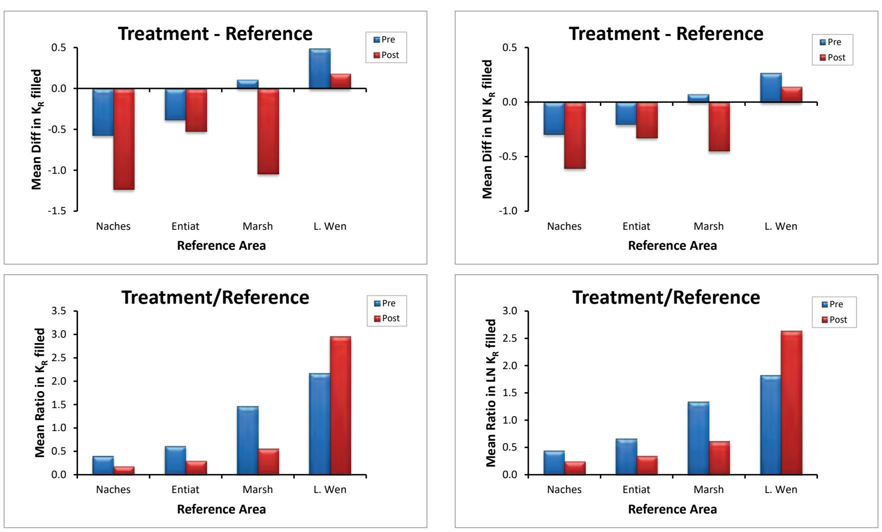

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Figure 18. Mean differences (Treatment – Reference; figures on the top) and mean ratios (Treatment/Reference; figures on the bottom) of transformed and untransformed fractions of carrying capacity filled with adult recruits before (pre) and after (post) spring Chinook supplementation in the Chiwawa Basin.

Table 29. Results of the Aspin-Welch unequal-variance test, randomization test (based on 10,000 Monte Carlo samples), and 95% CI (based on 5,000 bootstrap samples) on the fraction of the habitat capacity (K_R) that is filled with natural origin recruits. Analyses include both transformed and untransformed data. Tests determined if the mean ratios during the supplementation period were less than mean ratios during the pre-supplementation period.

Reference population	Aspin-Welch unequal-variance test			Randomization test P-value	Bootstrap 95% CI
	t-value	P-value	Effect size		
Fraction of Capacity Filled					
Naches	1.317	0.119	0.217	0.219	-0.103 – 0.482
Entiat	2.449	0.013	0.321	0.028	0.085 – 0.577
Marsh	2.001	0.035	0.905	0.070	0.138 – 1.788
Little Wenatchee	-1.148	0.864	0.791	0.278	-1.979 – 0.578
LN Fraction of Capacity Filled					
Naches	1.257	0.127	0.207	0.249	-0.099 – 0.484
Entiat	2.346	0.016	0.313	0.031	0.072 – 0.583
Marsh	1.737	0.056	0.729	0.111	0.028 – 1.531
Little Wenatchee	-1.525	0.924	0.815	0.142	-1.751 – 0.195

Comparing Stock-Recruitment Curves

As a final set of treatment and reference population comparisons, we compared the stock-recruitment curves of the Chiwawa population (using {R, S} data only from the supplementation period) to the reference populations (using all available {R, S} data). Specifically, we tested whether the regression parameters were equal between the Chiwawa population and the reference populations, and whether the fitted curves coincided between populations. Earlier in this report we described the data, methods, and results of fitting the Ricker, Beverton-Holt, and smooth hockey stick curves to the data. Because AIC_c was unable to identify a best approximating model, here we included all three models in our analyses. We tested the following hypotheses.

Parameter equivalence:

Ho: Stock-recruitment parameters (α and β) of the Chiwawa population = Stock-recruitment parameters of the reference populations.

Ha: Stock-recruitment parameters (α and β) of the Chiwawa population ≠ Stock-recruitment parameters of the reference populations.

Curve equivalence:

Ho: Modeled stock-recruitment curves of the Chiwawa population = Modeled stock-recruitment curves of the reference populations.

Ha: Modeled stock-recruitment curves of the Chiwawa population ≠ Modeled stock-recruitment curves of the reference populations.

We used two-sided randomization tests to test the null hypotheses of equal model parameters and that fitted curves coincided. Because the total number of permutations was in the millions, we used a Monte Carlo approach to randomly select 10,000 permutations. The test statistic for comparing the model parameters was formed by summing the difference between the population parameter estimates for each pair of populations. The test statistic for comparing the whole curve was formed by summing the difference between the estimated predicted values for each pair of populations at 500 equally spaced points along the curve.

Ricker Relationships

Ricker curves differed significantly between the Chiwawa and reference populations (Figure 19; Table 30). Interestingly, however, the parameters in the Ricker model did not differ significantly among most populations (Table 30). Only the β parameter differed significantly between the Chiwawa and Entiat populations.

In the Ricker model, the α parameter represents intrinsic productivity (i.e., recruits per spawner at low spawner densities). In this analysis, there was not enough evidence in the stock-recruitment data to reject the hypothesis of inequality in intrinsic productivity. Thus, this test was unable to demonstrate that supplementation, based on the Ricker curve, affected productivity in the Chiwawa population.

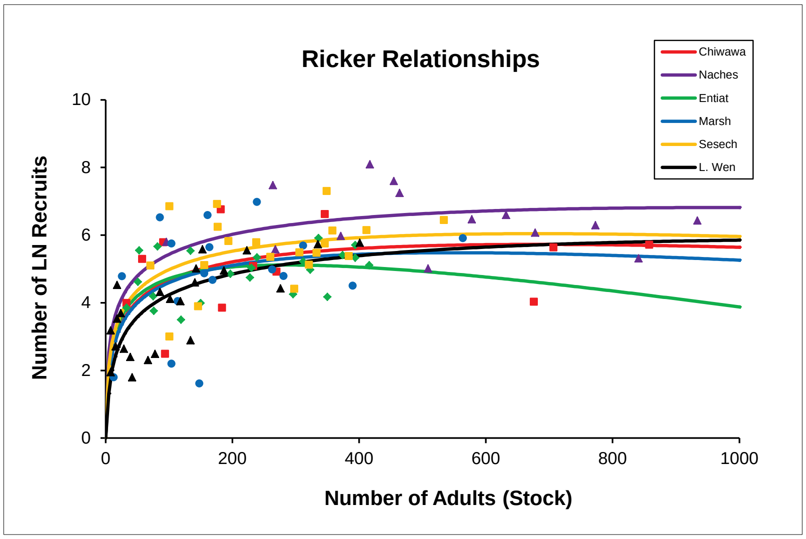

Figure 19. Scatter plot of the number of spawners and natural log adult recruits and fitted Ricker curves to the Chiwawa (supplemented population) and reference (un-supplemented) populations.

Table 30. Randomization test results comparing the equality of Ricker curves and equality of parameter values (α and β). Randomization tests were based on 10,000 Monte Carlo samples. Equality or curves was based on 500 points along the x-axis (spawner abundance axis).

Curves tested	Curve inequality randomization P-value	Parameter inequality		
		Model Parameter		Randomization P-value
		Chiwawa	Reference	
Chiwawa v. Naches	0.008	$\alpha = 1.2247$	$\alpha = 2.5267$	0.236
		$\beta = 0.0015$	$\beta = 0.0010$	0.600
Chiwawa v. Entiat	0.004	$\alpha = 1.2247$	$\alpha = 1.5836$	0.978
		$\beta = 0.0015$	$\beta = 0.0035$	0.025
Chiwawa v. Marsh	0.034	$\alpha = 1.2247$	$\alpha = 1.1855$	0.997
		$\beta = 0.0015$	$\beta = 0.0018$	0.688
Chiwawa v. Sesech	0.036	$\alpha = 1.2247$	$\alpha = 1.6818$	0.972
		$\beta = 0.0015$	$\beta = 0.0015$	0.997
Chiwawa v. L. Wenatchee	0.034	$\alpha = 1.2247$	$\alpha = 0.7439$	0.969
		$\beta = 0.0015$	$\beta = 0.0008$	0.203

Beverton-Holt Relationships

Beverton-Holt curves differed significantly only between the Chiwawa and Naches populations (Figure 20; Table 31). There was no significant difference in curves between the Chiwawa and the other reference populations. The parameters in the Beverton-Holt model did not differ significantly among any of the populations (Table 31). This was true even for the Chiwawa and Naches populations.

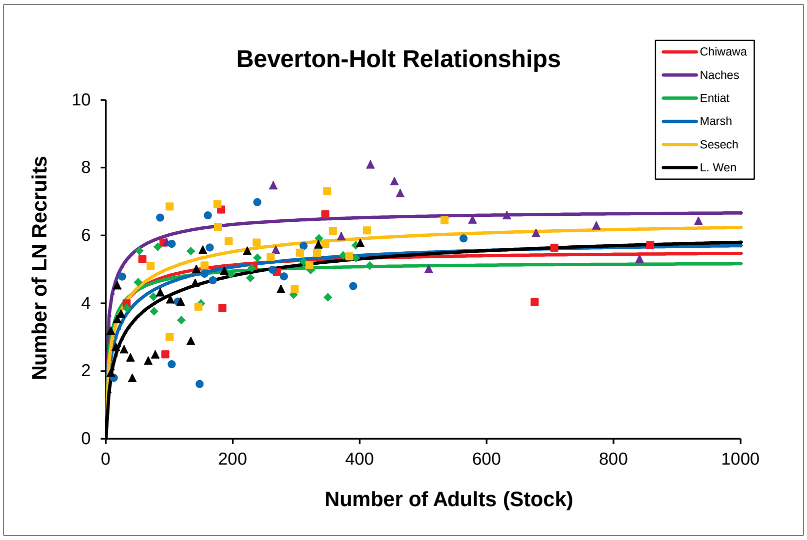

Figure 20. Scatter plot of the number of spawners and natural log adult recruits and fitted Beverton-Holt curves to the Chiwawa (supplemented population) and reference (un-supplemented) populations.

Table 31. Randomization test results comparing the equality of Beverton-Holt curves and equality of parameter values (α and β). Randomization tests were based on 10,000 Monte Carlo samples. Equality or curves was based on 500 points along the x-axis (spawner abundance axis).

Curves tested	Curve inequality randomization P-value	Parameter inequality		
		Model Parameter		Randomization P-value
		Chiwawa	Reference	
Chiwawa v. Naches	0.036	α = 264.25	α = 870.62	0.777
		β = 113.79	β = 112.24	0.963
Chiwawa v. Entiat	0.746	α = 264.25	α = 186.34	0.960
		β = 113.79	β = 65.33	0.954
Chiwawa v. Marsh	0.850	α = 264.25	α = 381.79	0.944
		β = 113.79	β = 281.04	0.891

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Curves tested	Curve inequality randomization P-value	Parameter inequality		
		Model Parameter		Randomization P-value
		Chiwawa	Reference	
Chiwawa v. Sesech	0.272	α = 264.25	α = 689.31	0.821
		β = 113.79	β = 351.59	0.869
Chiwawa v. L. Wenatchee	0.654	α = 264.25	α = 568.69	0.864
		β = 113.79	β = 725.87	0.751

Smooth Hockey Stick Relationships

Smooth hockey stick curves differed significantly between the Chiwawa and Naches populations and the Chiwawa and Sesech populations (Figure 21; Table 32). There was no significant difference in curves between the Chiwawa and the other reference populations. Most of the parameters in the smooth hockey stick model did not differ significantly among the populations (Table 32). However, the productivity parameter β did differ significantly between the Chiwawa and the Naches and the Chiwawa and Little Wenatchee populations. The β parameter for the Naches was significantly greater than the Chiwawa, while the β parameter for the Little Wenatchee was significantly less than the Chiwawa.

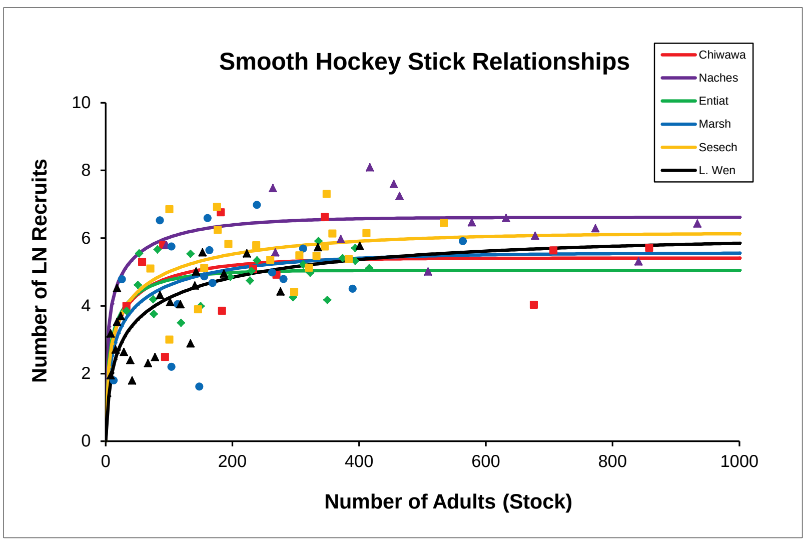

Figure 21. Scatter plot of the number of spawners and natural log adult recruits and fitted smooth hockey stick curves to the Chiwawa (supplemented population) and reference (un-supplemented) populations.

Table 32. Randomization test results comparing the equality of smooth hockey stick curves and equality of parameter values (α and β). Randomization tests were based on 10,000 Monte Carlo samples. Equality or curves was based on 500 points along the x-axis (spawner abundance axis).

Curves tested	Curve inequality randomization P-value	Parameter inequality		
		Model Parameter		Randomization P-value
		Chiwawa	Reference	
Chiwawa v. Naches	0.000	α = 5.41	α = 6.61	0.000
		β = 1.84	β = 5.99	0.000
Chiwawa v. Entiat	0.999	α = 5.41	α = 5.05	0.999
		β = 1.84	β = 2.17	0.999
Chiwawa v. Marsh	0.999	α = 5.41	α = 5.56	0.999
		β = 1.84	β = 1.27	0.999
Chiwawa v. Sesech	0.000	α = 5.41	α = 6.15	0.000
		β = 1.84	β = 1.80	0.999
Chiwawa v. L. Wenatchee	0.990	α = 5.41	α = 6.02	0.999
		β = 1.84	β = 0.75	0.000

Comparing different stock-recruitment curves and their parameters did not provide strong evidence that the supplementation program has negatively affected the productivity of the Chiwawa population.

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Analysis without Reference Populations

In some cases, suitable reference populations may not exist to compare with supplemented populations. It is therefore important to have alternative analyses to assess supplementation effects. In this section, we describe methods that can be used to assess supplementation effects when suitable reference populations are not available. We discuss before-after comparisons, correlation analysis, and comparisons to standards as alternatives when reference populations are unavailable.

Before-After Comparisons

Before-after analyses compare population metrics (spawner abundance, NORs, and productivity) before supplementation to those during supplementation. In this case, data collected before supplementation represent the reference condition. The assumption is that population trajectories measured during the pre-supplementation period would continue in the absence of supplementation. We compared trends in abundance and productivity, mean abundance and productivity, and stock-recruitment relationships before and after supplementation.

Trend Analysis

Comparing trends before and after supplementation can be used to assess the effects of supplementation. Here, we compared the slopes of trends of spawner abundance, NORs, and productivity before and during supplementation using t-tests. If the hatchery program is successfully supplementing the natural spring Chinook population, the trend for spawner abundance and NORs during supplementation should be greater than the slope during the pre-supplementation period. For productivity, the slope during the supplementation period should increase or remain the same as that during the pre-supplementation period.

Visual examination of trends of Chiwawa data indicates that spawner abundance, NORs, and productivity decreased during the pre-supplementation period, but increased during the supplementation period (Figure 22). Only the changes in NOR trends were significant (Figure 22). This was true for both transformed and untransformed data.

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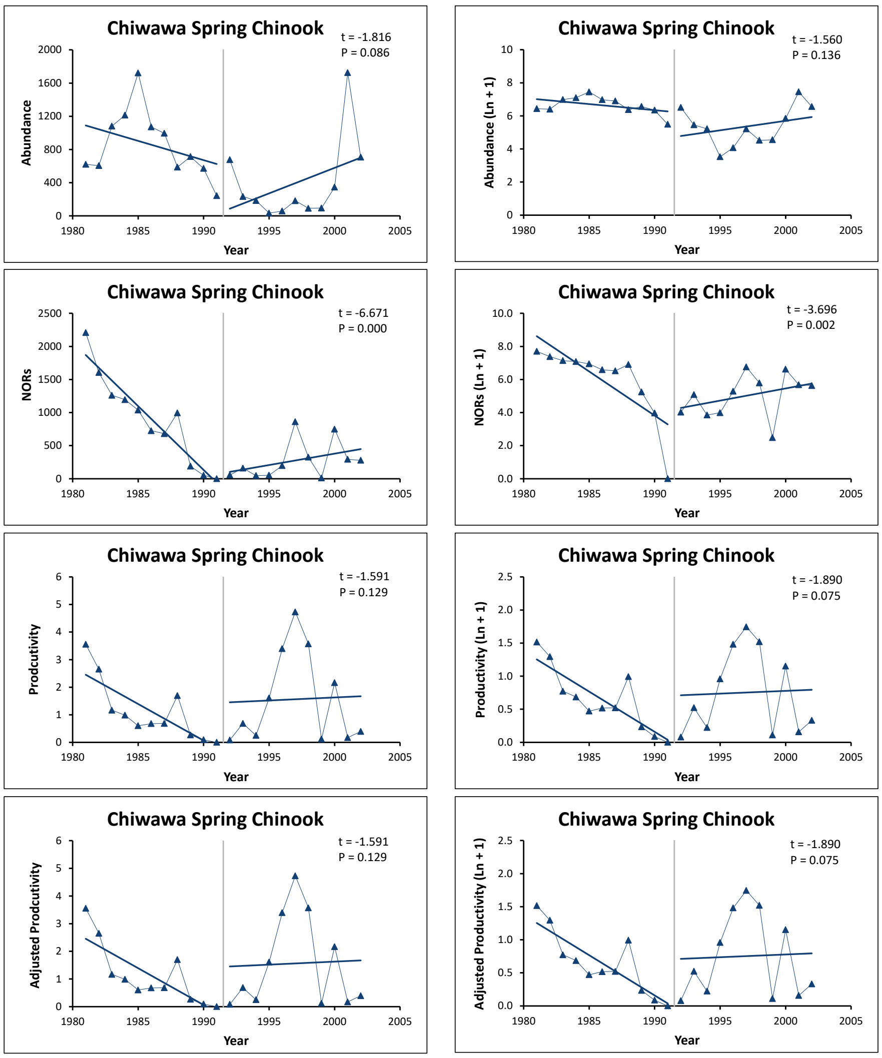

Figure 22. Trends in Chiwawa spring Chinook spawner abundance, natural-origin recruits (NORs), productivity (adults recruits per spawner), and adjusted productivity (adjusted for density dependence) before and during supplementation. The vertical lines in the figures separate the pre- and post-supplementation periods. Figures on the left show untransformed data; figures on the right include natural-log transformed data. Figures include results of t-tests comparing slope of trends before and during supplementation.

Analysis of Mean Scores

We also compared mean spawner abundance, NORs, and productivity data before and after supplementation. If the hatchery program is successfully supplementing the natural spring Chinook population, mean spawner abundance and NORs during the supplementation period should be greater than the pre-supplementation period. For productivity, the mean productivity during the supplementation period should be equal to or higher than the pre-supplementation period. We tested the following statistical hypotheses.

Spawner Abundance and NORs:

Ho: Mean spawner abundance and NORs before supplementation ≥ Mean spawner abundance and NORs during supplementation.

Ha: Mean spawner abundance and NORs before supplementation < Mean spawner abundance and NORs during supplementation.

Productivity (Recruits/Spawner):

Ho: Mean productivity before supplementation ≤ Mean productivity during supplementation.

Ha: Mean productivity before supplementation > Mean productivity during supplementation.

We tested before-after supplementation effects using a one-tailed Aspin-Welch unequal-variance test. We also used a randomization test, based on 10,000 Monte Carlo simulations, to assess differences in spawner abundance and productivity before and during supplementation. The randomization procedure only allowed the testing of two-tailed hypotheses. Therefore, we generated 95% confidence intervals on the mean difference (μ_{pre} - μ_{post}) using bootstrapping methods to determine if the significant result from the randomization test was in the right direction. We generated 5,000 bootstrap samples to calculate confidence intervals.

Mean spawner abundance during the supplementation period was significantly less than the pre-supplementation spawner abundance (Table 33). Mean spawner abundance decreased 46% between the pre- and post-supplementation periods. Likewise, mean NORs decreased significantly between the two periods (Table 33). On the other hand, productivity increased slightly, but not significantly, between the pre- and post-supplementation periods (Table 33). This was true for both adjusted and transformed productivity data.

Table 33. Statistical results comparing mean scores of spawner abundance, natural-origin recruits (NORs), and productivity (using both untransformed and natural-log transformed) before and during supplementation of Chiwawa spring Chinook. Randomization tests were based on 10,000 Monte Carlo samples and 95% CI were based on 5,000 bootstrap samples.

Population metric	Mean scores		Test on means			
			Aspin-Welch test		Random test P-value	Bootstrap 95% CI
	Before	During	t-value	P-value		
Abundance	856	393	2.383	0.986	0.028	112 - 843
LN Abundance	6.6	5.4	3.304	0.997	0.004	0.56 – 1.99
NORs	905	275	2.846	0.993	0.009	214 – 1034
LN NORs	6.0	5.0	1.197	0.876	0.250	-0.40 – 2.54
Productivity	1.13	1.56	-0.721	0.759	0.479	-1.55 – 0.73
LN Productivity	0.64	0.75	-0.450	0.671	0.649	-0.55 – 0.35
Adj Productivity	1.12	1.56	-0.721	0.759	0.477	-1.54 – 0.71
LN Adj Productivity	0.64	0.75	-0.450	0.671	0.652	-0.57 – 0.34

Analysis of Stock-Recruitment Curves

The third method compared stock-recruitment curves of the Chiwawa population during supplementation with those generated before supplementation. Specifically, we tested whether the regression parameters were equal between the pre- and post-supplementation periods, and whether the fitted curves coincided between the two time periods. We used the methods described earlier to fit the Ricker, Beverton-Holt, and smooth hockey stick curves to the two data sets. We tested the following hypotheses.

Parameter equivalence:

Ho: Stock-recruitment parameters (α and β) of the pre-supplementation period = Stock-recruitment parameters of the supplementation period.

Ha: Stock-recruitment parameters (α and β) of the pre-supplementation period ≠ Stock-recruitment parameters of the supplementation period.

Curve equivalence:

Ho: Modeled stock-recruitment curves from the pre-supplementation period = Modeled stock-recruitment curves from the pre-supplementation period.

Ha: Modeled stock-recruitment curves from the pre-supplementation period ≠ Modeled stock-recruitment curves from the pre-supplementation period.

We were only able to fit stock-recruitment curves to the post-supplementation data. Non-linear regression was unable to converge on a solution using only pre-supplementation data. Therefore, we were unable to use this method to test supplementation effects on the Chiwawa spring Chinook population. If we could have fit curves to both the pre- and post-supplementation periods, we would have used two-sided randomization tests to evaluate the null hypotheses of equal model parameters and that fitted curves coincided.

Before describing correlation approaches, it is important to note that comparing before-after data can sometimes be misleading. For example, the spawner abundance, NORs, and productivity data presented in Figure 22 suggest that supplementation is increasing the abundance and productivity of spring Chinook in the Chiwawa Basin. However, when we compared these trends to those from reference populations during the same time periods (Figures 9-11), it becomes clear that supplementation was not responsible for increasing the trends in spawner abundance, NORs, and productivity of the Chiwawa population. Thus, whenever possible, it is wise to compare before-after data with a reference population.

Correlation Analyses

A simple way to see if the supplementation program is increasing or decreasing productivity is to assess the association between the proportion of adult spawners that are made up of hatchery adults (pHOS) and productivity (recruits/spawner). If the supplementation program is working as planned, the increase in hatchery fish spawning naturally should increase the productivity of the population. It should not decrease the productivity of the population.

We tested the association between pHOS and adult productivity[22] using Pearson correlation. During the pre-supplementation period, productivity averaged 1.13 recruits/spawner; during the supplementation period, productivity averaged 1.39 recruits/spawner. This increase in productivity did not appear to be strongly correlated to pHOS (Figure 23). Correlation analysis showed that there was no significant association between pHOS and productivity, even though productivity increased with increasing pHOS.

[22] Note that the analysis could also include juvenile productivity (e.g., smolts/spawner).

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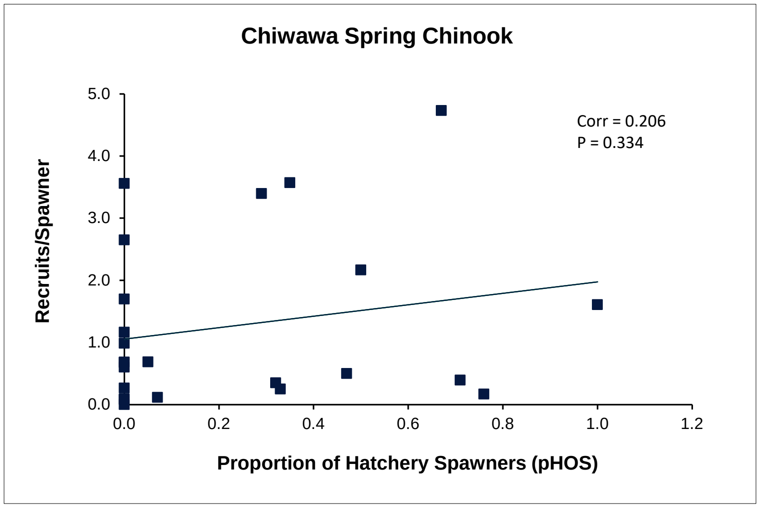

Figure 23. Association between the proportion of spawners that are made up of hatchery adults (pHOS) and the number of natural-origin recruits. The Pearson correlation coefficient (Corr) and its P-value (P) are shown in the figure.

The association between pHOS and productivity can also be assessed by testing the correlation between pHOS and the residuals from stock-recruitment curves fitted to the Chiwawa spawner and natural-origin recruitment data. This approach removes the effects of density dependence on the relationship between pHOS and productivity. A significant negative association provides evidence that hatchery-origin spawners may not be as productive as natural-origin spawners.

The Ricker, Beverton-Holt, and smooth hockey stick models were fit to the Chiwawa stock and recruitment data (including {S, R} data from both the pre- and post-supplementation period, 1981-2004) using methods described earlier. Residuals were calculated by subtracting the predicted recruitment values from the observed (modeled) values. Pearson correlation then tested the association between pHOS and the residuals from each model.

Although there was a negative trend in residuals with increasing pHOS, suggesting that hatchery-origin spawners may not be as productive as natural-origin spawners, the association was not significant (Figure 24). Thus, based on these analyses, there is no strong evidence that the supplementation program has significantly benefited or harmed the natural spring Chinook population.

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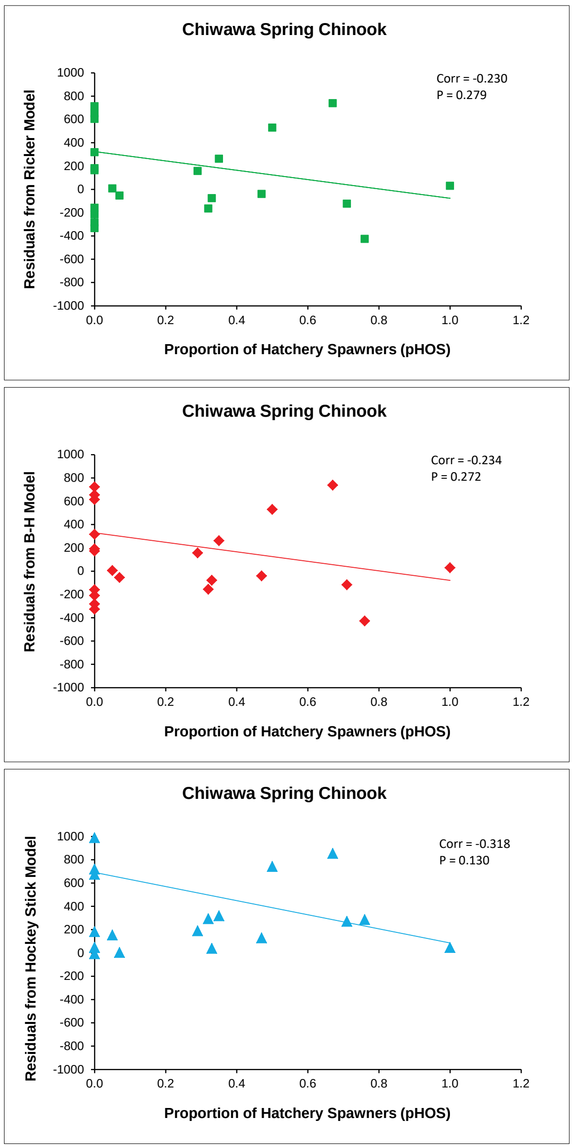

Figure 24. Association between the proportion of spawners that are made up of hatchery adults (pHOS) and the residuals from Ricker, Beverton-Holt (B-H), and smooth hockey stick stock-recruitment models. The Pearson correlation coefficient (Corr) and its P-value (P) are shown in the figures.

Comparison to Standards

In those cases in which suitable reference populations are not available and there are no pre-supplementation data, the investigator is left with comparing population parameters to relevant standards. Standards can include performance of natural-origin fish in similar environments (a type of reference condition), mitigation requirements, quantitative objectives of the program, Biological Assessment and Management Plan (BAMP) values, or other appropriate standards. An example of a statistical hypothesis would be:

Ho: Productivity (Recruits/Spawner) of the supplemented population $\geq$ standard productivity.

Ha: Productivity (Recruits/Spawner) of the supplemented population < standard productivity.

For these analyses to be useful, the standards must be based on biological reality.

Conclusions and Recommendations

Hatcheries are an important component of fish production within the Upper Columbia Basin. The goal of some of these programs is to supplement natural production in declining populations. The supplementation programs generally use both hatchery and natural (spawned and reared in nature from either wild or hatchery parents) adults for hatchery broodstock. These programs are designed to supplement natural populations by increasing natural reproduction while preventing the establishment of a domesticated hatchery stock. Thus, the programs should increase total spawning escapement and NORs, and not reduce the productivity of the natural population. Measuring the success of these programs is challenging and expensive.

In this paper, we described methods that can be used to determine if supplementation programs are achieving some of their goals. This paper focused on the use of reference populations to determine if the supplementation programs increase total spawning escapement, NORs, and maintain or increase productivities. In some cases, suitable reference populations may not be available (e.g., we found no suitable reference populations for Upper Columbia steelhead and sockeye). In these cases, alternative methods are needed to assess supplementation effects. We also described these alternative methods in this paper.

Identification of Reference Populations

Finding suitable reference populations that match well with supplemented populations is a difficult and time-consuming process. Our three-step selection process included identification of populations with similar life-history characteristics, few or no hatchery spawners, a long time series of accurate abundance and productivity estimates, and similar freshwater habitat impairments and out-of-basin effects. Those populations that met these criteria were then examined for their relationship with the supplemented population (in this case, the Chiwawa spring Chinook population). Several criteria were scored, including pNOS, correlation, trend, and effect size. Reference populations with total weighed scores of 81 or greater were selected as suitable reference populations.

This selection process provided a valuable framework for selecting suitable reference populations for supplemented populations. Interestingly, we found that a given reference population may match well with one parameter of the supplemented population (e.g., spawning escapement), but not for all parameters (e.g., not NORs or productivity). The reason for this may be related to errors in the estimation of population parameters and/or differential factors limiting population parameters of supplemented and reference populations. Therefore, depending on the parameter analyzed, a different suite of reference populations may be needed.

An important assumption in the use of reference populations is that the supplemented and reference populations that tracked each other before supplementation would continue to track each other in the absence of supplementation. Given that the reference populations did not match the Chiwawa population on all criteria examined, and some reference populations tracked the Chiwawa population more poorly than others, there may be some uncertainty as to whether differences observed between the supplemented and reference populations during the supplementation period are associated with the hatchery program, or other unaccounted factors. For example, any large-scale change (man-made or natural) within the reference or supplemented population could affect our ability to assess the effectiveness of the supplementation program.

To account for some of these uncontrollable factors, we recommend the use of a “causal-comparative” approach to strengthen the certainty of our inferences. This approach relies on correlative data to try and make a case for causal inference. We recommend that the following state variables be measured and tracked within the supplemented and reference populations: mean annual precipitation, total and riparian forest cover, road density, impervious surface, and alluvium. These variables can be used to describe differences in water temperatures at different life stages (pre-spawning, egg incubation, and summer rearing) and substrate characteristics, including fine sediments and embeddedness. These state variables can be used to help explain possible changes in spawner abundance, NORs, and productivity that are independent of supplementation. In addition, the use of multiple reference streams reduces the possibility that man-made changes to a single reference stream will influence the interpretation of the results.

Analyses with Reference Populations

Using reference populations, we evaluated the effects of supplementation on natural-log transformed and untransformed total spawning escapement, NORs, and productivity by comparing trends, analyzing mean differences, ratios, and rates, and comparing stock-recruitment curves and their parameters. For trend analysis, we compared the slopes of the trends between each supplemented/reference pair before and during supplementation. If the hatchery program is successfully supplementing the natural population, trends in spawner abundance and NORs should deviate significantly during the supplementation period (i.e., the slope of the supplemented population should be greater than the slopes of the reference populations during the supplementation period), but not during the pre-supplementation period. For productivity, the slope of the supplemented population, relative to the reference population, should increase or remain the same.

Because trend analysis only tests the slopes of the trend lines, it does not test for differences in elevations of the trend lines, additional analyses were needed to determine if supplementation increased spawner abundance, NORs, and productivity of the target population without changing the slopes of the trend lines. To do this, we derived three different response variables using natural-log transformed and untransformed spawner abundance, NORs, and productivity data. The first derived variable included difference scores, which were calculated as the difference between paired treatment and reference data (T-R). The second included ratios, which were calculated as the ratio of paired treatment and reference data (T/R). Finally, we calculated the differences in annual changes in paired treatment and reference population data (ΔT-ΔR). If the hatchery program is successfully supplementing the natural population, the mean difference or ratio score of paired spawner abundance data and NORs during the supplementation period should be greater than the pre-supplementation period. For productivity, the mean difference or ratio score during the supplementation period should be equal to or higher than the pre-supplementation period.

As a final set of analyses, we compared the stock-recruitment curves of the supplemented population (using stock and recruitment data only from the supplementation period) to the reference populations (using all available stock and recruitment data). Specifically, we tested whether the regression parameters were equal between the supplemented population and the reference populations, and whether the fitted curves coincided between populations. Here, we were most interested in comparing the productivity parameters in the models.

Surprisingly, these different analyses yielded similar results when they were applied to the Chiwawa spring Chinook and reference population data. Trend analysis was unable to detect a significant difference in trends between the supplemented and reference populations during the supplementation period. Even though we measured an increasing trend in spawner abundance, NORs, and productivity in the supplemented population during the supplementation period, these same parameters trended upward in the reference populations. Likewise, we were unable to detect a significant supplementation effect using difference scores, ratios, and differences in annual changes. However, we found the results from analysis of mean differences of annual change difficult to interpret and they may be insensitive to treatment effects. A simpler analysis, which is also easier to interpret, is to use trend analysis. Finally, comparing stock-recruitment curves and their parameters did not provide strong evidence that supplementation has affected the productivity of the natural population.

Based on these results, we do not recommend using difference scores of annual change (ΔT-ΔR), nor do we recommend comparing stock-recruitment curves and their parameters. As noted above, difference scores of annual change are difficult to interpret and may be redundant with trend analysis. Testing stock-recruitment curves and their parameters appears redundant with testing differences in productivity using difference scores or ratios. In addition, the analyses are computer intensive and do not appear to be very sensitive to changes.

There was little difference in results using difference scores and ratios. It appears that ratios may be more sensitive to change than difference scores (e.g., we found significant differences in some comparisons using ratios but not with difference scores), but ratios can be more difficult to interpret than difference scores. Nevertheless, we recommend the use of ratios in future analyses.

Correcting for Density Dependence and Carrying Capacity

The analyses described so far assumed that the density of spawners or recruits did not affect the survival and productivity of fish. However, without controlling for density effects, productivity of the population would continue to decline with increasing abundance. This scenario could occur in supplementation programs that increase the number of spawners, and could result in lower productivities relative to reference populations. In addition, lower productivities may be caused by differential environmental carrying capacities rather than the capacity of the supplemented fish to produce offspring. Therefore, we described two different methods for deriving density-corrected estimates of productivity. The first controlled the effects of density on productivity by partitioning observed productivities into density-independent and density-dependent productivity. These productivities were then combined in a single test. The second method corrected for differences in carrying capacities between the supplemented and reference populations. This was accomplished by calculating the percent saturation of NORs, which was estimated as the ratio of observed NORs to the maximum number of NORs that the habitat could support.

We fit Ricker, Beverton-Holt, and smooth hockey stick models to stock and recruitment data to estimate the maximum number of NORs (NORs at carrying capacity) and the maximum number of spawners needed to produce maximum NORs. We fit models to the supplemented and reference populations. Using information-theoretic criterion and evaluating the precision of estimated parameters, we found that the smooth hockey stick model provided the best estimates of maximum NORs and spawners. We used these modeled values to estimate density-independent and density-dependent productivities, and saturation of NORs.

Statistical analyses, using difference scores and ratios of adjusted Chiwawa spring Chinook productivity data, found no significant effects of supplementation on the productivity of the supplemented population. Indeed, the results from correcting for density dependence were similar to those without correcting for density dependence. This is in part because the abundance of the supplemented and reference populations has been below their respective carrying capacities in most years. This was clearly demonstrated in the analyses of NORs corrected for carrying capacity. In the supplemented population, the mean fraction of the carrying capacity filled with NORs decreased significantly during the supplementation period. In other words, the carrying capacity was filled with more NORs during the pre-supplementation period than during the supplementation period, which is contrary to the goal of supplementation. By comparison, two of the reference populations showed a similar decrease in saturation, while the other two reference populations actually increased in saturation. Analyzing the saturation scores using BACI-design analyses indicated that two of the four pairings differed significantly. That is, the percent saturation of the supplemented population decreased significantly relative to two reference populations.

Because productivity can be affected by the abundance of spawners and recruits, we recommend that future analyses comparing supplemented and reference populations adjust for density-dependent effects and differential carrying capacities. Although we detected only slight differences between adjusted and unadjusted results, as supplemented stocks recover, it will become more important to adjust productivities to account for density dependence. Importantly, the analyses using percent saturation placed NORs in the context of the carrying capacity of the environment. This will help managers determine if supplementation programs are filling or over-filling the capacity of the habitat with NORs.

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As we noted earlier, analyses using productivities adjusted for density dependence assume that there is a spawner abundance at which density-independent effects end and density-dependent effects begin. In reality, density-dependent effects occur at low spawning abundance and intensify as spawning abundance increases. We did not account for these increasing density-dependent effects at lower spawner abundances. This is an area that needs additional attention.

Analyses without Reference Populations

Because of the rigorous criteria we used to select reference populations, it is likely that reference populations may not exist for making comparisons with supplemented populations. For example, we used the criteria described in this paper to identify reference populations for supplemented steelhead and sockeye populations in the Upper Columbia Basin. We were unsuccessful in identifying any suitable reference populations. Therefore, in the absence of suitable reference populations, it is important to have alternative methods for assessing supplementation effects. We described three different types of analyses one can use to assess supplementation effects in the absence of reference populations. They include before-after comparisons, correlation analysis, and comparisons to standards.

Before-after analyses compare population metrics before supplementation with those during supplementation. In this case, data collected before supplementation represent the reference condition. The assumption is that population trajectories measured during the pre-supplementation period would continue in the absence of supplementation. We compared trends in spawner abundance, NORs, and productivity before and after supplementation. In addition, we compared mean scores in these three parameters before and after supplementation. Finally, we attempted to compare stock-recruitment parameters before and after supplementation. The hypotheses examined were that the spawner abundance and NORs would be greater during the supplementation period, and that productivities would not decline during the supplementation period.

Trend analysis indicated that the all three Chiwawa spring Chinook population parameters trended downward during the pre-supplementation period, but trended upward during supplementation. On the other hand, mean spawner abundance and NORs were lower during the supplementation period than during the pre-supplementation period. Mean productivities increased, but not significantly, during the supplementation period. We were unable to compare pre- and post-supplementation stock-recruitment curves because we were unable to fit stock-recruitment models to the pre-supplementation data.

We used correlation analyses to determine if the proportion of hatchery-origin fish that spawn naturally on the spawning grounds (pHOS) increased productivity. In addition, we used correlation to assess the association between pHOS and the residuals from stock-recruitment relationships. A significant negative association provides evidence that hatchery-origin spawners may not be as productive as natural-origin spawners. The analysis indicated that the productivity of Chiwawa spring Chinook increased with increasing pHOS, but the association was not significant. In contrast, there was a negative association between pHOS and the stock-recruitment residuals, but again the association was not significant. The latter analysis accounts for density-dependent effects.

In concert, the before-after comparisons and correlation analyses do not provide conclusive evidence that the supplementation program has increased spawner abundance and NORs, or that it has significantly reduced the productivity of the supplemented population. Although increasing

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the number of hatchery fish on the spawning grounds appears to reduce NORs and productivity, mean productivity actually increased during the supplementation period compared to the pre-supplementation period.

It is important to note that relying on only one set of analysis could result in drawing a wrong conclusion. For example, if we had only conducted trend analysis, we may have concluded wrongly that the Chiwawa spring Chinook supplementation program significantly increased spawner abundance, NORs, and productivity in the supplemented population. The analysis of mean scores and correlations indicates that the supplementation program has not increased spawner abundance or NORs in the supplemented population. Therefore, in the absence of suitable reference populations, we recommend that analyses include the evaluation of trends, means scores, and correlations. By conducting more than one set of analyses, one can use weight-of-evidence to assess the effects of supplementation programs.

Under the scenario that there are no reference populations or pre-supplementation data, one is left with comparing population parameters to relevant standards. These standards could come from mitigation requirements, quantitative objectives, or published or unpublished standards. One could also use correlation to evaluate the association between productivity and pHOS, but this requires a wide range in pHOS values to be most effective. A more extreme approach, which probably would not gain much traction with managers, is to shutoff the supplementation program for some time and then evaluate the effects of the program in a before-after design. The Entiat spring Chinook hatchery program provides a unique opportunity to evaluate this type of management decision.

Some Concerns and Limitations

No matter how hard we try to explain different sources of variation in population data, we are limited by the quality of the data. Teasing out the effects of supplementation requires long time series of population data. Because funding levels and methods change over time, the quality (i.e., accuracy and precision) of the data also changes over time. Importantly, the population parameters examined in this paper (spawner abundance, NORs, and productivity) are rarely measured directly in the field. That is, other population metrics, such as numbers of redds, number of fish counted at weirs or dams, scales, tags, etc., are sampled in the field. These metrics are then used to calculate spawner abundance[23], NORs, and productivity, often based on assumptions about fish/redd, pre-spawning loss, marking rates, and sampling rates. This has a tendency to increase the variability in the data independent of supplementation programs. In our studies, we can only control sampling within the supplemented populations, and even that is limited by available funding. We have no control over the sampling within reference populations. Thus, we have to assume that sampling within the reference populations will continue and that sampling effort will remain comparable to that in the supplemented populations.

In our analyses, we included both the Entiat and Little Wenatchee populations as references for the Chiwawa population. In the analyses, we treated them as equivalent to the other reference populations. That is, the statistical procedures used to compare the supplemented population to each reference population were identical. This is appropriate. However, the interpretation of the results must be different when comparing the Entiat and Little Wenatchee to the supplemented

[23] The smooth hockey stick model, which we used to estimate density-dependent correction factors for productivity and NORs, is sensitive to errors in spawner escapement estimates. Therefore, it is important to use accurate and precise estimates of spawner escapement.

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population, because they are populations that were influenced by hatchery fish. As noted earlier, the Entiat spring Chinook hatchery program has been discontinued. Therefore, it provides a unique type of reference where the comparison changes from both populations being supplemented to only one population being supplemented. For the Little Wenatchee, nearly all the strays came from the Chiwawa program. Straying should stop or be greatly reduced with the change in water supply to the Chiwawa Rearing Ponds. In sum, one must be careful in how they interpret these test-reference results.

Finally, it is important to point out that for this paper, we conducted 463 statistical tests. Because we set our Type I error rate at 0.05, by random chance alone, we may have incorrectly rejected about 23 null hypotheses. Inasmuch as this work was designed to evaluate different ways to analyze test-reference data, the number of future analyses will be greatly reduced based on the results from this work. However, if the Type I error rate is a concern to managers, researchers can use a lower error rate, such as $\alpha = 0.01$. Another option is to analyze test-reference data graphically. Although this is subjective, there are no statistical analyses and therefore no concerns with violating assumptions of statistical tests, including temporal correlation. We believe researchers should use the statistical procedures recommended in this report to support graphic analysis.

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ANCHOR QEA

Memorandum

To: Wells, Rocky Reach, and Rock Island HCP Hatchery Committees

Date: September 22, 2017

From: Tracy Hillman, HCP Hatchery Committees Chairman

cc: Sarah Montgomery, Anchor QEA, LLC

Re: Final Minutes of the August 16, 2017, HCP Hatchery Committees Meeting

The Wells, Rocky Reach, and Rock Island Hydroelectric Projects Habitat Conservation Plan (HCP) Hatchery Committees meeting was held at the Grant PUD office in Wenatchee, Washington, on Wednesday, August 16, 2017, from 9:00 a.m. to 12:00 p.m. Attendees are listed in Attachment A to these meeting minutes.

Action Item Summary

- Andrew Murdoch (Washington Department of Fish and Wildlife [WDFW]) will write an overview of proposed expanded sampling at the off-ladder fish trap (OLAFT) at Priest Rapids Dam (Item I-A). *(Note: this item is ongoing.)*
- Sarah Montgomery will clarify the review period for the Chelan PUD Draft Statement of Agreement (SOA) Regarding the District's Coho Obligation and provide an update to the Hatchery Committees (Item II-A). *(Note: Montgomery clarified this in the action items from the August 16, 2017, meeting.)*
- Mike Tonseth will coordinate with Todd Seamons (WDFW) to produce an outline or recommended approach for genetic monitoring (Item III-E).
- Mike Tonseth will send the revised Table 3 of the Hatchery Monitoring and Evaluation (M&E) Plan to Tracy Hillman for inclusion in the 2017 Update (Item III-G). *(Note: Tonseth provided the table to Hillman on August 17, 2017.)*
- Sarah Montgomery will send SOAs regarding Non-target Taxa of Concern (NTTOC) study results to Tracy Hillman (Item III-G). *(Note: Montgomery did this on September 20, 2017.)*
- Tracy Hillman and Todd Pearsons will revise NTTOC and adaptive management language in the Draft 2017 Update to the M&E Plan for PUD Hatchery Programs and provide a revised version for Hatchery Committees review (Item III-G). *(Note: Hillman revised the plan and Montgomery distributed a revised version for review on September 2, 2017.)*

Decision Summary

- The Rocky Reach and Rock Island Hatchery Committees representatives approved Chelan PUD's Draft 2018 Hatchery M&E Implementation Plan as follows: Chelan PUD, WDFW, U.S. Fish and Wildlife Service (USFWS), Yakama Nation (YN), and National Marine Fisheries Service (NMFS) approved during the meeting on August 16, 2017, and Colville Confederated Tribes (CCT) approved on August 18, 2017 (Item II-B).

Agreements

- There were no agreements discussed during today's meeting besides the decision above.

Review Items

- Sarah Montgomery sent an email to the Rocky Reach and Rock Island Hatchery Committees on August 15, 2017, notifying them that the Chelan PUD Draft SOA Regarding District's Coho Obligation is available for a 30-day review, with comments due to Catherine Willard by September 14, 2017. Chelan PUD indicated they will request approval of the SOA at the Hatchery Committees September 20, 2017, meeting.
- Sarah Montgomery sent an email to the Hatchery Committees on September 1, 2017, notifying them that the Draft 2016 Douglas PUD and Grant PUD M&E Annual Report is available for a 60-day review, with edits and comments due to Greg Mackey by October 31, 2017. (Note: Douglas PUD requested comments in 30 days if possible, which would be October 2, 2017.)

Finalized Documents

- Sarah Montgomery sent an email to the Hatchery Committees on September 15, 2017, notifying them the Chelan PUD and Grant PUD 2016 Final M&E Annual Report and Appendices is now available for download from the Hatchery Committees Extranet site.

I. Welcome

A. Review Agenda, Review Last Meeting Action Items, and Approve the July 19, 2017, Meeting Minutes (Tracy Hillman)

Tracy Hillman welcomed the Hatchery Committees and asked for any additions or changes to the agenda. Catherine Willard added the Chelan Falls Trap to the agenda. *(Note: Sarah Montgomery combined the two items regarding spring Chinook salmon in the Methow basin because discussions were interrelated.)*

The Hatchery Committees reviewed the revised draft July 19, 2017, meeting minutes.
Sarah Montgomery said there are no outstanding comments to be discussed. Hatchery Committees

representatives present approved the draft July 19, 2017, meeting minutes, as revised. Kirk Truscott provided his approval of the meeting minutes prior to the meeting.

Action items from the Hatchery Committees meeting on July 19, 2017, and follow-up discussions were addressed *(note: italicized text below corresponds to agenda items from the meeting on July 19, 2017)*:

- *Andrew Murdoch (Washington Department of Fish and Wildlife [WDFW]) will write an overview of proposed expanded sampling at the off-ladder fish trap (OLAFT) at Priest Rapids Dam (Item I-A).*
  This item is ongoing. Keely Murdoch requested that Cory Kamphaus (YN) be involved in this discussion.
- *Hatchery Committees representatives will review McLain Johnson's Genetic Monitoring Update (Item I-A).*
  This item will be discussed today.
- *Sarah Montgomery will clarify the review period for the Chelan PUD Draft 2018 Hatchery Monitoring and Evaluation (M&E) Implementation Plan and provide an update to the Hatchery Committees (Item II-A).*
  This item is complete.
- *Tracy Hillman will revise Appendix 4 of the Draft 2017 Update to the Monitoring and Evaluation Plan for PUD Hatchery Programs to include release number targets, and provide it for Hatchery Committees review (Item III-C).*
  This item is complete and available for review.
- *Tracy Hillman will revise the Draft 2017 Update to the M&E Plan for PUD Hatchery Programs and provide it for Hatchery Committees review (Item III-C).*
  This item is complete and will be discussed today.

II. Chelan PUD

A. Draft Coho Salmon Mitigation SOA (Catherine Willard)

Catherine Willard shared the document titled *Draft Statement of Agreement Regarding District's Coho Obligation*, which Sarah Montgomery distributed to the Hatchery Committees on August 15, 2017 (Attachment B). Willard said the 7 percent coho salmon hatchery compensation rate was agreed to by the Rocky Reach and Rock Island Coordinating Committees. She said the SOA is an agreement about the methodology used to calculate hatchery compensation levels (the same methodology as used in recalculation) and is also an agreement that Chelan PUD will meet its obligation through funding and/or facility use to support a coho salmon reintroduction project. She said she also distributed a revised presentation (originally presented at the May 17, 2017, Hatchery Committees meeting), *Approach Used to Determine Chelan PUD's Coho Hatchery Mitigation*, which Montgomery distributed to the Hatchery Committees on August 15, 2017. She said the presentation includes more detail about how the smolt numbers were calculated.

Montgomery said the SOA is available for a 30-day review, with comments due to Willard on September 14, 2017, and said she would remind the Hatchery Committees of this review timeline. Willard said Chelan PUD will request approval of this SOA at the September 20, 2017, Hatchery Committees meeting and asked for any immediate questions.

Mike Tonseth asked why calculations for Rocky Reach coho salmon mitigation are based on mortality at both Rocky Reach and Rock Island dams. Keely Murdoch said coho salmon from the Methow basin migrate past both dams. Willard said Rocky Reach Dam has mitigation related to the Methow basin, whereas Rock Island Dam has mitigation associated with the Wenatchee and Methow basins. Willard said she would clarify this language in the final version of the SOA.

B. Draft 2018 Hatchery M&E Implementation Plan (Catherine Willard)

Catherine Willard said the Chelan PUD Draft 2018 Hatchery M&E Implementation Plan (Attachment C) is currently available for a 30-day review. Tracy Hillman said the changes between the 2017 and 2018 plans are minor and include only date and authorship changes. Willard said Chelan PUD requests that the Rocky Reach and Rock Island Hatchery Committees approve this plan, which they did as follows: Chelan PUD, USFWS, WDFW, YN, and NMFS approved during the meeting on August 16, 2017. CCT did not have representation at the meeting, and Hillman received approval from Kirk Truscott via phone on August 18, 2017.

III. Joint HCP-HC/PRCC HSC

A. USFWS Bull Trout Consultation Update (Bill Gale)

Bill Gale said he received a consultation update from Karl Halpuka (USFWS), which he shared with the Hatchery Committees as follows:

- The USFWS is working on the Methow steelhead consultation, and Halpuka plans to write a coverage memorandum similar to the one completed for spring Chinook salmon.
- The USFWS is working on finalizing the Biological Opinion for the batch of Wenatchee subbasin programs.

Emi Kondo (NMFS) added that NMFS and USFWS have not yet received feedback from the U.S. Army Corps of Engineers regarding consulting for the Ringold program, so consultation for the batch of unlisted upper Columbia River (UCR) summer Chinook salmon programs is on hold. Mike Tonseth said he has been discussing the UCR unlisted programs' consultations with the USFWS and National Oceanic and Atmospheric Administration. He understands that in order for the consultation to move forward, the Ringold program's Hatchery and Genetic Management Plan needs a proposed action, the proposed action for the consultation needs to be finalized, and cover letters that identify consultation pathways need to be submitted.

B. NMFS Consultation Update (Brett Farman/Emi Kondo)

Emi Kondo said she is providing an update on consultation for the unlisted programs in the UCR. She said the Ringold program involves consultation with the U.S. Army Corps of Engineers, and that consultation has not yet been initiated. She said she is working on finalizing the proposed action, which is necessary to initiate consultation with USFWS. Kondo said she will soon send an updated version of the proposed action for applicants and others to review, then everyone can meet to discuss changes. She asked for interested parties outside of the applicant pool to please let her know so she can include them in the meeting.

She said applicants have made progress deciding which Endangered Species Act (ESA) pathway to pursue for these consultations. She said Douglas PUD representatives indicated they intend to use Section 10 coverage and Chelan PUD representatives indicated they intend to use Section 4(d) coverage. She said discussions with Grant PUD representatives regarding coverage for their programs are ongoing. She said one topic of discussion is Chelan PUD's trap on the Chelan River. She said it is operated when water temperatures are over 21 degrees, which could be an issue if ESA-listed species are being trapped. She said this discussion is ongoing with Chelan PUD and WDFW.

Kondo said the next steps for this consultation are finalizing the proposed action, determining the ESA pathways, initiating consultation with a request letter, and NMFS replying with a letter of sufficiency. She said effects to bull trout can be analyzed by USFWS after those steps are complete.

Tracy Hillman asked which listed species have the potential to be collected in the Chelan Falls Trap. Mike Tonseth said steelhead and spring Chinook salmon could be collected at the Chelan Falls Trap and the trap would operate starting on July 1. Bill Gale said, while unlikely, bull trout are also a listed species that could be collected in the trap. Catherine Willard said monthly snorkel surveys have shown no bull trout present in past years during July and August, the period the trap would be in operation. Tonseth said spring Chinook salmon are difficult to differentiate from unlisted summer/fall Chinook salmon, particularly in the early part of the trapping season. Willard said the start date will be later than July 1, and said the trap cannot be operated until July 15, which could reduce the potential to trap ESA-listed species.

C. Wenatchee Spring Chinook Salmon Update (Mike Tonseth)

Mike Tonseth said he has provisional data regarding the status of Wenatchee spring Chinook salmon in 2017. He said WDFW switched to video analysis in the middle of July, but continued sampling. At that point, he said approximately 1,300 spring Chinook salmon had passed Tumwater Dam. Tonseth said WDFW surplused 302 male Chinook, which were mostly jacks. Two fish were not jacks, and an additional 30 fish appear to originate from Leavenworth National Fish Hatchery (NFH) because they are adipose-clipped and coded wire tag-absent; however, these fish are difficult to characterize. Keely Murdoch emphasized that these fish should not be labeled as fish of a certain program unless their origin is definitively known. Tonseth agreed and said WDFW are calling these fish "maybe Leavenworth NFH-origin" fish. Tracy Hillman asked if 300 of the total spring Chinook salmon observed at Tumwater Dam is a particularly high proportion of jacks. Tonseth said yes, and this could be due to a poor migration year in 2015 and ocean conditions.

Tonseth said the Wenatchee spring Chinook salmon program has collected sufficient spring Chinook salmon to meet its production obligations. However, he said the natural-origin target for the Chiwawa program has not been met due to three factors: 1) adult natural-origin fish are limited and hard to acquire, 2) the collection weir was not operational as early in the season as intended because of high flows, and 3) towards the end of the collection season, mechanical issues took the weir out of operation for 1 week at a critical point. He said towards the end of the collection season, the weir was lowered to avoid impinging fish.

Bill Gale asked what the forecasted proportion of natural origin broodstock (pNOB) is using these provisional data. Willard replied the forecasted pNOB for the Wenatchee spring Chinook salmon program is 0.73. Tonseth said WDFW is still sampling at Tumwater Dam as part of broodstock collection, and video data were being used to differentiate spring and summer Chinook salmon. The WDFW genetics lab will help finalize assignments using scale analysis.

Alene Underwood asked how many females the program is short. Tonseth replied the program is approximately four females short of its natural-origin target.

Todd Pearsons asked about spring Chinook salmon collection for the Nason Creek Program. Tonseth said WDFW has collected the full conservation and safety-net program broodstock targets. Hillman asked if any White River-origin fish were collected. Tonseth said WDFW over collects for the Nason Creek Program by approximately 10 percent to account for White River origin fish. He said some fish are also of Chiwawa River origin, so those fish are collected and retained for the Chiwawa River program. Pearsons asked how many fish are genetically typed. Tonseth said any fish genetically sampled as part of broodstock collection are checked against the genetic baselines for those rivers. The baseline includes genetic signatures for Nason Creek, Chiwawa River, and the White River.

Pearsons asked if 10 percent of the broodstock collected are genetically typed. Tonseth said yes, and since the broodstock target is 70 fish, they collected 77 fish. He said 6 of the collected fish were not retained for the program.

D. Chelan Falls Trap (Catherine Willard)

Catherine Willard said the Chelan Falls Trap has been operating and the Chelan Falls summer Chinook salmon program is currently about 30 females short of its broodstock collection target. She said trapping will continue through this week, but will not occur next week because of habitat improvement projects in the Habitat Channel of the Chelan River. She said the first week of September will be the last week the trap is operational and there is a chance the program will fall short of its broodstock collection target by the end of the trapping period. She said the Brood Year 2017 Salmon Broodstock Collection Protocols state the Hatchery Committees will discuss the potential shortage and whether broodstock collection may default to surplus summer Chinook from the Entiat National Fish Hatchery (NFH), which would be a transfer of 30 or less female summer Chinook salmon. Mike Tonseth said he understands that many summer Chinook salmon have returned to the area around Eastbank Fish Hatchery (FH) and that could be an additional or alternate source of collection. Willard said Chelan PUD prefers using fish that are surplused from Entiat NFH due to safety concerns with collecting broodstock at the Eastbank FH outfall. Tracy Hillman noted that the Hatchery Committees previously discussed alternate broodstock sources for this program in case it fell short of its target. Tonseth said the Hatchery Committees discussed Entiat NFH as the back-up source of broodstock, but would still need to discuss it with USFWS to see if Entiat NFH can support the request. Bill Gale asked when Chelan PUD would know if the program is short. Willard said September 1 is the last day for trapping. Gale said that timing would likely not be a problem, so he and Chelan PUD will begin coordinating the logistics of this potential transfer. Genetic Monitoring Update (Mike Tonseth)

Tracy Hillman said the genetic monitoring update is related to the update to the Hatchery M&E Plan (Item III-G). Mike Tonseth said McLain Johnson (WDFW) sent an update regarding genetic monitoring including a memo, *Update - Hatchery M&E Genetic Monitoring Objectives* (Attachment D), and a spreadsheet, *Genetic Tables* (Attachment E), which Sarah Montgomery distributed to the Hatchery Committees on April 6, 2017. Tonseth said there are two key decisions the Hatchery Committees need to make. He said the Hatchery Committees had previously requested that Todd Seamons conduct a power analysis to determine how frequently genetic analyses should be performed in order to determine whether hatchery programs are having an effect on natural populations. He said he discussed this with Seamons and the power analysis is a complex task that WDFW is not comfortable undertaking without a contract. He said the power analysis will be important to making decisions about analysis frequency, and he thinks Chelan, Douglas, and Grant PUDs should make the decision whether or not to fund the analysis.

He said the second key decision the Hatchery Committees need to make is about genetic panels. He said any new analysis will use a single nucleotide polymorphism (SNP) panel; however, baseline data were analyzed using a microsatellite panel. A decision about rerunning past samples with the SNP panel could be made soon in order to complete those re-analyses by the time the new analysis frequency is determined. He said a related decision is where the genetic baseline starts for each program. Tonseth said the baseline is currently in the 1980s or 1990s for most programs and tissue is still available to rerun the analyses using the newer SNP methodology. Catherine Willard asked if the new genetic samples could be run using the older microsatellite methods so that they are comparable to past results, yet still answer the genetic objectives in the M&E Plan. Tonseth said the analyses could probably be performed, but using SNPs is the preferred method because it is more accurate and provides better resolution. Tonseth said one additional decision would be whether to increase the number of markers analyzed for certain programs. Bill Gale said one benefit of using SNP panels is that it provides higher resolution and has more available markers.

Gale suggested asking Seamons to outline these questions and the costs and benefits associated with each. Keely Murdoch agreed and said it would be helpful to have something documented that she can discuss internally. Todd Pearsons said there are many genetic tests being performed to meet the M&E objectives and perhaps fewer tests could be run in a way that would still meet the objectives.

Tonseth said it's possible that the two objectives in the M&E Plan are not the "right" questions to be asking to determine if hatchery programs are having genetic effects on natural populations. He said from a recovery perspective, maintaining or building diversity is important and it is also important to make sure hatchery programs do not pose a genetic risk to recovery. He said asking Seamons to consider the objectives could change the outlook of genetic monitoring in this basin and create more delays, but it is important to consider the purpose of the genetics monitoring and objectives.

Hillman summarized that members present would like Seamons to produce a small paper including appropriate questions, tasks, and necessary analyses, and asked if the WDFW Genetics Lab would need funding to complete the paper. Tonseth said he would check. Pearsons said determining if the M&E Plan objectives are asking the "right" questions is a good first step and asked if gathering geneticists from multiple agencies would be helpful to identify key questions and long-term monitoring objectives. Tonseth said he thinks he should talk to Seamons first and see if he (Seamons) has a recommended approach or outline, then it could be circulated amongst other geneticists. Hillman suggested that Seamons start by looking at the current Hatchery M&E Plan. Pearsons said the Hatchery M&E Plan objectives were established in 2005, so it might be time to update the objectives. Tonseth said the M&E Plan is a good starting point and getting geneticists to agree on the right monitoring questions would give future discussions and analyses more direction.

E. Spring Chinook Salmon in the Methow Basin: Status of Adult Management and Translocation to the Chewuch River (Mike Tonseth)

Mike Tonseth said Greg Mackey asked him for an update on adult management of spring Chinook salmon in the Methow basin and the status of the Chewuch River translocation study planned for 2017.

Tonseth said Charles Frady (WDFW) provided provisional estimates of spring Chinook salmon to Wells FH, which were 529 wild fish and 4,471 hatchery-origin fish. He estimated that 2,356 hatchery fish are likely bound for the Methow basin and the rest would go to the Okanogan basin. Tonseth said Winthrop NFH's broodstock collection target for spring Chinook salmon is 551 fish and he believes this target has been met in 2017, but not all the fish originate from the conservation program. Bill Gale said of the roughly 2,400 hatchery spring Chinook salmon estimated to enter the Methow basin, approximately 1,500 fish originate from Winthrop NFH and 900 originate from Methow FH.

Tonseth said the Methow spring Chinook program was not able to meet the full natural-origin return component in 2017 through trapping at Wells Dam despite trapping 5 days per week. A total of 74 of the 122 required wild fish were collected. As a result, the balance of the program will be backfilled with returning conservation hatchery fish to fulfill the production obligation. In addition, conservation hatchery fish returns to Methow and Winthrop hatcheries are insufficient to meet the Winthrop NFH safety-net production target and will therefore backfill the production shortage with adults from the safety-net program. Michael Humling (USFWS) said Winthrop NFH to date has surplussed 1,108 hatchery fish.

Additionally, Tonseth said the collection shortage means that the translocation study in the Chewuch River planned for 2017 will not occur this year. Gale said that it seems outplanting is not needed in this case because trapping efficiency in the Methow basin is lower than desired, so there are enough hatchery fish out in the system that outplanting hatchery fish would not be desirable. Keely Murdoch said the purpose of the outplanting study is not to make sure there are enough conservation fish on spawning grounds, but to get these conservation fish spawning in harder-to-reach places. She said if there were enough conservation fish for the program, but they were all spawning in one area, translocation would still be appropriate. Tonseth agreed and said the study is intended to evaluate the efficacy of adult translocation as a surrogate to early-term imprinting, in order to address homing fidelity issues in Methow spring Chinook salmon. Tonseth said he thinks there are years that the study would not be necessary or appropriate because there are sufficient hatchery fish on spawning grounds. Gale asked how many of the adipose-present, conservation fish were trapped out of the approximately 900 entering the Methow basin. Tonseth said Methow FH retained 71 of these fish and any more of these fish would have been transported to Winthrop NFH. Gale said Winthrop NFH has been successful in removing Winthrop hatchery-origin fishreturning to the basin and, of the 1,100 fish surplused and with broodstock collected, approximately 80 to 90 percent of the Winthrop hatchery-origin run has been removed between Methow FH and Winthrop NFH; however, the Methow FH trap does not appear to be removing enough fish to meet targets.

Tonseth said current operations need to be evaluated to determine whether percent natural influence (PNI) and proportion of hatchery origin spawners objectives can be reasonably met in the basin. Gale said he hopes under current operations that 80 percent of the run can be removed. Tom Kahler suggested discussing this with Charlie Snow (WDFW). Snow said the Methow FH trap is open and is checked at least every weekday and he is not certain about weekend trapping operations, but he thinks fish are trapped and held. Humling said he believes that in previous years the trap was not operated on weekends, but this year it is.

Gale asked if there is a way to know whether fish enter the Methow Fish Hatchery outfall then turn around (trap avoidance). Murdoch said a PIT tag array was used last year during the beginning of the trapping season. Kahler said Douglas PUD does not own the property where the PIT tag array would go, so it is challenging to install and maintain, and in the past, the YN have done so. Tonseth said using the 3-population PNI model, and if the preliminary numbers discussed today are accurate, PNI would be roughly 0.6 or 0.7. Gale said once final numbers of fish are available and the 3-population PNI is being calculated, the Hatchery Committees should discuss how to improve trapping for future years.

F. M&E Plan for PUD Hatchery Programs 2017 Update (All)

Tracy Hillman said he revised the M&E Plan for PUD Hatchery Programs to reflect changes discussed during the July 19, 2017, Hatchery Committees meeting and also incorporated comments from reviewers. Sarah Montgomery distributed a revised version of the plan for review on July 26, 2017 (Attachment F).

Hillman reviewed the edits in the document, and questions and comments were discussed as summarized in the following paragraphs.

Hillman asked if Table 3 should be updated for the 2017 version. Mike Tonseth said he has an updated version of Table 3 and will send it to Hillman for incorporation.

In Section 4, Natural Environment Monitoring Indicators, Hillman said fecundity at size is not currently included in the M&E annual report, so the Hatchery Committees might consider adding this section to the report. Tonseth said fecundity at size is used during the season to assess broodstock needs due to differences in age-at-return. He said it is used to adaptively manage broodstock targets. Hillman said in the annual report, mean fecundity for brood year is reported, but not fecundity at size. He said because it will be analyzed in the comprehensive (10-year) and statistical (5-year) reports, maybe it should be included in the annual report as well. Todd Pearsons said the annual report for the Priest Rapids programs includes fecundity by age.

In Section 6, Harvest Monitoring Indicators, Hillman said McLain Johnson pointed out that adult management is mentioned, but it is not mentioned elsewhere in the document. Hillman asked if language about adult management should be added to other sections. Tonseth said adult management is alluded to in other sections because it is necessary to meet objectives.

In Section 7, Regional Objectives, Hillman asked if NTTOC objectives have been completed. Bill Gale said it is complete for all species except Pacific lamprey. Tom Kahler said the Hatchery Committees originally determined not to include Pacific lamprey, so they would have to make a new determination to include lamprey in this section. Mike Tonseth said one reason lamprey were not included was because there were coding issues with the NTTOC model. Keely Murdoch added that sufficient data for lamprey were not available. Gale said as additional information becomes available, NTTOC species could be an issue, so programs still have the responsibility to manage to minimal impacts towards NTTOC species. Kahler said the Hatchery Committees approved an SOA in 2014 regarding this topic and suggested summary language from that SOA be added here. Montgomery said she would find the SOA and send it to Hillman.

In Section 8, Adaptive Management, Hillman said Pearsons included a comment with multiple items to discuss. Pearsons said one question he has is which data to include during the next 5-year or 10-year review and how to evaluate hypotheses. He said programs change through time and they could be analyzed as one program that is adaptively managed through time (treatment is one program with changes), or the programs could be blocked into major periods and analyzed as different treatments. He said one concern for blocking the programs into different treatments is not having sufficient sample size to assess important variables. Hillman said, for example, in a time series of natural-origin returns, the entire series could be evaluated as one treatment, or it could be broken into a few important treatment periods. Breaking the series into several treatment units results in lost statistical power. Thus, it is important to identify important treatment breaks in the time series. He said a program that has changed significantly over time should not be analyzed as one treatment. Pearsons suggested performing an analysis on each hatchery program and parsing out periods of the program to see if improvements that can be explained by program changes have been made over time. Gale said each hatchery program might have individual breakpoints for program changes, but hatchery programs influence each other and it would be difficult to blend peripheral program changes or basin changes in this type of analysis. He gave the example of the Nason Creek program, when the Chiwawa program underwent recalculation, potentially affecting natural-origin recruits in Nason Creek. Peter Graf said he began looking at the hatchery programs and levels of scale and suggested starting each analysis by looking at each species in each basin at a time and determining issues and changes for that species and basin first. Tonseth said this topic clearly requires more discussion and suggested adding language to the M&E Plan stating that discussion about adaptive management is ongoing.

Hillman emphasized that as discussions move forward, it will be important to consult with staff who know the program history. Tonseth said determining a chronology of major events for each program would be helpful and the Hatchery Committees could start by looking at the latest version of the Hatchery Report written by the Upper Columbia Salmon Recovery Board, which included a timeline of programs and changes.

Pearsons said his second question pertaining to Section 8 is about the number of NORs between treatment and control streams decreasing after supplementation. He said in comparing the NOR numbers between treatment and control streams before and after supplementation, reference populations decreased, and supplemented programs also decreased. He asked if this is a result of supplementation or an in-basin or out-of-basin effect. He said since there are no "clean" in-basin reference streams, it is difficult to determine the cause of this decline. He said in-basin reference streams are important to understanding hatchery effects, but the patterns in this basin are unclear. Gale asked what the "before" period represents, and Pearsons said before 1989, and the "after" period is the entire supplementation period. Gale suggested blocking the analysis into 5-year periods to determine variability over time. Gale said blocking the analysis in this way would result in a more detailed graph and dataset and more programs could be added for comparison. Hillman said that would include looking at more breakpoints in the data and time series. Graf said he has anecdotally noticed natural breakpoints in the data, which may or may not be associated with program changes. Hillman said he would work with Pearsons to draft revised language for Section 8.

In Appendix 5, Hillman said he added release numbers to the table. Gale requested adding a footnote that Chief Joseph 10j spring Chinook salmon come from Winthrop NFH (as Methow Composite fish).

Hillman said he will make all the requested edits and provide a revised version for Hatchery Committees review.

IV. HCP Administration

A. Next Meetings

The next Hatchery Committees meetings are on September 20, 2017 (Grant PUD), October 18, 2017 (Grant PUD), and November 15, 2017 (Grant PUD).

V. List of Attachments

Attachment A	List of Attendees
Attachment B	Draft Statement of Agreement Regarding District's Coho Obligation
Attachment C	Chelan PUD Draft 2018 Hatchery M&E Implementation Plan
Attachment D	Update - Hatchery M&E Genetic Monitoring Objectives
Attachment E	Genetic Tables
Attachment F	Draft 2017 Update - M&E Plan for PUD Hatchery Programs

Attachment A
List of Attendees

Name	Organization
Tracy Hillman	BioAnalysts, Inc.
Sarah Montgomery	Anchor QEA, LLC
Catherine Willard*	Chelan PUD
Alene Underwood[0]	Chelan PUD
Tom Kahler*	Douglas PUD
Todd Pearsons‡	Grant PUD
Peter Graf‡	Grant PUD
Deanne Pavlik-Kunkel‡	Grant PUD
Mike Tonseth*	Washington Department of Fish and Wildlife
Charlie Snow†	Washington Department of Fish and Wildlife
Bill Gale*	U.S. Fish and Wildlife Service
Michael Humling†	U.S. Fish and Wildlife Service
Brett Farman*†	National Marine Fisheries Service
Emi Kondo†	National Marine Fisheries Service
Keely Murdoch*	Yakama Nation

Notes:
* Denotes Hatchery Committees member or alternate
† Joined by phone
‡ Joined for the joint HCP-HC/PRCC HSC discussion
[0] Joined for the Chelan PUD items

Rocky Reach and Rock Island HCP Hatchery Committees
DRAFT Statement of Agreement
Regarding District's Coho Obligation
August 16, 2017

Statement

The Rocky Reach and Rock Island HCP Hatchery Committees (hereafter "Committees") agree that Chelan PUD shall provide coho compensation for the Methow River and Wenatchee River sub-basins at a rate equivalent to 7.0% at each project to meet Chelan PUD's No Net Impact hatchery obligations for brood years 2017 to 2021 (release years 2019 to 2023); therefore, 7.0% will be used as the coho hatchery compensation rate until the next scheduled hatchery compensation recalculation (2023). Methodology described in the SOA Regarding the 2013 No Net Impact Recalculation Methodology (dated July 20th, 2011) will be used to calculate hatchery compensation levels for coho.

In order to meet this obligation, Chelan PUD and the Yakama Nation intend to enter into an agreement where Chelan PUD will provide funding for the Mid-Columbia Coho Reintroduction Project (facility use may be included as part of the agreement). As long as Chelan PUD is meeting the terms of the agreement with the Yakama Nation, and remains consistent with any future recalculated hatchery compensation obligations, the Committees agree that Chelan PUD is fulfilling its coho hatchery obligation for the term of the Rocky Reach and Rock Island Habitat Conservation Plans.

Background

On June 20, 2007, the Committees agreed to implement coho hatchery compensation as detailed in Section 8.4.3.a of the Rocky Reach and Rock Island HCPs and agreed that the District shall begin providing hatchery compensation no later than October 1, 2007. On March 28, 2017, the Rocky Reach and Rock Island Coordinating Committees agreed to use Chelan PUD's yearling Chinook acoustic tag survival estimates and coho PIT-tag based survival estimates to estimate juvenile coho survival of 93.98% at Rock Island and 92.94% at Rocky Reach (Skalski and Townsend 2017) which culminated in a 93% survival value at both projects.

Calculations for Rocky Reach Coho Obligation

Compensation for **hatchery-origin smolts** will be determined by multiplying the Program's annual release targets from the Methow sub-basin hatchery program by the unavoidable project mortality (1-(0.93 x 0.93)) for Rocky Reach and Rock Island.

Compensation for **natural-origin smolts** produced is determined by:

- Mean NOR[1] to Rocky Reach (return years 2008 to 2011 and 2013 to 2015) = 43
- Mean NOR in absence of project mortality: 43/0.9300 = 46
- Adult equivalents to meet NNI: 46-43=3
- Mean 8 year SAR (release years 2008-2015 Methow sub-basin hatchery program) = 0.59%
- Compensation for natural-origin smolts: 3/0.0059 = 508 smolts

Calculations for Rock Island Coho Obligation

Compensation for **hatchery-origin smolts** will be determined by multiplying the Program's annual release targets from the Wenatchee sub-basin hatchery program by the unavoidable project mortality (1-0.93) for Rock Island.

Compensation for **natural-origin smolts** is determined by:

- Mean NOR to Rock Island (return years 2007-2016) = 529
- Mean NOR in absence of project mortality: 529/0.9300 = 569
- Adult equivalents to meet NNI: 569-529 = 40
- Mean 10 year SAR[2] (release years 2006-2015 Wenatchee sub-basin hatchery program) = 0.75%
- Compensation for natural-origin smolts: 40/0.0075 = 5,333 smolts

[1]Natural-origin return=NOR
[2]SAR=releases from the Wenatchee hatchery programs and returns to Priest Rapids Dam (versus Rock Island Dam due to historic variable PIT tag detection efficiency at the adult ladders).

Chelan County PUD Hatchery Monitoring and Evaluation Implementation Plan 2018

Deleted: 2017

Prepared by:

Catherine Willard

Deleted: Alene Underwood and

July 2017

Deleted: 2016

Contents

1. INTRODUCTION 1
2. AQUACULTURE MONITORING 4
2.1 Broodstock Collection and Stock Assessment 5
2.2 In-Hatchery Monitoring 5
2.3 Release Monitoring 6
3. JUVENILE MONITORING 8
3.1 Freshwater productivity of Supplemented Stocks 8
3.2 Tributary Evaluations 9
4. ADULT MONITORING 10
4.1 Spawning Escapement Estimates 12
Wenatchee Steelhead 12
Chiwawa and Methow Spring Chinook 12
Wenatchee Summer Chinook 13
4.2 Harvest Reporting 13
5. DATA MANAGEMENT , ANALYSIS, AND REPORTING 14
5.1 Data Management 14
5.2 Data Analysis 14
5.3 Reporting 14
6. Lake Wenatchee Sockeye Salmon 14
6.1 Juvenile Monitoring 15
6.2 Adult Monitoring 15
Appendix A 20

1. Introduction

The Habitat Conservation Plan (HCP) specifies that a monitoring and evaluation plan will be developed for the hatchery program. The approach to monitoring the hatchery programs was guided by the "*Monitoring and Evaluation Plan for PUD Hatchery Programs: 2013 Update"* (Hillman et al. 2013) and the "*Conceptual Approach to Monitoring and Evaluating the Chelan County Public Utility District Programs*" (Murdoch and Peven 2005).

The purpose of this document is to define the tasks associated with the approved scope of work to implement Chelan PUD's (CPUD's) hatchery monitoring and evaluation (M&E) plan for 2018. Additionally, monitoring and evaluation activities for Lake Wenatchee sockeye in 2018 are included in this document. As monitoring tasks are completed in 2017 and are evaluated for their efficacy, methodologies to accomplish the tasks defined in the 2018 Implementation Plan may be modified [with Habitat Conservation Plan's Hatchery Committee (HCP-HC) approval].

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The work described in this plan has Endangered Species Act (ESA) coverage provided by NFMS Section 10(a)(1)(A) permits 18121 and 1395 and Section 10(a)(1)(B) permit 1347. All activities conducted under this Implementation Plan shall adhere to all terms and conditions as specified in the referenced permits. These permits allow for changes to monitoring or research protocols with the caveat that such modifications are approved by NMFS prior to implementing those changes. Terms and conditions relevant to monitoring and evaluating the hatchery programs have been used to inform the various measurements below and associated scopes of work with entities performing the work. A report summarizing compliance with the terms and conditions set forth under the above-references permits is required for submittal to NMFS; a copy of this completed report will be provided to the HCP HC.

The Implementation Plan includes all four components of the hatchery M&E Program including: (1) aquaculture monitoring; (2) juvenile monitoring; (3) adult monitoring; and (4) data, analysis and reporting. Under each component are study design elements that will be used to inform the overarching program components. Figure 1 illustrates the relationship of the components and study design elements used to address each component. Table 1 depicts which study design element is being performed by entity, and the associated objectives for each study design element as referred to in Hillman et al. 2013. For Lake Wenatchee sockeye salmon, the proposed M&E activities cover juvenile and adult life history stages and provide the data necessary to track or estimate viable salmonid population parameters (VSP) and is described in Section 6.0.

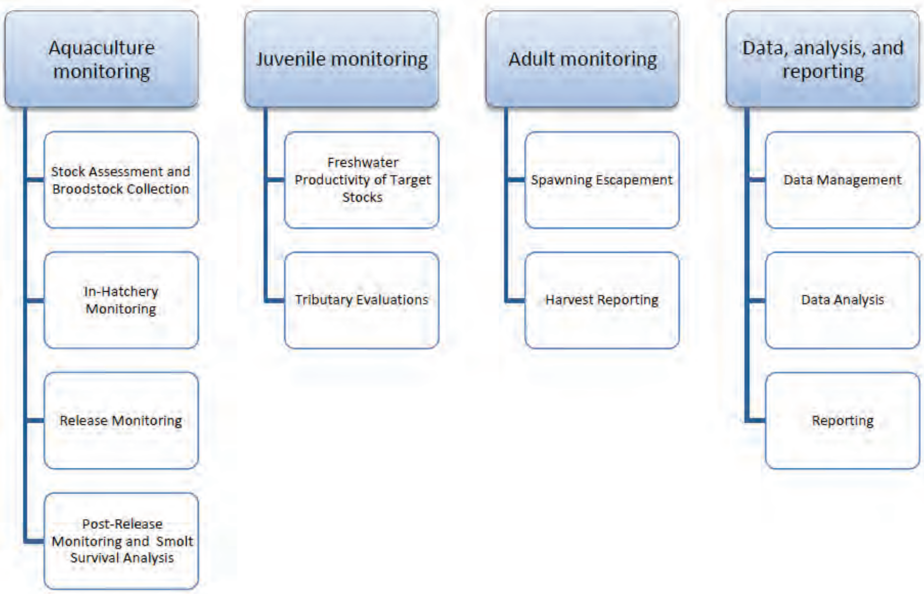

Figure 1. The four components of the hatchery monitoring and evaluation program and the study design elements within each component.

Table 1. Study design elements performed by entity, and the associated objectives for each study design element as referred to in Hillman et al. 2013.

Monitoring and evaluation component	Objectives[1]	Study Design Elements	Chiwawa spring Chinook	Wenatchee summer Chinook	Methow spring Chinook[4]	Chelan Falls summer Chinook[5]	Wenatchee Steelhead
Aquaculture Monitoring	3,5,8	Stock assessment and broodstock collection	WDFW	WDFW	WDFW	WDFW	WDFW
	5, 8	In-hatchery monitoring	WDFW CPUD[2]	WDFW CPUD[2]	WDFW Biomark[3]	WDFW CPUD[2]	WDFW CPUD[2]
	9	Release monitoring	WDFW	WDFW	WDFW	WDFW	WDFW
	9	Post-release monitoring and smolt survival analysis	WDFW	WDFW	WDFW	WDFW	WDFW
Juvenile monitoring	2	Freshwater productivity of stocks	WDFW	WDFW	WDFW	NA	WDFW
		Tributary evaluations	WDFW	WDFW	WDFW	NA	WDFW
Adult monitoring	1,2,3,4,5,6, 8,10	Spawning escapement	CPUD	WDFW	WDFW	BioAnalysts	WDFW
	8	Harvest reporting	WDFW	WDFW	WDFW	WDFW	WDFW
Data, analysis, and reporting	All	Data management	WDFW CPUD BioAnalysts	WDFW BioAnalysts	WDFW	WDFW BioAnalysts	WDFW BioAnalysts
		Data analysis	WDFW CPUD BioAnalysts	WDFW BioAnalysts	WDFW	WDFW BioAnalysts	WDFW BioAnalysts
		Reporting	WDFW CPUD BioAnalysts	WDFW BioAnalysts	WDFW	WDFW BioAnalysts	WDFW BioAnalysts

[1] Monitoring questions relative to Objective 7 will be addressed at the next 10 year HCP check-in.
[2]CPUD crews will PIT tag in-hatchery fish.
[3]Biomark will PIT tag in-hatchery fish.
[4]In 2018, monitoring and evaluation for the Methow spring Chinook program is described in "Implementation of Comprehensive Monitoring and Evaluation of Wells Hatchery Complex Programs".
[5]Because the Chelan summer Chinook program is primarily an augmentation program, monitoring and evaluation efforts focus on straying, release characteristics, and harvest.

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2. Aquaculture Monitoring

The aquaculture monitoring component is comprised of two basic elements: (1) stock assessment and broodstock collection at adult trapping locations and (2) in-hatchery monitoring including spawning, rearing, and release of juveniles. Data collected during these elements primarily support monitoring questions 5.1.1, 5.2.1, 8.1.1, 8.2.1, 8.3.1, 8.3.2, 8.4.1, 9.1.1, 9.2.1, 9.3.1 and 9.4.1, but also contribute data to monitoring questions 3.2.1, and 3.2.2 (Hillman et al. 2013). Table 2 below provides a summary of the variables to be measured in 2018 under the aquaculture monitoring component and what objective the measure(s) supports. The text that follows in this section further describes the activities.

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Table 2. Monitoring and Evaluation Plan (Hillman et al. 2013) objectives and the associated measured variables for the aquaculture monitoring component.

Objectives	**Measured Variables** *(Applicable Study Component(s))*
Objective 3: Determine if the hatchery adult-to adult survival (i.e., hatchery replacement rate, HRR) is greater than the natural adult-to adult survival (i.e., natural replacement rate, NRR) and the target hatchery survival rate.	• Number of hatchery and naturally produced fish collected for broodstock (*Broodstock Collection and Stock Assessment*) • Number of broodstock used by brood year (hatchery and naturally produced fish) (*Broodstock Collection and Stock Assessment*)
Objective 5: Determine if the run timing, spawn timing, and spawning distribution of the hatchery component is similar to the natural component of the target population or is meeting program-specific objectives.	• Ages of hatchery and naturally produced fish sampled via PIT tags or stock assessment monitoring (*Broodstock Collection and Stock Assessment*) • Time (Julian date) of ripeness of hatchery and natural origin steelhead captured for broodstock (*Broodstock Collection and Stock Assessment*)
Objective 8: Determine if hatchery programs have caused changes in phenotypic characteristics of the natural populations.	• Size (length), gender, and total/salt age of broodstock (*Broodstock Collection and Stock Assessment*) • Assess age of fish (*Broodstock Collection and Stock Assessment*) • Length, weight, and age (covariate) of hatchery and natural-origin broodstock after eggs have been removed (*Broodstock Collection and Stock Assessment*) • Number and weight of eggs (*Broodstock Collection and Stock Assessment*)
Objective 9: Determine if hatchery fish were released at the programmed size and number.	• Fork length and weights of random samples of hatchery juveniles at release (*Release Monitoring*) • Monthly individual lengths and weights of random samples of hatchery juveniles (*In-Hatchery Monitoring*) • Numbers of smolts released from the hatchery (*Release Monitoring*)

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2.1 Broodstock Collection and Stock Assessment

Broodstock collection and stock assessment for Wenatchee summer steelhead, Wenatchee summer Chinook, Methow spring Chinook, Chelan Falls summer Chinook, and Chiwawa River spring Chinook, hatchery programs will, in most instances, occur concurrent to and consistent with the Broodstock Collection Protocol approved annually by the HCP-HC and relevant permits. Data collection during broodstock collection will be consistent with Murdoch and Peven (2005). A representative sample of fish trapped throughout the entire run, either collected for broodstock or released back to the river, will be sampled for origin, age, sex, size, and migration timing. Biological sampling of all fish trapped will include presence of internal (CWT or PIT) and external (VIE) tags or marks, scales, length, and sex (determined by ultrasound). PIT tags will be injected into all target species (Chinook and steelhead), whether collected for broodstock or released back to the river to monitor for potential fallbacks. All non-target species will be enumerated daily. Measures of central tendency and spread will be calculated and reported for each metric.

2.2 In-Hatchery Monitoring

The in-hatchery monitoring component will begin when adult fish are collected and retained for broodstock and ends when juvenile fish are released. Life stage specific in-hatchery survival and growth rates, disease monitoring, and an estimate of the number of fish released will be collected and analyzed according to Murdoch and Peven (2005). Additional data to be collected includes individual lengths and weights of juveniles during monthly sampling, and the weight of gonadal mass and body of spawned broodstock. Measures of the central tendency and spread will be calculated and reported for each metric.

Fish Marking

All of Chelan PUD's hatchery fish will be coded-wire tagged (CWT) and externally marked or marked as otherwise agreed to by the HCP HC. A comprehensive marking strategy will be developed by the HCP-HC and included as an Addendum to this Plan. The identification of these hatchery-produced fish is needed for a suite of adult metrics and may be used for adult management and/or fisheries as contemplated by the co-managers.

Using methods described in Keller and Murauskas (2012), hatchery fish will be PIT-tagged (Table 3) at Eastbank Hatchery approximately two to four weeks before the fish are transferred to acclimation ponds or in the spring prior to release. Additional PIT-tagging may occur for program specific studies/comparisons as approved by the HCP-HC. The data collected from the PIT-tags will assist in release monitoring, migration timing, juvenile survival, and smolt-to-adult survival. For all fish marking, quality control check will be performed during and immediately following tagging and prior to release.

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Table 3. Chelan PUD's hatchery program release goals and recommended number of fish PIT tagged.

Program	Release goals	Number of fish PIT tagged[1]	PIT tag rate (%)
Chiwawa spring Chinook	144,026	10,000	6.9
Wenatchee steelhead	247,300	20,000	8.0
Wenatchee summer Chinook	318,816 (CPUD Program) 181,184 (GPUD Program)	20,600	4.1
Methow spring Chinook	60,156	5,000	8.3
Chelan Falls summer Chinook	576,000	10,000	1.7

[1] Additional PIT tagging may take place for Chelan PUD approved studies and/or comparisons.

2.3 Release Monitoring

Hatchery fish will be released during smoltification in the spring, typically between 15 April and 1 June. Whenever possible, the exact release dates will coincide with environmental conditions that promote a rapid emigration that minimizes both the potential negative ecological interactions of hatchery fish with naturally produced fish and predation on hatchery fish by avian or other predators. The default release method will incorporate a volitional approach, as approved by the HCP HC, unless it can be demonstrated other approaches are better. The monitoring data collected for each stock are described below.

Chiwawa and Methow Spring Chinook

Pre-release sampling data will be conducted consistent with Murdoch and Peven (2005), including individual weights to the nearest 0.1 gram. Data collected will support monitoring questions 9.1, 9.2, 9.3 and 9.4 in the updated monitoring and evaluation plan (Hillman et al. 2013). PIT tag monitoring of spring Chinook released in the Chiwawa River will occur during the release period (April). Juvenile Chinook will pass through two 92-cm diameter PIT-tag antennas connected to Allflex 310 readers and Quantitative Sampling Technologies (QST) QuBE data logger. The release location and type (i.e., volitional, forced, or trucked) are recorded for each observation file created and uploaded to the PTAGIS database maintained by the Pacific States Marine Fisheries Commission after each year of release. PIT-tagged fish in each observation (release) file are assumed to represent untagged fish. Observation files contain the PIT tags associated with the original tag files and will be used for analysis (see Post-release Monitoring Section). The total number of fish released will be based on the population size at CWT tagging (100%), subtracting mortality enumerated by hatchery staff that occurred from tagging to release.

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Wenatchee Summer Steelhead–
Pre-release sampling will be conducted consistent with Murdoch and Peven (2005), including individual weights to the nearest 0.1 gram. Data collected will support monitoring questions 9.1, 9.2, 9.3 and 9.4 in the updated monitoring and evaluation plan. Monitoring of steelhead released in the Wenatchee River sub-basin will occur during loading of fish into transport trucks, unless fish are released directly into the Chiwawa River. Steelhead will pass through a series of PIT-tag antennas, each connected to a data logger, thereby allowing the creation of a PIT-tag observation file for each truckload of steelhead consisting of unique tag records. The release location (stream and rkm), release type (volitional or forced), and hatchery group (HxH or WxW) will be recorded for each tag file created. PIT-tagged fish in each observation (release) file are assumed to represent untagged fish. However, because PIT-detection efficiency during loading will not be 100%, the number of fish in each truckload will be estimated using volumetric displacement. Observation files contain the PIT tags associated with the original tag files and will be used for analysis (see Post-release Monitoring Section). The total number of fish released will be based on the population size at CWT tagging (100%), subtracting mortality enumerated by hatchery staff that occurred from tagging to release.

Wenatchee and Chelan Falls Summer Chinook
Pre-release sampling will be conducted consistent with Murdoch and Peven (2005), including individual weights to the nearest 0.1 gram. Data collected will support monitoring questions 9.1, 9.2, 9.3 and 9.4 in the updated monitoring and evaluation plan. Should PIT tagging occur, a monitored release strategy consistent with other Chinook stocks (i.e., Chiwawa Spring Chinook) will be implemented. The total number of fish released will be based on the population size at CWT tagging (100%), subtracting mortality enumerated by hatchery staff that occurred from tagging to release.

2.4 Post-Release Monitoring and Survival Analysis
Data will be collected during rearing, acclimation, release, and the emigration period that may prove valuable in explaining variability in adult survival (Murdoch and Peven 2005). Rearing densities have been reported to influence the survival of hatchery fish (Martin and Wertheimer 1989; Banks 1994) and may also be linked to disease prevalence during rearing (Banks 1994; Ogut and Reno 2004). Acclimation of hatchery fish before release has been found to increase survival and reduce stray rates when the duration of the acclimation period is sufficient (Clarke et al. 2010, 2012; Rosenberger et al. 2013). These metrics (i.e., rearing density and acclimation period) will be collected annually to determine their influence on fish survival.

PIT-tagged groups of hatchery fish will be used to estimate survival during their emigration. Variation in survival during the emigration period may also inform observed adult survival rates. Survival during emigration and travel will be estimated using interrogation or release files and the standard Cormack-Jolly-Seber (CJS) estimator. CJS estimates are termed apparent survival estimates because it is unknown whether fish suffered mortality (e.g., size or time of release) or simply failed to emigrate (i.e., residualized or were precocial males). In the latter case, the proportion of PIT-tagged fish detected in the Methow sub-basin, Wenatchee or Columbia rivers after the emigration period is complete may explain variation in smolt survival rates. The post-release performance of PIT-tag groups will be estimated and monitored annually, consistent

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with methods in Murdoch and Peven (2005). Additionally, precocity of hatchery releases will be evaluated by examining the proportion of PIT tag releases detected in adult fish ladders and tributaries within the same year as release.

3. Juvenile Monitoring

Data collected during these elements primarily support monitoring questions 2.1.1 and 2.2.1. and the monitoring objectives described in Table 4 (Hillman et al. 2013). Table 4 below provides a summary of the variables to be measured in 2018 under the juvenile monitoring component and what objective the measure supports. The text that follows in this section further describes the activities.

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Table 4. Monitoring and Evaluation Plan (Hillman et al. 2013) objectives and the associated measured variables for the juvenile monitoring component.

Objective	Measured Variables *(Applicable Study Component(s))*
Objective 2: Determine if the proportion of hatchery fish on the spawning grounds affects the freshwater productivity of supplemented stocks.	• Number of juveniles (smolts, parr [where appropriate], and emigrants) (*Freshwater Productivity of Supplemented Stocks*)

3.1 Freshwater productivity of Supplemented Stocks

Steelhead, Spring Chinook, and Summer Chinook

The freshwater productivity of supplemented stocks in the Wenatchee sub-basin will be monitored using smolt traps in the Chiwawa River and the lower Wenatchee River consistent with historical trapping efforts. Additionally, a newly derived analytical method which uses PIT-tag mark-recapture data will be utilized that reduces bias and increases precision by including estimates of emigration during the winter non-trapping periods. Up to 3,000 parr will be PIT tagged in the Chiwawa River in the fall, based on the spatial distribution and abundance estimated during parr snorkel surveys, to generate estimates of migration during the non-trapping periods. A random sample of a minimum of 10 percent of fish per remote site will be held in a live box for 24 hours to evaluate tag loss and delayed mortality. Using PIT tagged parr detections at the lower Chiwawa PIT array during the non-trapping period, the total number of PIT-tagged parr that emigrated will be estimated, and then expanded by the tag rate. Overwinter mortality of PIT-tagged parr is assumed to be the same as non-PIT-tagged parr. Overwinter survival estimates of Chiwawa River parr will be derived by estimating survival to the lower Wenatchee PIT tag array and analyses with the TribPit Survival software program and/or estimating survival of fall parr and spring smolts to McNary. PIT-tag mark-recapture trials conducted during the trapping period in the fall will also be used to estimate detection probabilities of the PIT-tag array at a given discharge level. Abundance and variance will be estimated using the same methods as those used in the smolt trap estimate. The estimated abundance and variance from each method and time period (trapping and non-trapping

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periods) will be summed to estimate a total production estimate. Under the proposed methodology, unbiased estimates of abundance during the entire migration period will be generated with relatively high precision (PSE < 15%), which is consistent with NOAA Fisheries' recommendations (Crawford and Rumsey 2011). Historical estimates will be revised using the new estimation techniques.

Specific actions to monitor the freshwater productivity of supplemented spring Chinook salmon in the Methow sub-basin have yet to be determined. As these become available, the plan will be amended and presented to the HC by December.

3.2 Tributary Evaluations

Chiwawa River

Snorkel surveys will be utilized to estimate parr abundance within the Chiwawa subwatershed during the summer. This approach has been used in the Chiwawa subwatershed since 1992. In parallel to addressing Objective 2, additional juvenile data can help to assess the habitat carrying capacity in each tributary. This information can add value to the overall M&E plans and help inform management decisions.

Sampling will follow a stratified random sampling design. Landscape classification will be used to stratify streams in the Chiwawa subwatershed that support juvenile Chinook salmon. In the Chiwawa subwatershed, WDFW found that classification "explained" most of the variability in fish numbers caused by geology, land type, valley bottom type, stream state condition, and habitat type (Hillman 2013). The same classification method was used to identify sections of the Little Wenatchee River (reference area) that corresponded to discrete reaches in the supplemented subwatersheds, but that had no release of hatchery Chinook. Consistent with previous efforts, habitat types within each land-class or reach will be identified and quantified annually. At least three units of each habitat type within each reach will be randomly selected for estimating densities of salmon and trout. Thus, overall sampling consists of a stratified- random sampling design, which increases the accuracy and precision of population estimates.

Densities of salmon and trout will be estimated in August and September by direct underwater observation within the randomly-selected habitat units. Underwater methods will follow those described by Thurow (1994), Dolloff et al. (1996), and O'Neal (2007). Habitat surface areas and volumes will be estimated during fish sampling. Numbers of fish counted will be adjusted for detection probabilities using the models published in Hillman et al. (1992). For each habitat type within a state type and reach stratum, the mean density of salmon and trout will be calculated as the ratio of mean numbers to mean area or volume sampled (Cochran 1977). Total numbers of fish will be estimated per habitat type within a state type and reach stratum as the product of mean density of fish in a given habitat type, times total area or volume of that habitat type within the stratum (Cochran 1977). Total numbers of fish within the supplemented subwatershed will be estimated as the sum of all population numbers per habitat type in state type/reach strata. Bootstrapping methods will be utilized to estimate variance and percent errors (based on 95% confidence interval) for total numbers of fish.

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4. Adult Monitoring

The adult monitoring component is comprised of two basic elements: (1) estimating spawning escapement and (2) harvest monitoring. Data collected during these elements primarily support monitoring questions 1.1.1, 1.2.1, 2.1.1, 2.2.1, 3.2.1, 3.2.2, 4.1.1, 5.1.1, 5.2.1, 5.3.1, 5.3.2, 6.3.1, but also contribute data to monitoring questions 6.1.1, 6.2.1, 8.1.1, 8.2.1, 8.4.1, 10.1.1, 10.1.2, 10.1.3 and 10.1.4. Table 5 below provides a summary of the variables to be measured in 2018 under the adult monitoring component and what objective the measure(s) supports. The text that follows in this section further describes the activities.

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Table 5. Monitoring and Evaluation Plan (Hillman et al. 2013) objectives and the associated measured variables for the adult monitoring component.

Objective	Measured Variables *(Applicable Study Component(s))*
Objective 1: Determine if conservation programs have increased the number of naturally spawning and naturally produced adults of the target population and if the program has reduced the natural replacement rate (NRR) of the supplemented population.	• Number of hatchery and naturally produced fish on spawning grounds *(Spawning Escapement Estimates)* • Number of hatchery and naturally produced fish taken for broodstock (*Broodstock Collection and Stock Assessment*) • Number of hatchery and naturally produced fish taken in harvest (if recruitment is to the Columbia) *(Harvest Reporting)*
Objective 2: Determine if the proportion of hatchery fish on the spawning grounds affects the freshwater productivity of supplemented stocks.	• Number of hatchery and naturally produced fish on the spawning grounds (*Spawning Escapement Estimates*) • Number of redds *(Spawning Escapement Estimates)*
Objective 3: Determine if the hatchery adult-to-adult survival (i.e., hatchery replacement rate, HRR) is greater than the natural adult-to-adult survival (i.e., natural replacement rate, NRR) and the target hatchery survival rate.	• Number of hatchery and naturally produced fish on spawning grounds *(Spawning Escapement Estimates)* • Number of hatchery and naturally produced fish harvested *(Harvest Reporting)*
Objective 4: Determine if the proportion of hatchery-origin spawners (pHOS or PNI) is meeting management target.	• Number of hatchery and naturally produced fish on spawning grounds *(Spawning Escapement Estimates)*
Objective 5: Determine if the run timing, spawn timing, and spawning distribution of the hatchery component is similar to the natural component of the target population or is meeting program-specific objectives.	• Time (Julian date) of hatchery and naturally produced salmon carcasses or marked steelhead detected on spawning grounds within defined reaches *(Spawning Escapement Estimates)* • Time (Julian date) of arrival at mainstem projects and within tributaries (e.g., traps, PIT arrays) with

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Objective	Measured Variables *(Applicable Study Component(s))*
	the intent to identify biologically significant differences *(Spawning Escapement Estimates)* • Location (GPS coordinates) of female salmon carcasses observed on spawning grounds *(Spawning Escapement Estimates)*
Objective 6: Determine if stray rate of hatchery fish is below the acceptable levels to maintain genetic variation among stocks.	• Number of hatchery fish collected for broodstock (*Broodstock Collection and Stock Assessment*) • Number of hatchery fish taken in fishery (*Harvest Reporting*) • Locations of live and dead strays (used to tease out overshoot) *(Spawning Escapement Estimates)* • Number of hatchery carcasses (PIT-tagged and/or CWT) found in non-target and target spawning areas or number of returning spawners counted via PIT-tag detection or at weirs in close temporal proximity to spawning areas (stray data into the Entiat sub-basin will be obtained from USFWS Fisheries Resource Office-Leavenworth) *(Spawning Escapement Estimates)*
Objective 8: Determine if hatchery programs have caused changes in phenotypic characteristics of natural populations.	• Total and salt (ocean) age and gender of hatchery and naturally produced salmon carcasses collected on spawning grounds *(Spawning Escapement Estimates)* • Whenever possible, age at maturity and sex ratio will be measured at weirs or dams near the spawning stream to avoid the size-related carcass recovery bias on spawning grounds (carcass sampling or ultrasound on live fish) *(Spawning Escapement Estimates)* • Assess age of fish, including harvested fish *(Spawning Escapement Estimates and Harvest Reporting)*
Objective 10: Determine if appropriate harvest rates have been applied to conservation, safety-net, and segregated harvest programs to meet the HCP/SSSA goal of providing harvest opportunities while also contributing to population management and minimizing risk to natural populations.	• Numbers of hatchery fish taken in harvest *(Harvest Reporting)* • Numbers of natural-origin fish taken in harvest *(Harvest Reporting)*

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4.1 Spawning Escapement Estimates

Chelan Summer/Fall Chinook

Chinook spawning ground surveys will be conducted in the Chelan River and (see Appendix A for survey reaches). Spawning ground surveys will be conducted via foot or raft beginning late September and continuing until spawning has ended (usually mid-November). Frequency of surveys will vary depending on method.

Summer Chinook carcass surveys will be conducted in the Chelan River beginning in September and ending in November consistent with methods described in Murdoch and Peven (2005). A representative sample (i.e., 20%) of spawners as determined by spawner abundance and distribution (typically 100% of the carcasses encountered in the Chelan River) will be sampled. Biological data will include collection of scale samples for age analysis, length measurements (POH and FKL), gender, egg voidance, and a check for tags or marks. DNA samples (five-hole punches from operculum) will be collected as needed to address different objectives. These data will be used to assess length-at-age, size-at-age, egg voidance, origin (hatchery or naturally produced), stray rates, and genetics. All carcass surveys will be conducted within the historical reaches.

Wenatchee Steelhead

The number of hatchery and naturally produced steelhead returning to the Wenatchee sub- basin will be estimated using a PIT tag mark recapture model. The estimated spawner abundance for the Wenatchee steelhead population will be a combination of PIT tag-based tributary and redd-based mainstem Wenatchee River estimates. Steelhead redd counts will be conducted weekly in all major spawning areas in the mainstem Wenatchee River (see Appendix A for survey reaches); minor spawning areas in the mainstem Wenatchee River will be surveyed once, based on the spawn timing in adjacent major spawning areas, to estimate redd abundance at peak spawning. The estimated total number of redds in the Wenatchee River mainstem will be expanded by the sex ratio of the population to estimate spawner abundance. Spawner abundance in tributaries of the Wenatchee River will be estimated using a PIT tag mark recapture model.

Chiwawa Spring Chinook

Chiwawa spring Chinook spawning escapement will be estimated based on the total number of redds found in each tributary (Murdoch et al. 2010) using methods described in Murdoch and Peven (2005). Weekly redd and carcass surveys will be conducted simultaneously from the first week of August through September (see Appendix A for survey reaches). Redd-based estimates assume that each female constructs one redd, which WDFW has found to be appropriate for this population (Murdoch et al. 2009). The total number of redds in each reach will be estimated using methods described in Millar et al. (2012) and using the observer efficiency model currently under development by WDFW. Redd counts will be expanded and the number of hatchery and naturally produced fish will be estimated using methods in Murdoch et al. (2010). Carcasses encountered during surveys will be sampled according to methods outlined in Murdoch and Peven (2005). All CWTs (i.e., snout or adipose) from carcasses will be read and the data entered into the Regional Mark Processing Center database within one year of collection.

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Additionally, all redds and female carcasses will be geo-referenced using hand-held GPS devices. Carcass recovery bias has been detected in the Chiwawa spring Chinook population (Murdoch et al. 2010) and if not corrected will bias estimates of hatchery and naturally produced fish on the spawning grounds. While it may be appropriate to correct for carcass recovery bias for some monitoring questions (e.g., 2.2), when comparisons to reference populations are made in monitoring questions 1.1.and 1.2, carcass bias will not be corrected because other monitoring programs have not corrected for a similar bias.

Wenatchee Summer Chinook

Wenatchee summer Chinook spawning ground counts will begin the first week in September and continue through the end of spawning in November (see Appendix A for survey reaches). Total census redd counts will be conducted by foot or raft depending on stream size, flow, and density of spawners within the stream reach (see Appendix A for survey reaches). All stream reaches will be surveyed once per week. Redd data will be collected using methods described in Murdoch and Peven (2005). The total number of redds in each reach will be estimated using methods described in Millar et al. (2012) and using the observer efficiency model currently under development by WDFW. Weekly ground-based census counts and the true number of redds (determined via intensive surveys) will be compared in order to generate observer efficiency. River characteristics (e.g., channel width, water depth, discharge, visibility, and habitat complexity), observer experience, and survey effort will be incorporated into a model to predict observer efficiency in all river reaches. Predicted redd generate observer efficiency for each river reach will be used to adjust ground-based redd counts to estimate the total reach redd count. Ground-based surveys will also be used to estimate redd life for each river reach. The estimated spawner abundance in the Wenatchee River and an associated level of precision will be calculated using the estimated total redd count for each reach, mean redd life, and the sex ratio of the population similar to methods described in Millar et al. (2012). Salmon carcass data collected during spawning ground surveys will be consistent with Murdoch and Peven (2005). All CWTs (i.e., snout or adipose) from carcasses will be sent to the WDFW lab in Olympia. The CWT lab will extract and read CWTs and submit all required information to RMIS within one year of collection.

4.2 Harvest Reporting

In years when the expected hatchery adult returns are in excess of the levels needed to meet the hatchery program goals (i.e., broodstock and/or escapement), surplus fish may be available for harvest. Harvesting or removal of surplus hatchery fish may have benefits to the natural populations by reducing potential negative ecological and genetic impacts (e.g., density dependent effects, loss of fitness, and loss of genetic variation). The contribution of hatchery fish to fisheries will be monitored using CWT recoveries on a brood-year basis supporting Objective 10.

To obtain the necessary data to determine if the harvest rates are meeting objectives, a statistically valid creel program will be designed and implemented for all sport and/or conservation fisheries in the Upper Columbia River to estimate harvest of hatchery fish from

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both Chelan and Grant County PUD funded hatchery programs (Murdoch and Peven 2005). Information collected during creel surveys are an integral component to calculating the HRR (Objective 3), particularly given most CWT recoveries for PUD mitigation programs occur in the Upper Columbia River and its tributaries, with the exception of summer Chinook where most CWT recoveries occur in ocean fisheries. Because of considerable time lags in reporting of CWT's to the Regional Marking Information System (RMIS) database, it requires an ongoing query of recovery data until the number of estimated fish does not change.

5. Data Management , Analysis, and Reporting

5.1 Data Management

A Microsoft Access database maintained by WDFW will contain all the monitoring data collected for hatchery evaluations. The database will contain and manage all data associated with aquaculture monitoring, juvenile monitoring, and adult monitoring.

All data entered into the database are evaluated for quality control and quality assurance by WDFW. Quality control checks using analyses such as modified Z-scores, boxplots, and the Generalized Extreme Studentized Deviate Procedure (Iglewicz and Hoaglin 1993) will be conducted for all data entry. In the event outliers are identified, discussion will occur on whether identified outliers are true data points or transcription errors. This process ensures that the data used to test statistical hypotheses are correct and accurate.

5.2 Data Analysis

The analyses proposed are consistent with the Monitoring and Evaluation Plan for PUD Hatchery Programs: 2013 Update (Hillman et al. 2013). Each of the objectives will be addressed using the appropriate statistical tests, as well as graphic analyses that convey relevant information.

5.3 Reporting

An annual M&E report will be generated following the completion of each calendar year and will be available for HCP-HC review by June 1 of the following year. Additionally, monthly progress reports will be made available to the HCP-HC.

6. Lake Wenatchee Sockeye Salmon

The Chelan PUD will conduct monitoring and evaluation (M&E) activities to track key population attributes related to Lake Wenatchee sockeye salmon in 2018(Table 6). In the absence of a sockeye hatchery program, M&E activities are no longer rooted in the context of evaluating the effects of sockeye salmon supplementation, but instead focus directly on the performance of the natural population, which is a unique departure from historic monitoring obligations. Broadly, the proposed M&E activities cover juvenile and adult life history stages and provide the data necessary to track or estimate viable salmonid population parameters (VSP): abundance, productivity, spatial structure and diversity (McElhaney et al. 2000). The data collected may also have utility in future hatchery compensation recalculation efforts.

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Chelan PUD is conducting these M&E activities to support commitments made under the 2011 hatchery recalculation effort, which also included a steelhead production commitment for a sockeye species swap (SOA 2011). This section of the implementation plan describes the specific commitments by juvenile and adult life history stages.

6.1 Juvenile Monitoring

Chelan PUD will conduct or fund activities to monitor and evaluate the temporal distribution and age/size of out-migrating smolts, and estimate smolt production (Table 6). Smolt production will be estimated from data collected at the lower Wenatchee smolt trap and via back calculations based on collected adult return data (i.e., age-at-return estimates, SARs, and adult escapement to the tributaries). Collectively, these activities include: (1) funding of the lower Wenatchee River smolt trap concurrent with efforts aimed at evaluating Chelan PUD funded supplemented populations in the Wenatchee River sub-basin; (2) tagging up to 5,000 PIT tags for natural-origin juveniles encountered during smolt trapping activities and collecting scale samples at this location; and (3) estimating adult escapement estimates to the tributaries, and collection of adult return data at Tumwater (see the *Adult Monitoring* section for details) to back-calculate smolt production.

The monitoring data obtained will provide a useful set of tools for evaluating the performance of natural origin sockeye salmon within the sub-basin and downstream and also support the evaluation of VSP parameters [e.g., outmigration timing and size (diversity); and PIT tagging juveniles for SAR estimates (productivity)].

6.2 Adult Monitoring

Several M&E activities associated with adult returns of Lake Wenatchee sockeye salmon will be conducted and/or funded by Chelan PUD (Table 6). These efforts include (1) continuation of accurate adult counts at Rock Island, Rocky Reach, and Tumwater dams; (2) sampling of scales for age distribution, sex ratio determination, and returns of PIT-tagged adults at Tumwater Dam; (3) reach-specific conversion estimates between Rock Island Dam and spawning grounds in the White and Little Wenatchee rivers (i.e., Rock Island to Tumwater Dam to spawning tributaries); and (4) providing between 250 to 1,000 PIT tags to estimate adult spawning escapement in the Little Wenatchee and White rivers utilizing PIT tags and mark-recapture techniques (the software program Sample Size 2.0.7, developed by the University of Washington School of Aquatic and Fisheries Science (P. Westhagen, J. Lady, and J. Skalski) was used to determine the minimum number of tags required (i.e., 250) to estimate adult sockeye escapement at a +/- 7 percent confidence interval). Chelan PUD will adjust the number of PIT-tagged individuals in order to maintain precision in estimates at the lowest rate of interference to migrating populations, if it is warranted due to annual changes in escapement and detection probabilities. In an effort to PIT tag the run at large, adults will be PIT tagged at Tumwater consistent with the Tumwater Operations Protocol, daily throughout the run.

Collectively, these data will provide reliable metrics of adult returns and spawning escapement (abundance), recruits-per-spawner (productivity), distribution of spawners among tributaries (spatial structure), and run-timing and age structure for adult immigrants (diversity).

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Table 6. Chelan PUD's proposed Lake Wenatchee sockeye salmon monitoring and evaluation activities.

Life History Stage	M&E Activity	Entity Performing the Activity	Related analysis	VSP parameter addressed
Juvenile	Concurrent operation of the lower Wenatchee smolt trap to collect juvenile outmigration data	WDFW	Generate distribution of outmigration timing, estimate smolt production and determine average smolt size.	Diversity and productivity
Juvenile	PIT tagging smolts at lower Wenatchee smolt trap (up to 5,000 fish annually) and collecting/aging scale samples	WDFW	Estimate smolt-to-adult returns.	Productivity
Juvenile	Develop adult return based smolt production estimates	WDFW	Use collected data (i.e., adult age-at-return data, SARs, adult escapement to the tributaries) to back-calculate smolt production.	Productivity
Adult	Rock Island and Rocky Reach Dam adult counts	CPUD	Initial spawner abundance (Okanogan stock separation)	Abundance and spatial structure
Adult	PIT tag subsample (250 adults) of returning adults at Tumwater Dam to support mark-recapture evaluation	WDFW	Calculate spawner abundance and relative distribution among ~~in~~ tributaries	Abundance and spatial structure
Adult	Collect and age scales[1] and determine sex via ultrasound from returning adults at Tumwater Dam	WDFW	Estimate age-at-return, sex ratio, and relative productivity of contributing spawner cohorts	Productivity and diversity
Adult	Tumwater Dam adult counts	WDFW	Estimate potential spawner abundance (pre Lake-Wenatchee harvest), potential productivity (recruits/spawner), and run timing distribution	Abundance and diversity
Adult	Operate PIT detection arrays on Little Wenatchee and White River	WDFW	Calculate spawner abundance (post-Lake Wenatchee harvest and other mortality), actual productivity (recruits/spawner), and entry-to-spawning-habitat timing distribution, and spatial spawner distribution among tributaries	Abundance, productivity, spatial structure, and diversity
All	Data management, analysis, and reporting	BioAnalysts CPUD	------	NA

[1] Scales would be collected concurrently from adults that are PIT tagged at Tumwater Dam.

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Appendix A

Designated survey reaches for Methow subbasin summer Chinook spawning ground surveys.

River	Reach	Code	RM
Methow	Mouth to Methow Bridge	M1	0.0-14.78
	Methow Bridge to Carlton Bridge	M2	14.78-27.17
	Carlton Bridge to Twisp Bridge	M3	27.17-39.55
	Twisp Bridge to MVID	M4	39.55-44.85
	MVID to Winthrop Bridge	M5	44.85-49.80
	Winthrop Bridge to Hatchery Dam	M6	49.80-51.55

Designated survey reaches for Wenatchee River basin summer Chinook spawning grounds surveys. Asterisks denotes reaches where redd observer efficiency will be assessed.

Reach Code	Reach Section	River Mile
W10	Lake Wenatchee to Bridge	54.20-53.58
	Bridge to Swamp *	53.58-52.66
	Swamp to Chiwawa River	52.66-48.39
W9	Chiwawa River to Schugart Flats	48.39-47.93
	Schugart Flats to Old Plain Bridge	47.93-46.21
	Old Plain Bridge to RR Bridge	46.21-41.91
	RR Bridge to RR Tunnel	41.91-39.28
	RR Tunnel to Swing Pool *	39.28-36.67
	Swing Pool to Tumwater Br	36.67-35.55
W8	Tumwater Br to Swiftwater Campground *	35.55-33.50
	Swiftwater Campground to Unimproved Campground	33.50-33.08
	Unimproved Campground to Tumwater Dam	33.08-30.91
W7	Tumwater Dam to Penstock Br	30.91-28.66
	Penstock Br to Icicle Road Br *	28.66-26.43
W6	Icicle Road Br to Icicle Mouth	26.43-25.61
	Icicle Mouth to Boat Takeout *	25.61-24.49
	Boat Takeout to Leavenworth Br	24.49-23.90
W5	Leavenworth Br to Irrigation Flume *	23.90-22.77
	Irrigation Flume to Peshastin Br	22.77-20.00
W4	Peshastin Br to Dryden Dam *	20.00-17.76
W3	Dryden Dam to Williams Canyon	17.76-15.54
	Williams Canyon to Upper Cashmere Br	15.54-10.22
	Upper Cashmere Br to Lower Cashmere Br	10.22-9.49
W2	Lower Cashmere Br to Old Monitor Br *	9.49-7.12
	Old Monitor Br to Sleepy Hollow Br	7.12-3.27
W1	Sleepy Hollow Br to River Bend *	3.27-1.73
	River Bend to Siphon	1.73-1.29
	Siphon to Mouth	1.29-0.45

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Designated survey reaches for Wenatchee Basin spring Chinook spawning grounds surveys.

Reach Code	Reach Section	River Mile
Chiwawa River and Tributaries (Rock and Chikamin)		
C7	Buck Cr to Phelps Cr	36.39-33.46
C6	Phelps Cr (Trinity) to Maple Cr Br	33.46-29.64
C5	Maple Cr Br to Atkinson Flats	29.64-26.59
C4	Atkinson Flats to Schaefer Cr	26.59-24.24
C3	Schaefer Cr to Rock Cr Campground	24.24-22.97
R1 - Rock	Mouth to Chiwawa River Road Bridge	0.00-1.05
C2	Rock Cr Campground to Grouse Cr	22.97-12.27
K1 - Chikamin	Mouth to Chiwawa River Road Bridge	0.00-0.68
C1	Grouse Cr to Mouth	12.27-0.00
Nason Creek		
N4	White Pine Creek to Lower R.R. Bridge	16.09-13.68
N3	Lower R.R. Bridge to Hwy 2 Bridge	13.68-9.13
N2	Hwy 2 Bridge to Kahler Cr	9.13-4.46
N1	Kahler Cr to Mouth	4.46-0.00
White River and Tributaries (Panther and Napeaqua)		
H4	Falls to Grasshopper Meadows	21.16-19.78
T1 - Panther	Boulder field to Mouth	0.43-0.00
H3	Grasshopper Meadows to Napeaqua River	19.78-17.59
Q1 - Napeaqua	Take out to Mouth	0.91-0.00
H2	Napeequa River to Sears Cr Bridge	17.59-11.97
H1	Sears Cr Bridge to Mouth	11.97-0.00
Little Wenatchee River		
L3	Rainy Cr to Lost Cr	10.78-6.74
L2	Lost Cr to Old Fish Weir	6.74-2.13
L1	Old Fish Weir to Mouth	2.13-0.00
Upper Wenatchee River		
W10	Lake Wenatchee to Chiwawa River	54.20-48.39
Chiwaukum Creek		
U1	Metal bridge to Mouth	1.0 – 0.0
Icicle River		
I1	Hatchery to Mouth	3.02-0.00
Peshastin Creek and Tributaries (Ingalls Creek)		
D1 - Ingalls	Trailhead to mouth	0.64-0.00
P2	Ingalls Creek to Camas Cr	9.14-5.63
P1	Camas Cr to Mouth	5.63-0.00

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Designated survey reaches for Wenatchee River basin steelhead spawning grounds surveys. Asterisks denote index reaches. Spawning escapements in tributaries will be estimates using PIT-tag arrays.

Reach Code	Reach Section	River Mile
W10	Lake Wenatchee to Chiwawa River*	54.20-48.39
W9	Chiwawa River to Tumwater Bridge*	48.39-35.55
W8	Tumwater Br to Swiftwater Campground	35.55-33.50
	Swiftwater Campground to Unimproved Campground*	33.50-33.08
	Unimproved Campground to Tumwater Dam	33.08-30.91
W7	Tumwater Dam to Icicle Road Bridge	30.91-26.43
W6	Icicle Road Br to Leavenworth boat ramp*	26.43-24.49
	Boat Takeout to Leavenworth Bridge	24.49-23.90
W5	Leavenworth Bridge to Peshastin Bridge	23.90-20.00
W4	Peshastin Bridge to Dryden Dam	20.00-17.76
W3	Dryden Dam to Lower Cashmere Bridge	17.76-9.49
W2	Lower Cashmere Bridge to Sleepy Hollow Bridge *	9.49-3.27
W1	Sleepy Hollow Bridge to Mouth	3.27-0.45

Tributary	River mile of PIT tag array
Mission Creek	0.54
Peshastin Creek	1.91
Chumstick Creek	0.31
Icicle River	0.26
Chiwaukum Creek	0.24
Chiwawa River	0.58
Nason Creek	0.52
Little Wenatchee River	1.74
White River	1.65

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State of Washington
Department of Fish and Wildlife
Wenatchee Research Office
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Date: April 6th, 2017
To: HCP Hatchery Committee
From: McLain Johnson, Team Leader (WDFW)
Cc: Mike Tonseth, Permit Biologist and HC Representative (WDFW)
Todd Seamons, Director of Molecular Genetics Laboratory (WDFW)
Subject: Update - Hatchery M + E Genetic Monitoring Objectives

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The “Monitoring and Evaluation Plan for PUD Hatchery Programs 2013 Update,” describes investigating population genetics to monitor and evaluate hatchery programs. Specifically, Objective 7 details three monitoring indicators (‘Allele Frequency’, ‘Genetic Distances between Populations’, and ‘Effective Spawning Population’) used to examine the potential for changes in genetic diversity of natural populations as a result of hatchery programs. These investigations are scheduled to be conducted at ten year intervals, with samples for each stock and species being gathered on separate timelines (based on the completion year of the previous analyses).

Beginning in January of 2016, WDFW began preparing to investigate these genetic indicators, through a series of requests made by co-managers and the HC. These requests led to defined tasks that include: (1) Update the inventory of existing genetic samples for UC hatchery programs, (2) Gather all relevant previous reports pertinent to genetic investigations in the Upper Columbia, (3) Develop a timeline for sample collection, analyses, and reporting to meet the monitoring objectives outlined above, and, (4) Investigate a potential analyses with geneticists, this investigation would inform an updated sample interval for conducting future genetic investigations outlined in the monitoring and evaluation plan.

Below, you will find each task with a completion summary. Genetic sampling is slated to begin taking place in 2017 (spring Chinook Salmon and summer steelhead). Further, pertinent notes and questions for the future of genetic sampling are outlined beneath each summary. Attached with this document, you will find an Excel file that contains the updated inventory and upcoming sampling timeline (see tab labeled “Guide”).

(1) *Update the inventory of existing genetic samples for UC hatchery programs*.

During April and May of 2016, the WDFW Genetics lab catalogued its collection of genetic samples stowed in their temperature controlled storage room. During this effort, WDFW cross referenced and updated an existing inventory previously developed in 2010. Further, WDFW included additional stocks/samples at the request of co-managers. The additional stocks/samples were included in the inventory despite not being stored at the WDFW Genetics Lab in Olympia. These included samples from the USFWS, YN and GCPUD. The inventory is attached to the memo electronically (Tabs 1 through Tab 18 in attached file).

Notes to HC – During the development of this updated inventory, questions arose as to the future of historic samples. The inventory provides insight of what questions are possible to ask, and the historic samples will be relevant to those questions. Will historic samples be used in upcoming analyses? If so, which samples? There may be limitations to the amount and condition of genetic material available in some cases. Further, advancements (SNP markers) in genetic profiling would make historic samples more informative, but the historic samples would need to be extracted and analyzed to use these new developed markers. Currently, samples from USFWS programs are included in the inventory, but are not included in the timeline. Is there a desire to include USFWS programs need to be included in the timeline? They report on a different schedule, and samples are stored in a separate lab (Abernathy).

(2) *Gather all relevant previous reports pertinent to genetic investigations in the Upper Columbia*.

During June and July of 2016, WDFW conducted a review of the literature and assembled a report list. This activity involved a series of meetings with co-managers and the Genetics Lab. A list of relevant reports and literature is included with the inventory and timeline file attached electronically (Tab “Guide”, Column E).

Notes to HC – As previous research/reports were being gathered, it was clear that many hatchery programs have evolved (e.g. differing broodstock, release locations, mating crosses) since the inception the programs. Previous analyses may not be comparable to upcoming analyses. The availability and quantity of historic samples will shape what analyses can be performed. Do upcoming analyses need to be comparable to previous analyses? How will program changes influence the scope of the analyses?

(3) *Develop a timeline for sample collection, analyses, and reporting to meet the monitoring objectives*.

From July through November of 2016, WDFW met with co-managers and the Genetics Lab on several occasions to discuss time frame and logistics (e.g., manpower, sample location, sample frequency, sample amount, analyses timeframe, etc.). Stocks/programs were also added to the timeline at request of co-managers (e.g., CCT). Attached electronically is the timeline (with collection and reporting schedule, on Tab 19).

Notes to HC – SNP markers/panels have been developed for many of the stocks/species to be examined in the timeline. However, there may be further refinement of SNP panels for some stocks/species, which may add time (and cost) to the analyses. Do we need to use SNP's for all programs? Other labs or groups may have SNP panels that could be borrowed and used, but that will take more coordination. Also, the timeline spreads the genetic work over a five year period. This allows for two years of collection, a year of analyses, and a different species to be examined annually. This may lengthen the sampling interval for some programs to greater than ten years. Is this acceptable? Finally, how do conservation programs fit into monitoring and evaluation analyses? Would there be different criteria in evaluating whether there are hatchery impacts (as opposed to safety net or harvest programs)?

(4) *Investigate potential analyses with geneticists, this investigation would inform an updated sample interval for conducting future genetic investigations outlined in the monitoring and evaluation plan.*

During February of 2017, WDFW consulted with two specialists (Scott Blankenship at Cramer Fish Sciences and Todd Seamons at WDFW Genetics Lab) to explore the potential of conducting an analyses to derive an adequate sample interval for genetic investigations. There comments are quoted below:

<u>From Todd Seamons</u>:

"The first thing we would need to do for a power analysis is decide on the specific statistical tests that we would be using for the analysis. There is some guidance in the Upper C M&E plan, but we typically tackle the question from a lot of different angles. The more statistical analyses we choose at the beginning, the more effort for the power analysis. We could focus on one or two tests with the caveat that the power analysis is only relevant for those tests.

The power of the statistical tests relies on both the genetic power (i.e., the type and number of markers) and sample sizes, and we would necessarily cover several different time periods or some continuous range of time, since that's the question driving the request for the power analysis in the first place. Covering a lot of that sample space would take a lot of time. We would evaluate SNP markers only. In order to reduce the time, we could focus on one or two different numbers of markers and one or two sample sizes, again with caveats.

We would probably tackle this with both simulated and empirical data.

Hatchery production can have a number of effects on wild fish, thus modeling the effects (e.g., with simulated data) could involve any number of covariates and would necessarily involve simplifying assumptions. Each covariate increases the complexity of the model and the time needed to evaluate it. To do it right, we'd likely want to do some sort of sensitivity analysis to violation of assumptions, which could add substantial amount of time."

From Scott Blankenship:

"Yes, I agree with Todd, the more metrics folks care to look at the more effort it will take to configure and implement.

As I mentioned, the analyses done by NMFS regarding recovery planning (specifically population viability) may provide you a starting place to discuss the logic and underlying issues of evaluating population on the 2-3 generation time frame.

Some more food for thought. On the whole, the couple decades of hatchery evaluations appears to have landed on a few topics to consider. Very broadly these are: 1) Reproductive Success; 2) Life history traits alterations; 3) Hatcheries goals; 4) Co-existence. I am not suggesting it is appropriate to bring these issues up to various hatchery committees, but some of these issues may be floating around. Taking a more restricted genetics only view, some standard topics to consider are loss of within-population genetic diversity, homogenization, reduction in effective population size (N_e), and domestication selection. Interestingly, Peven and Murdoch 2005 attempted to deal with all those except domestication. Although, I acknowledge what would be considered an evaluation of diversity probably has changed in the past 10 years."

Please let me know if you have any questions.

Best,

McLain Johnson

McLain Johnson

Species	Stock	Tab	Notes	Relevent Reports
Spring Chinook	Wenatchee River	1		Blankenship et al. 2009, Williamson et al. 2010, Ford et al 2012, 2015
Spring Chinook	Entiat River	2		Blankenship et al. 2009, Williamson et al. 2010, Ford et al 2012, 2015
Spring Chinook	Methow River	3		Small et al. 2007
Spring Chinook	Okanogan River	4		none (new addition to the inventory)
Spring Chinook	Mixed Program/Populations	5	no further analyses needed	Blankenship et al. 2009, Small et al. 2007, Ford et al (in progress), with Seamons et al (in progress)
Steelhead	Wenatchee River	6		Seamons et al. 2012
Steelhead	Entiat River	7		Seamons et al. 2012, Annual RRS Reports to BPA
Steelhead	Methow River	8		Blankenship et al., Twisp RRS
Steelhead	Okanogan River	9		none (new addition to the inventory)
Steelhead	Mixed Program/Populations	10	no further analyses needed	
Summer Chinook	Wenatchee River	11		Kassler et al. 2011
Summer Chinook	Methow River	12		Kassler et al. 2011
Summer Chinook	Okanogan River	13		Kassler et al. 2011
Summer Chinook	Mixed Program/Populations	14	add Chief Joseph program?	Kassler et al. 2011
Sockeye	Wenatchee	15		Blankenship et al. 2009
Sockeye	Okanogan	16		none (new addition to the inventory)
Fall Chinook	Hanford Reach	17	waiting on CRITFC	waiting on CRITFC
Mixed	USFWS Stocks	18	Provided by Matt Cooper	Smith and Adams 2011, Smith 2012
Timeline	Genetic Sampling Timeline	19		

Species	Stock	Source	Origin	Brood	Run	Stage	Location	Code	*N*	MGL N	genotyped	panel	report n	Report	Notes
Spring Chinook	Chiwawa	carcass	N		1989	A	WDFW	89AZ		NA	microsats	GAPS	38	Blankenship et al.	
Spring Chinook	Chiwawa				1993		WDFW	93DJ		100	microsats	GAPS	96	Blankenship et al.	
Spring Chinook	Chiwawa				1994		WDFW	94DI		100	microsats	GAPS	96	Blankenship et al.	
Spring Chinook	Chiwawa				1996		WDFW	96BN		18	microsats	GAPS	18	Blankenship et al.	
Spring Chinook	Chiwawa	Broodstock	H		1998	A	WDFW	98DS		32	microsats	GAPS	32	Blankenship et al.	
Spring Chinook	Chiwawa	Broodstock	H		2000	A	WDFW	00DM		51	microsats	GAPS	48	Blankenship et al.	
Spring Chinook	Chiwawa				2001		WDFW	01EN		348	microsats	GAPS	96	Blankenship et al.	
Spring Chinook	Chiwawa	Tumwater Dam	H	2004	2004	A	WDFW	04NF	1324	2859*	microsats	GAPS	235	Blankenship et al.	*2875 samples total for all 04NF
Spring Chinook	Chiwawa				1993		WDFW	93DH		100					
Spring Chinook	Chiwawa				1993		WDFW	93DI		100					
Spring Chinook	Chiwawa				1993		WDFW	93FM		8					
Spring Chinook	Chiwawa	Broodstock	W		1998	A	WDFW	98DR		15					
Spring Chinook	Chiwawa		W		2000		WDFW	00DL		43					
Spring Chinook	Chiwawa	Broodstock			2002	A	WDFW	02IC		72					
Spring Chinook	Chiwawa	Tumwater Dam	W	2004	2004	A	WDFW	04NF	901	2859*					*2875 samples total for all 04NF
Spring Chinook	Chiwawa	Tumwater Dam	H	2004	2004	J	WDFW	04NF	634	2859*					*2875 samples total for all 04NF
Spring Chinook	Chiwawa	Smolt Trap	W	2004	2005	J	NMFS	33720	576	0					
Spring Chinook	Chiwawa	Tumwater Dam	W	2005	2005	A	WDFW	05BG	598	4105*					*4206 samples total for all 05BG
Spring Chinook	Chiwawa	Tumwater Dam	H	2005	2005	J	WDFW	05BG	293	4105*					*4206 samples total for all 05BG
Spring Chinook	Chiwawa	Smolt Trap	H	2004	2006	S	NMFS	33870	2000	0					
Spring Chinook	Chiwawa	Smolt Trap	W	2004	2006	S	NMFS	33908	708	0					
Spring Chinook	Chiwawa	Smolt Trap	W	2005	2006	J	NMFS	34180	1243	0					
Spring Chinook	Chiwawa	Tumwater Dam	W	2006	2006	A	WDFW	06AJ	576	2388*					*2388 samples total for all 06AJ
Spring Chinook	Chiwawa	Tumwater Dam	H	2006	2006	J	WDFW	06AJ	200	2388*					*2388 samples total for all 06AJ
Spring Chinook	Chiwawa	Tumwater Dam	W	2006	2006	J	WDFW	06AJ	1	2388*					*2388 samples total for all 06AJ
Spring Chinook	Chiwawa	Smolt Trap	W	2006	2007	J	NMFS	34201	988	0					
Spring Chinook	Chiwawa	Smolt Trap	W	2005	2007	S	NMFS	34204	1152	0					
Spring Chinook	Chiwawa	Smolt Trap	H	2005	2007	S	NMFS	34207	2112	0					
Spring Chinook	Chiwawa	Tumwater Dam	H	2007	2007	A	WDFW	07BW	3235	3905*					*3905 samples total for all 07BW
Spring Chinook	Chiwawa	Tumwater Dam	W	2007	2007	A	WDFW	07BW	348	3905*					*3905 samples total for all 07BW
Spring Chinook	Chiwawa	Tumwater Dam	H	2007	2007	J	WDFW	07BW	276	3905*					*3905 samples total for all 07BW
Spring Chinook	Chiwawa	Tumwater Dam	W	2007	2007	J	WDFW	07BW	1	3905*					*3905 samples total for all 07BW
Spring Chinook	Chiwawa	Smolt Trap	H	2006	2008	S	NMFS	34385	2112	0					
Spring Chinook	Chiwawa	Smolt Trap	W	2007	2008	J	NMFS	34387	1149	0					
Spring Chinook	Chiwawa	Smolt Trap	W	2006	2008	S	NMFS	34390	2112	0					
Spring Chinook	Chiwawa (aggregate?)	Tumwater Dam	H	2008	2008	A	WDFW	08CS	5335	6035*					*6035 samples total for all 08CS
Spring Chinook	Chiwawa (aggregate?)	Tumwater Dam	W	2008	2008	A	WDFW	08CS	668	6035*					*6035 samples total for all 08CS
Spring Chinook	Chiwawa (aggregate?)	Tumwater Dam	H	2008	2008	J	WDFW	08CS	11	6035*					*6035 samples total for all 08CS
Spring Chinook	Chiwawa	Broodstock	HxW		2014	A	WDFW	14RL	196	196					
Spring Chinook	Chiwawa	adult trap	W		2015	A	WDFW	15FJ	2423	2423					
Spring Chinook	Chiwawa	Broodstock	HxW		2015	A	WDFW	15IM	109	109					
Spring Chinook	Little Wenatchee		N		1993		WDFW	93EF		30	microsats	GAPS	30	Blankenship et al.	
Spring Chinook	Nason				1993		WDFW	93EE		51	microsats	GAPS	51	Blankenship et al.	
Spring Chinook	Nason	Broodstock			2000	A	WDFW	00IQ		60	microsats	GAPS	60	Blankenship et al.	captive broodstock
Spring Chinook	Nason				2000		WDFW	00DN		46					

Species	Stock	Source	Origin	Brood	Run	Stage	Location	Code	*N*	MGL N	genotyped	panel	report n	Report	Notes
Spring Chinook	Nason				2003		WDFW	03FT		32					
Spring Chinook	Nason	Smolt Trap	W	2004	2006	S	NMFS	33907	315	0					
Spring Chinook	Nason	Smolt Trap	W	2005	2006	J	NMFS	34181	1031	0					
Spring Chinook	Nason	Smolt Trap	W	2006	2007	J	NMFS	34202	1081	0					
Spring Chinook	Nason	Smolt Trap	W	2005	2007	S	NMFS	34379	588	0					
Spring Chinook	Nason	Smolt Trap	W	2006	2008	S	NMFS	34386	846	0					
Spring Chinook	Nason	Smolt Trap	W	2007	2008	J	NMFS	34388	1000	0					
Spring Chinook	Nason	Unknown	U		2013	A	WDFW	13GA	198	198					
Spring Chinook	Nason	Broodstock	HxW		2014	A	WDFW	14RM	21	21					
Spring Chinook	Nason	Unknown	U		2015	A	WDFW	15EU	82	82					
Spring Chinook	Nason	Broodstock	HxW		2015	A	WDFW	15IN	122	122					
Spring Chinook	Wenatchee				2001		WDFW	01EM		580	microsats	GAPS	163	Blankenship et al.	
Spring Chinook	Wenatchee	Smolt Trap	W	2004	2006	S	NMFS	33871	635	0					
Spring Chinook	Wenatchee	Smolt Trap	W	2005	2007	S	NMFS	34208	1879	0					
Spring Chinook	Wenatchee	Smolt Trap	W	2006	2008	S	NMFS	34384	582	0					
Spring Chinook	Wenatchee	adult trap	HxW		2009	A	WDFW	09CH	5216	5216					
Spring Chinook	Wenatchee	adult trap	HxW		2010	A	WDFW	10DF	5618	5617					
Spring Chinook	Wenatchee	adult trap	HxW		2011	A	WDFW	11BV	6125	6125					
Spring Chinook	Wenatchee	adult trap	HxW		2012	A	WDFW	12CI	5500	5500					
Spring Chinook	Wenatchee	adult trap	HxW		2013	A	WDFW	13CB	3900	3900					
Spring Chinook	Wenatchee	adult trap	HxW		2014	A	WDFW	14FE	2027	2027					
Spring Chinook	White	carcass	W		1989	A	WDFW	89AZ		NA	microsats	GAPS	55	Blankenship et al.	
Spring Chinook	White	carcass			1991	A	WDFW	91EL		NA	microsats	GAPS	22	Blankenship et al.	
Spring Chinook	White	carcass			1992	A	WDFW	92DT		NA	microsats	GAPS	36	Blankenship et al.	
Spring Chinook	White				1993		WDFW	93EV		24	microsats	GAPS	24	Blankenship et al.	
Spring Chinook	White				2003		WDFW	03FS		5					
Spring Chinook	White	Smolt Trap	W	2005	2006	J	NMFS	34033	95	0					
Spring Chinook	White	red pump	W		2006	J	WDFW	06ES		477					
Spring Chinook	White	Smolt Trap	W	2006	2007	J	NMFS	34203	483	0					
Spring Chinook	White	Smolt Trap	W	2005	2007	S	NMFS	34206	598	0					
Spring Chinook	White	carcass	HxW		2007	mixed	WDFW	07KM	1050	0					
Spring Chinook	White	Smolt Trap	W	2007	2008	J	NMFS	34397	173	0					
Spring Chinook	White	Smolt Trap	W	2006	2008	S	NMFS	34398	95	0					

Species	Stock	Source	Origin	Brood	Run	Stage	Location	Code	*N*	MGL N	genotyped	panel	report n	Report	Notes
Spring Chinook	Entiat				1997		WDFW	97CU		97	microsats	GAPS	48	Blankenship et al.	
Spring Chinook	Entiat				1998		WDFW	98DW		17					
Spring Chinook	Entiat				2000		WDFW	00CC		15					

Species	Stock	Source	Origin	Brood	Run	Stage	Location	Code	*N*	MGL N	genotyped	panel	report n	Report	Notes
Spring Chinook	Chewuch		W		1992	A	WDFW	92DO		NA	microsats	GAPS+	47	Small et al.	
Spring Chinook	Chewuch		W		1993	A	WDFW	93DZ		104	microsats	GAPS+	104	Small et al.	
Spring Chinook	Chewuch		W		2001	A	WDFW	01AAN		128	microsats	GAPS+	115	Small et al.	
Spring Chinook	Chewuch		H		2001	A	WDFW	01AAO		188	microsats	GAPS+	108	Small et al.	
Spring Chinook	Chewuch	Carcass	M	2005	2005	A	WDFW	05HY	50	56	microsats	GAPS+	88	Small et al.	
Spring Chinook	Chewuch	Broodstock	M	2006	2006	A	WDFW	06DC	219	218	microsats	GAPS+	56	Small et al.	
Spring Chinook	Chewuch				1993		WDFW	93FN		20					
Spring Chinook	Chewuch				1995		WDFW	95DB		100					
Spring Chinook	Chewuch	Carcass			2003	A	WDFW	03GL		26					
Spring Chinook	Chewuch				2004	A	WDFW	04FF		17					
Spring Chinook	Chewuch	Carcass	M	2007	2007	A	WDFW	07AZ	51	46					
Spring Chinook	Chewuch	Broodstock	W	2008	2008	A	WDFW	08GK	48	48					
Spring Chinook	Chewuch	carcass	W	2009	2009	A	WDFW	09EA	67	67					
Spring Chinook	Chewuch	carcass	W	2010	2010	A	WDFW	10FJ	68	68					
Spring Chinook	Chewuch	carcass	W	2011	2011	A	WDFW	11EV	73						Snow added, samples at Methow Field Office 5-3-16
Spring Chinook	Chewuch	carcass	W	2012	2012	A	WDFW	12GY	55						Snow added, samples at Methow Field Office 5-3-16
Spring Chinook	Chewuch	carcass	W	2013	2013	A	WDFW	13HV	31						Snow added, samples at Methow Field Office 5-3-16
Spring Chinook	Chewuch	carcass	W	2014	2014	A	WDFW	14EJ	55						Snow added, samples at Methow Field Office 5-3-16
Spring Chinook	Chewuch	carcass	W	2015	2015	A	WDFW	15DB	60						Snow added, samples at Methow Field Office 5-3-16
Spring Chinook	Methow		W		2001	A	WDFW	01AAJ		62	microsats	GAPS+	62	Small et al.	
Spring Chinook	Methow		H		2001	A	WDFW	01AAK		512	microsats	GAPS+	142	Small et al.	
Spring Chinook	Methow	Carcass	M	2005	2005	A	WDFW	05HW	39	48	microsats	GAPS+	59	Small et al.	
Spring Chinook	Methow	Broodstock	M	2006	2006	A	WDFW	06DA	266	272	microsats	GAPS+	46	Small et al.	
Spring Chinook	Methow	Broodstock	M	2006	2006	A	WDFW	06EP	153	153	microsats	GAPS+	127	Small et al.	
Spring Chinook	Methow				1993		WDFW	93EA		93	microsats	GAPS+	100	Small et al.	
Spring Chinook	Methow				1995		WDFW	95DC		100					
Spring Chinook	Methow				1999		WDFW	99CB		94					
Spring Chinook	Methow	Broodstock	W		2000	A	WDFW	00CX		7					
Spring Chinook	Methow	Broodstock			2002	A	WDFW	02HN		93					
Spring Chinook	Methow	Carcass			2003	A	WDFW	03GJ		13					
Spring Chinook	Methow	Broodstock			2003	A	WDFW	03GK		85					
Spring Chinook	Methow				2004	A	WDFW	04FG		61					
Spring Chinook	Methow	Carcass	M	2007	2007	A	WDFW	07AX	175	175					
Spring Chinook	Methow	Smolt Trap	W	2005	2007	J	WDFW	07CD	494	494					
Spring Chinook	Methow	Broodstock	M	2007	2007	A	WDFW	07DH	154	224					
Spring Chinook	Methow	Smolt Trap	W	2006	2007	J	WDFW	07HF	47	66					
Spring Chinook	Methow	Smolt Trap	W	2006	2008	J	WDFW	08CU	637	633					
Spring Chinook	Methow	Smolt Trap	W	2007	2008	J	WDFW	08CV	94	95					
Spring Chinook	Methow	Broodstock	M	2008	2008	A	WDFW	08DM	95						Snow added, samples at MFO 5-3-17. Includes 56 wild fish. Note: MGL lists as Chiwawa wild…
Spring Chinook	Methow	Broodstock	W	2008	2008	A	WDFW	08GJ	62	62					
Spring Chinook	Methow	carcass	H	2008	2008	A	WDFW	08GM	143	143					"Methow River-hatchery Broodstock"
Spring Chinook	Methow	smolt trap	W	2007	2009	S	WDFW	09CV	105	105					
Spring Chinook	Methow	smolt trap	W	2008	2009	J	WDFW	09CW	581	581					
Spring Chinook	Methow	carcass	W	2009	2009	A	WDFW	09EB	66	66					
Spring Chinook	Methow	hatchery sampling	H	2009	2009	A	WDFW	09EC	140	140					

Species	Stock	Source	Origin	Brood	Run	Stage	Location	Code	*N*	MGL N	genotyped	panel	report n	Report	Notes
Spring Chinook	Methow	Broodstock	M	2010	2010	A	WDFW	10FG	204						Snow added, samples at MFO 5-3-17. includes 167 wild fish trapped at Wells Dam.
Spring Chinook	Methow	carcass	W	2010	2010	A	WDFW	10FI	108	108					
Spring Chinook	Methow	adult trap	H	2010	2010	A	WDFW	10FL	144	144					
Spring Chinook	Methow	adult trap	W	2011	2011	A	WDFW	11ER	159	153					"Methow Hatchery wild broodstock, Wells Dam "
Spring Chinook	Methow	carcass	W	2011	2011	A	WDFW	11EU	82						Snow added, samples at Methow Field Office 5-3-16
Spring Chinook	Methow	adult trap	H		2011	A	WDFW	11EW	10	NA					11EW samples do not exist in WDFW archive
Spring Chinook	Methow	Broodstock	W	2012	2012	A	WDFW	12DP	64						Snow added, samples at MFO 5-3-17. Fish trapped at Wells Dam.
Spring Chinook	Methow	carcass	W	2012	2012	A	WDFW	12GX	46						Snow added, samples at Methow Field Office 5-3-16
Spring Chinook	Methow	Broodstock	H	2012	2012	A	WDFW	12HB	103						Snow added, samples at Methow Field Office 5-3-17
Spring Chinook	Methow	smolt trap	W		2012	J	WDFW	12KM	141	141					
Spring Chinook	Methow	Broodstock	W	2013	2013	A	WDFW	13CK	48						Snow added, samples at Methow Field Office 5-3-17
Spring Chinook	Methow	carcass	W	2013	2013	A	WDFW	13HW	36						Snow added, samples at Methow Field Office 5-3-16
Spring Chinook	Methow	carcass	H	2013	2013	A	WDFW	13HX	141						Snow added, samples at Methow Field Office 5-3-16
Spring Chinook	Methow	smolt trap	W		2013	J	WDFW	13IH	180	180					
Spring Chinook	Methow	carcass	W	2014	2014	A	WDFW	14EI	73						Snow added, samples at Methow Field Office 5-3-16
Spring Chinook	Methow	carcass	W	2015	2015	A	WDFW	15DA	66						Snow added, samples at Methow Field Office 5-3-16
Spring Chinook	Methow	smolt trap	W		2015	J	WDFW	15PE	100	100					
Spring Chinook	Twisp		W		1992	A	WDFW	92DQ		NA	microsats	GAPS+	59	Small et al.	
Spring Chinook	Twisp		W		1993		WDFW	93EB		48	microsats	GAPS+	48	Small et al.	
Spring Chinook	Twisp		W		2001	A	WDFW	01AAL		65	microsats	GAPS+	61	Small et al.	
Spring Chinook	Twisp		H		2001	A	WDFW	01AAM		44	microsats	GAPS+	44	Small et al.	
Spring Chinook	Twisp	Carcass	M	2005	2005	A	WDFW	05HX	34	34	microsats	GAPS+	44	Small et al.	
Spring Chinook	Twisp	Broodstock	M	2005	2005	A	WDFW	05IA	18	17	microsats	GAPS+	12	Small et al.	
Spring Chinook	Twisp	Broodstock	M	2006	2006	A	WDFW	06DB	40	40	microsats	GAPS+	29	Small et al.	
Spring Chinook	Twisp	hatchery sampling	HxW		2006	A	WDFW	06EQ	15	15	microsats	GAPS+	15	Small et al.	
Spring Chinook	Twisp				1994		WDFW	94DJ		100					
Spring Chinook	Twisp	Broodstock			2000	A	WDFW	00CV		41					
Spring Chinook	Twisp	Broodstock			2002	A	WDFW	02HL		12					
Spring Chinook	Twisp				2003		WDFW	03FU		106					
Spring Chinook	Twisp	Carcass			2003	A	WDFW	03GH		8					
Spring Chinook	Twisp	Broodstock			2003	A	WDFW	03GI		28					
Spring Chinook	Twisp		H		2004	A	WDFW	04FD		59					
Spring Chinook	Twisp		W		2004	A	WDFW	04FE		67					
Spring Chinook	Twisp	Carcass	M	2007	2007	A	WDFW	07AY	28	32					
Spring Chinook	Twisp	Broodstock	H	2008	2008	A	WDFW	08GL	65	65					
Spring Chinook	Twisp	Broodstock	W	2008	2009	A	WDFW	08GI	16	16					
Spring Chinook	Twisp	carcass	H		2009	A	WDFW	09DY	32	32					
Spring Chinook	Twisp	carcass	W		2009	A	WDFW	09DZ	12	12					
Spring Chinook	Twisp	carcass	W		2010	A	WDFW	10FH	41	41					
Spring Chinook	Twisp	carcass	H		2010	A	WDFW	10FK	41	41					
Spring Chinook	Twisp	carcass	W	2011	2011	A	WDFW	11ES	25						Snow added, samples at Methow Field Office 5-3-16
Spring Chinook	Twisp	carcass	H	2011	2011	A	WDFW	11ET	8						Snow added, samples at Methow Field Office 5-3-16
Spring Chinook	Twisp	carcass	W	2012	2012	A	WDFW	12GZ	28						Snow added, samples at Methow Field Office 5-3-16
Spring Chinook	Twisp	carcass	H	2012	2012	A	WDFW	12HA	59						Snow added, samples at Methow Field Office 5-3-16
Spring Chinook	Twisp	Broodstock	H	2012	2012	A	WDFW	12HA	13						Snow added, samples at Methow Field Office 5-3-17

Species	Stock	Source	Origin	Brood	Run	Stage	Location	Code	*N*	MGL N	genotyped	panel	report n	Report	Notes
Spring Chinook	Twisp	carcass	W	2013	2013	A	WDFW	13HT	14						Snow added, samples at Methow Field Office 5-3-16
Spring Chinook	Twisp	carcass	H	2013	2013	A	WDFW	13HU	41						Snow added, samples at Methow Field Office 5-3-16
Spring Chinook	Twisp	carcass	W	2014	2014	A	WDFW	14EK	44						Snow added, samples at Methow Field Office 5-3-16
Spring Chinook	Twisp	carcass	H	2014	2014	A	WDFW	14EL	31						Snow added, samples at Methow Field Office 5-3-16
Spring Chinook	Twisp	adult trap	W		2015	A	WDFW	15CW	180	180					
Spring Chinook	Twisp	carcass	W	2015	2015	A	WDFW	15DC	47						Snow added, samples at Methow Field Office 5-3-16
Spring Chinook	Twisp	carcass	H	2015	2015	A	WDFW	15DD	19						Snow added, samples at Methow Field Office 5-3-16

Species	Stock	Source	Origin	Brood	Run	Stage	Location	Code	*N*	MGL N	genotyped	panel	report n	Report	Notes
Spring Chinook	Okanogan	none													

Stock	Stock	Source	Origin	Brood	Run	Stage	Location	Code	*N*	MGL N	genotyped	panel	report n	Report	Notes
Spring Chinook	Chiwawa/Eastbank/White	Tumwater Dam	H	2005	2005	A	WDFW	05BG	3214	4105*	microsats	GAPS	268	Blankenship et al.	*4206 samples total for all 05BG
Spring Chinook	Chiwawa/Eastbank/White	Tumwater Dam	H	2006	2006	A	WDFW	06AJ	1597	2388*	microsats	GAPS	280	Blankenship et al.	*2388 samples total for all 06AJ
Spring Chinook	Leavenworth				2000		WDFW	00IN		100	microsats	GAPS	96	Blankenship et al.	may not have tissue
Spring Chinook	Winthrop				1992	A	WDFW	92DR		NA	microsats	GAPS+	100	Small et al.	
Spring Chinook	Winthrop				1999		WDFW	99CR		14					
Spring Chinook	Winthrop	Broodstock			2000	A	WDFW	00DR		100					
Spring Chinook	Winthrop	Broodstock			2002	A	WDFW	02HK		407					
Spring Chinook	Winthrop				2003	A	WDFW	03NS		12					
Spring Chinook	Winthrop/Chewuch/Twisp		H/W		2001		WDFW	01EL		798	microsats	GAPS+	209	Small et al.	
Spring Chinook	Unknown	Unknown	U		2015	U	WDFW	15ER	43	43					Upper C, but unknown what the collection is.
Spring Chinook	Methow &Chewuch	Broodstock	M	2005	2005	A	WDFW	05HZ	27	38	microsats	GAPS+	7	Small et al.	
Spring Chinook	Methow Composite				1998		WDFW	98CX		100					
Spring Chinook	Methow Composite		H		2000		WDFW	00CW		104					
Spring Chinook	Methow Composite	Broodstock			2002	A	WDFW	02HJ		448					
Spring Chinook	Methow Composite				2004		WDFW	04FB		100					
Spring Chinook	Methow Composite				2004		WDFW	04FC		97					
Spring Chinook	Methow Composite				2004	A	WDFW	04FH		6					
Spring Chinook	Methow Composite	carcass	H	2014	2014	A	WDFW	14EH	149						Snow added, samples at Methow Field Office 5-3-16
Spring Chinook	Methow Composite	carcass	H	2015	2015	A	WDFW	15CZ	102						Snow added, samples at MFO 5-3-16, incl. 33 H-origin broodstock
Spring Chinook	Twisp and Methow				1999		WDFW	99CQ		23					
Spring Chinook	Wells Hatchery	adult trap	W		2008	A	WDFW	08DM	110	110					
Spring Chinook	Wells Hatchery	hatchery sampling	H		2008	A	WDFW	08HY	143	143					
Spring Chinook	Wells Hatchery	adult trap	W		2009	A	WDFW	09DX	153	153					
Spring Chinook	Wells Hatchery	adult trap	W		2010	A	WDFW	10FG	263	263					
Spring Chinook	Wells Hatchery	carcass	W		2012	A	WDFW	12DP	139	139					
Spring Chinook	Wells Hatchery	carcass	W		2013	A	WDFW	13CK	83	83					
Spring Chinook	Wells Hatchery	adult trap	W		2014	A	WDFW	14EE	207	207					

Species	Stock	Source	Origin	Brood	Run	Stage	Repository	Code	*N*	MGL N	genotyped	panel	report n	Report	Notes
Steelhead	Chiwawa	Smolt Trap	W	2008	2007	J	WDFW	07AO	132	132	SNP	A/B	127	Seamons et al. 2012	
Steelhead	Chiwawa	Smolt Trap	W	2009	2008	J	WDFW	08CG	144	144	SNP	A/B	143	Seamons et al. 2012	
Steelhead	Chiwawa	hook and line	W		2009	J	WDFW	09NF		38	SNP	A/B	35	Seamons et al. 2012	
Steelhead	Nason	Smolt Trap	W	2008	2007	J	WDFW	07AN	85	85	SNP	A/B	81	Seamons et al. 2012	
Steelhead	Nason	Smolt Trap	W	2009	2008	J	WDFW	08CF	139	139	SNP	A/B	133	Seamons et al. 2012	
Steelhead	Nason	hook and line	W		2009	J	WDFW	09NG		127	SNP	A/B	103	Seamons et al. 2012	
Steelhead	Peshastin	smolt trap	HxW		2008	S	WDFW	08CH		144	SNP	A/B	142	Seamons et al. 2012	
Steelhead	Peshastin	hook and line	W		2009	J	WDFW	09NE		35	SNP	A/B	34	Seamons et al. 2012	
Steelhead	Peshastin	unknown	HxW		2010	J	WDFW	10OY		277	SNP	A/B	94	Seamons et al. 2012	
Steelhead	Wenatchee	Broodstock	M	1998	1997	A	WDFW	97AC	58	58					
Steelhead	Wenatchee	Broodstock	H	1999	1998	A	WDFW	98AE	36	36	SNP	A/B	32	Seamons et al. 2012	
Steelhead	Wenatchee	Broodstock	W	1999	1998	A	WDFW	98AF	35	35	SNP	A/B	30	Seamons et al. 2012	
Steelhead	Wenatchee	Broodstock	W	2000	1999	A	WDFW	99ND	36	36	SNP	A/B	33	Seamons et al. 2012	
Steelhead	Wenatchee	Broodstock	H	2000	1999	A	WDFW	99NE	65	65	SNP	A/B	60	Seamons et al. 2012	
Steelhead	Wenatchee	Broodstock	W	2001	2000	A	WDFW	00DP	50	50	SNP	A/B	50	Seamons et al. 2012	
Steelhead	Wenatchee	Broodstock	H	2001	2000	A	WDFW	00DQ	100	100	SNP	A/B	99	Seamons et al. 2012	
Steelhead	Wenatchee	Broodstock	W	2002	2001	A	WDFW	01MR	95	95	SNP	A/B	95	Seamons et al. 2012	
Steelhead	Wenatchee	Broodstock	H	2002	2001	A	WDFW	01MS	64	64	SNP	A/B	64	Seamons et al. 2012	
Steelhead	Wenatchee	Broodstock	W	2003	2002	A	WDFW	02NO	52	50	SNP	A/B	50	Seamons et al. 2012	
Steelhead	Wenatchee	Broodstock	H	2003	2002	A	WDFW	02NP	87	89	SNP	A/B	89	Seamons et al. 2012	
Steelhead	Wenatchee	Broodstock	W	2004	2003	A	WDFW	03KV	75	74	SNP	A/B	71	Seamons et al. 2012	
Steelhead	Wenatchee	Broodstock	H	2004	2003	A	WDFW	03KW	61	NA	SNP	A/B	61	Seamons et al. 2012	May not have tissue, may have only DNA plates
Steelhead	Wenatchee	Broodstock	W	2005	2004	A	WDFW	04JY	87	87					
Steelhead	Wenatchee	Broodstock	H	2005	2004	A	WDFW	04JZ	100	100					
Steelhead	Wenatchee	Broodstock	H	2006	2005	A	WDFW	05NA	68	68					
Steelhead	Wenatchee	Broodstock	W	2006	2005	A	WDFW	05NB	93	93					
Steelhead	Wenatchee	Broodstock	H	2007	2006	A	WDFW	06CW		65	SNP	A/B	64	Seamons et al. 2012	
Steelhead	Wenatchee	Broodstock	W	2007	2006	A	WDFW	06CX		74	SNP	A/B	74	Seamons et al. 2012	
Steelhead	Wenatchee	Smolt Trap	W	2008	2007	J	WDFW	07AM	144	144	SNP	A/B	139	Seamons et al. 2012	
Steelhead	Wenatchee	Tumwater Dam	H	2008	2007	A	NMFS	07EV	891	0					
Steelhead	Wenatchee	Tumwater Dam	W	2008	2007	A	NMFS	07EV	520	0					
Steelhead	Wenatchee	Broodstock	W	2009	2008	A	WDFW	08AF		75	SNP	A/B	74	Seamons et al. 2012	
Steelhead	Wenatchee	Broodstock	H	2009	2008	A	WDFW	08AG		56	SNP	A/B	56	Seamons et al. 2012	
Steelhead	Wenatchee	Smolt Trap	HxW	2009	2008	J	WDFW	08CE	144	144	SNP	A/B	98	Seamons et al. 2012	
Steelhead	Wenatchee	Tumwater Dam	H	2009	2008	A	NMFS	08CT	230	13*					*13 samples total for all 08CT
Steelhead	Wenatchee	Tumwater Dam	W	2009	2008	A	NMFS	08CT	86	13*					*13 samples total for all 08CT
Steelhead	Wenatchee	broodstock	U		2009	A	WDFW	08CT		13*					*13 samples total for all 08CT
Steelhead	Wenatchee	adult trap	U		2008	A	WDFW	08CT		13*					*13 samples total for all 08CT
Steelhead	Wenatchee	Broodstock	W		2009	A	WDFW	09AU		84	SNP	A/B	82	Seamons et al. 2012	
Steelhead	Wenatchee	Broodstock	H		2009	A	WDFW	09AV		74	SNP	A/B	74	Seamons et al. 2012	
Steelhead	Wenatchee	adult trap	HxW		2010	A	WDFW	10DG		1393					
Steelhead	Wenatchee	adult trap	W		2010	A	WDFW	10FD		92	SNP	A/B	90	Seamons et al. 2012	
Steelhead	Wenatchee	adult trap	H		2010	A	WDFW	10FE		77	SNP	A/B	76	Seamons et al. 2012	
Steelhead	Wenatchee	adult trap	HxW		2011	A	WDFW	11BW		226					
Steelhead	Wenatchee	unknown	U		2011	A	WDFW	11KZ		1393					
Steelhead	Wenatchee	Broodstock	W		2011	A	WDFW	11LT		59					
Steelhead	Wenatchee	Broodstock	H		2011	A	WDFW	11LU		66					
Steelhead	Wenatchee	adult trap	HxW		2012	A	WDFW	12CJ		47					
Steelhead	Wenatchee	Broodstock	HxW		2015	A	WDFW	15IP		113					

Species	Stock	Source	Origin	Brood	Run	Stage	Repository	Code	*N*	MGL N	genotyped	panel	report n	Report	Notes
Steelhead	Entiat	Smolt Trap	W	2008	2007	J	WDFW	07AL	144	144	SNP	A/B	134	Seamons et al. 2012	
Steelhead	Entiat	Smolt Trap	W	2009	2008	J	WDFW	08CI	86	86	SNP	A/B	82	Seamons et al. 2012	
Steelhead	Entiat	smolt trap	U		2009	S	WDFW	09NC		85	SNP	A/B	74	Seamons et al. 2012	
Steelhead	Entiat	smolt trap	W		2010	S	WDFW	10OX		84	SNP	A/B	82	Seamons et al. 2012	

Species	Stock	Source	Origin	Brood	Run	Stage	Repository	Code	*N*	MGL N	genotyped	panel	report n	Report	Notes
Steelhead	Chewuch	In River	W	2008	2007	J	WDFW	07ER	83	83	microsats	span+	80	Blankenship et al.	
Steelhead	Chewuch	In River	W	2009	2008	J	WDFW	08CO	60	60	microsats	span+	60	Blankenship et al.	
Steelhead	Methow	Smolt Trap	W	2008	2007	S	WDFW	07AP	137	179	microsats	span+	113	Blankenship et al.	
Steelhead	Methow	In River	W	2008	2007	J	WDFW	07AS	36	38	microsats	span+	36	Blankenship et al.	
Steelhead	Methow	Smolt Trap	W	2009	2008	J	WDFW	08CJ	162	162	microsats	span+	156	Blankenship et al.	
Steelhead	Methow	In River	W	2009	2008	J	WDFW	08CM	30	30	microsats	span+	30	Blankenship et al.	
Steelhead	Twisp	Smolt Trap	W	2008	2007	S	WDFW	07AQ	143	173	microsats	span+	113	Blankenship et al.	
Steelhead	Twisp	In River	W	2008	2007	J	WDFW	07AU	36	36	microsats	span+	32	Blankenship et al.	
Steelhead	Twisp	Smolt Trap	W	2009	2008	J	WDFW	08CK	652	651	microsats	span+	185	Blankenship et al.	
Steelhead	Twisp	In River	W	2009	2008	J	WDFW	08CN	19	19	microsats	span+	19	Blankenship et al.	
Steelhead	Twisp	adult trap	W		2009	A	WDFW	09CZ		92	SNP	E/F	92	Twisp RRS	
Steelhead	Twisp	adult trap	H		2009	A	WDFW	09DA		265	SNP	E/F	263	Twisp RRS	
Steelhead	Twisp	adult trap	W		2009	J	WDFW	09DB		3	SNP	E/F	3	Twisp RRS	
Steelhead	Twisp	adult trap	H		2009	J	WDFW	09DC		1	SNP	E/F	1	Twisp RRS	
Steelhead	Twisp	adult trap	H		2010	A	WDFW	10DQ		171	SNP	E/F	170	Twisp RRS	
Steelhead	Twisp	adult trap	W		2010	A	WDFW	10DR		176	SNP	E/F	176	Twisp RRS	
Steelhead	Twisp	adult trap	W		2010	A	WDFW	10DW		386	SNP	A/B, E/F	385	Twisp RRS	38 E/F
Steelhead	Twisp	hook and line	W		2010	J	WDFW	10DX		898	SNP	A/B, E/F	893	Twisp RRS	114 E/F
Steelhead	Twisp	adult trap	H		2011	A	WDFW	11CH		117	SNP	E/F	116	Twisp RRS	
Steelhead	Twisp	adult trap	W		2011	A	WDFW	11CI		147	SNP	E/F	145	Twisp RRS	
Steelhead	Twisp	river	W		2011	J	WDFW	11CL		144	SNP	C/D, E/F	119	Twisp RRS	8 E/F
Steelhead	Twisp	smolt trap	W		2011	S	WDFW	11CM		219	SNP	A/B, E/F	219	Twisp RRS	12 E/F
Steelhead	Twisp	hook and line	W		2011	J	WDFW	11GB		2071	SNP	C/D, E/F	1473	Twisp RRS	579 E/F
Steelhead	Twisp	adult trap	W		2012	A	WDFW	12DI		123	SNP	E/F	123	Twisp RRS	
Steelhead	Twisp	adult trap	H		2012	A	WDFW	12DJ		156	SNP	E/F	156	Twisp RRS	
Steelhead	Twisp	adult trap	U		2012	A	WDFW	12DL		26	SNP	E/F	26	Twisp RRS	
Steelhead	Twisp	electrofishing	U		2012	S	WDFW	12DM		2547	SNP	E/F	1307	Twisp RRS	
Steelhead	Twisp	smolt trap	U		2012	S	WDFW	12DN		133	SNP	C/D, E/F	129	Twisp RRS	20 E/F
Steelhead	Twisp	smolt trap	U		2012	S	WDFW	12DO		325	SNP	E/F	71	Twisp RRS	
Steelhead	Twisp	adult trap	W		2013	A	WDFW	13CD		51	SNP	E/F	51	Twisp RRS	
Steelhead	Twisp	adult trap	H		2013	A	WDFW	13CE		119	SNP	E/F	89	Twisp RRS	
Steelhead	Twisp	adult trap	U		2013	A	WDFW	13CG		23	SNP	E/F	23	Twisp RRS	
Steelhead	Twisp	electrofishing	U		2013	S	WDFW	13CH		2158	SNP	E/F	1235	Twisp RRS	
Steelhead	Twisp	smolt trap	U		2013	S	WDFW	13CI		300	SNP	E/F	244	Twisp RRS	
Steelhead	Twisp	smolt trap	U		2013	S	WDFW	13CJ		412	SNP	E/F	316	Twisp RRS	
Steelhead	Twisp	adult trap	W		2014	A	WDFW	14DX		66	SNP	E/F	66	Twisp RRS	
Steelhead	Twisp	adult trap	W		2014	A	WDFW	14DY		102	SNP	E/F	101	Twisp RRS	
Steelhead	Twisp	adult trap	W		2014	A	WDFW	14EA		25	SNP	E/F	25	Twisp RRS	
Steelhead	Twisp	electrofishing	W		2014	J	WDFW	14EB		2861					
Steelhead	Twisp	smolt trap	W		2014	S	WDFW	14EC		328					
Steelhead	Twisp	smolt trap	W		2014	J	WDFW	14ED		248					
Steelhead	Twisp	adult trap	W		2015	A	WDFW	15CK		57					
Steelhead	Twisp	electrofishing	W		2015	mixed	WDFW	15CL		163					
Steelhead	Twisp	adult trap	W		2015	A	WDFW	15CN		19					
Steelhead	Twisp	electrofishing	W		2015	U	WDFW	15CO		3476					
Steelhead	Twisp	smolt trap	W		2015	S	WDFW	15CU		268					

Species	Stock	Source	Origin	Brood	Run	Stage	Repository	Code	*N*	MGL N	genotyped	panel	report n	Report	Notes
Steelhead	Twisp	smolt trap	W		2015	S	WDFW	15CV		401					

Species	Stock	Source	Origin	Brood	Run	Stage	Repository	Code	*N*	MGL N	genotyped	panel	report n	Report	Notes
Steelhead	Okanogan	Smolt Trap	W	2008	2007	S	WDFW	07AR	89	89	microsats	span+	86	Blankenship et al.	
Steelhead	Okanogan	Smolt Trap	W	2009	2008	J	WDFW	08CL	120	120	microsats	span+	119	Blankenship et al.	

Species	Stock	Source	Origin	Brood	Run	Stage	Repository	Code	*N*	MGL N	genotyped	panel	report n	Report	Notes
Steelhead	Wells Hatchery	Broodstock	W	1996	1995	A	WDFW	95AA	37	32	microsats	span+	28	Blankenship et al.	
Steelhead	Wells Hatchery	Broodstock	U	1996	1995	A	WDFW	95AB	65	100	microsats	span+	45	Blankenship et al.	
Steelhead	Wells Hatchery	Broodstock	H	1998	1997	A	WDFW	97AB	100	100					
Steelhead	Wells Hatchery	Broodstock	W	1998	1997	A	WDFW	97AC	58	58	microsats	span+	56	Blankenship et al.	"Mid-Columbia Naturals (su)"
Steelhead	Wells Hatchery	Broodstock	HxH	1999	1998	A	WDFW	98AA	100	100					
Steelhead	Wells Hatchery	Broodstock	W	1999	1998	A	WDFW	98AB	12	12					
Steelhead	Wells Hatchery	Broodstock	HxW	1999	1998	A	WDFW	98LH	100	NA					98LH does not exist in WDFW archive
Steelhead	Wells Hatchery	Broodstock	W	1999	1998	A	WDFW	98LI	26	28					
Steelhead	Wells Hatchery	Broodstock	U	2000	1999	A	WDFW	99NB	325	325	microsats	span+	95	Blankenship et al.	
Steelhead	Wells Hatchery	Broodstock	W	2000	1999	A	WDFW	99NC	39	39	microsats	span+	37	Blankenship et al.	
Steelhead	Wells Hatchery	Broodstock	H	2001	2000	A	WDFW	00PU	100	100					
Steelhead	Wells Hatchery	Broodstock	W	2001	2000	A	WDFW	00PW	32	32					
Steelhead	Wells Hatchery	Broodstock	H	2002	2001	A	WDFW	01MP	100	100					
Steelhead	Wells Hatchery	Broodstock	W	2002	2001	A	WDFW	01MQ	23	16					
Steelhead	Wells Hatchery	Broodstock	W	2003	2002	A	WDFW	02HO	26	26					
Steelhead	Wells Hatchery	Broodstock	HxW	2003	2002	A	WDFW	02HP	60	60					
Steelhead	Wells Hatchery	Broodstock	HxH	2003	2002	A	WDFW	02HQ	60	60					
Steelhead	Wells Hatchery	Broodstock	W	2004	2003	A	WDFW	03KS	113	113	microsats	span+	92	Blankenship et al.	
Steelhead	Wells Hatchery	Broodstock	HxH	2004	2003	A	WDFW	03KT	48	49	microsats	span+	48	Blankenship et al.	
Steelhead	Wells Hatchery	Broodstock	HxW	2004	2003	A	WDFW	03KU	99	99	microsats	span+	95	Blankenship et al.	
Steelhead	Wells Hatchery	Broodstock	W	2005	2004	A	WDFW	04KQ	63	63					
Steelhead	Wells Hatchery	Broodstock	HxH	2005	2004	A	WDFW	04KR	100	100					
Steelhead	Wells Hatchery	Broodstock	HxW	2005	2004	A	WDFW	04KS	99	99					
Steelhead	Wells Hatchery	Broodstock	W	2006	2005	A	WDFW	05LQ	85	85	microsats	span+	85	Blankenship et al.	
Steelhead	Wells Hatchery	Broodstock	HxH	2006	2005	A	WDFW	05LR	100	100	microsats	span+	49	Blankenship et al.	
Steelhead	Wells Hatchery	Broodstock	HxW	2006	2005	A	WDFW	05LS	100	100	microsats	span+	50	Blankenship et al.	
Steelhead	Wells Hatchery	Broodstock	H	2007	2006	A	WDFW	06CY	144	144					
Steelhead	Wells Hatchery	Broodstock	W	2007	2006	A	WDFW	06CZ	44	46					
Steelhead	Wells Hatchery	Broodstock	W	2008	2007	A	WDFW	07AV	88	88	microsats	span+	88	Blankenship et al.	
Steelhead	Wells Hatchery	Broodstock	U	2008	2007	A	WDFW	07AW	100	100	microsats	span+	97	Blankenship et al.	
Steelhead	Wells Hatchery	adult trap	H		2008	A	WDFW	08CP		97					
Steelhead	Wells Hatchery	adult trap	W		2008	A	WDFW	08CQ		68					
Steelhead	Wells Hatchery	adult trap	H		2010	A	WDFW	10BM		99					
Steelhead	Wells Hatchery	adult trap	W		2010	A	WDFW	10BN		72					
Steelhead	Wells Hatchery	adult trap	H		2011	A	WDFW	11AM		100					
Steelhead	Wells Hatchery	adult trap	W		2011	A	WDFW	11AN		44					
Steelhead	Wells Hatchery	adult trap	W		2012	A	WDFW	12BF		64					
Steelhead	Wells Hatchery	adult trap	H		2012	A	WDFW	12BG		140					
Steelhead	Wells Hatchery	adult trap	W	2013	2012	A	WDFW	13AQ		17					Snow added. Samples at Methow Field Office 5-3-16.
Steelhead	Wells Hatchery	adult trap	H	2013	2012	A	WDFW	13AR		100					Snow added. Samples at Methow Field Office 5-3-16.
Steelhead	Wells Hatchery	adult trap	H	2014	2013	A	WDFW	14BI		111					Snow added. 111 samples between numbers 3 and 148. located at MFO 5-3-16
Steelhead	Wells Hatchery	adult trap	H	2015	2014	A	WDFW	14EG		100					Snow added. Samples at Methow Field Office 5-3-16.

Species	Stock	Source	Origin	Brood	Run	Stage	Repository	Code	*N*	MGL N	genotyped	panel	report n	Report	Notes
Summer Chinook	Wenatchee	Carcass	H	2006	2006	A	WDFW	06CP	141	141	microsats	GAPS	95	Kassler et al.	
Summer Chinook	Wenatchee	Carcass	W	2006	2006	A	WDFW	06CQ	144	144	microsats	GAPS	95	Kassler et al.	
Summer Chinook	Wenatchee	Carcass	W	2006	2006	A	WDFW	06CR	144	144	microsats	GAPS	95	Kassler et al.	
Summer Chinook	Wenatchee	Carcass	H	2007	2007	A	WDFW	07DX	127	127					
Summer Chinook	Wenatchee	Carcass	W	2007	2007	A	WDFW	07DY	127	127					
Summer Chinook	Wenatchee	Carcass	W	2007	2007	A	WDFW	07DZ	133	133					
Summer Chinook	Wenatchee	Carcass	H	2008	2008	A	WDFW	08FU	143	143	microsats	GAPS	95	Kassler et al.	
Summer Chinook	Wenatchee	Carcass	W	2008	2008	A	WDFW	08FV	133	133	microsats	GAPS	95	Kassler et al.	
Summer Chinook	Wenatchee	Carcass	W	2008	2008	A	WDFW	08FW	144	144	microsats	GAPS	95	Kassler et al.	
Summer Chinook	Wenatchee	carcass	HxW	2009	2009	A	WDFW	09CJ	108	108					
Summer Chinook	Wenatchee	carcass	W	2009	2009	A	WDFW	09CK	144	144					
Summer Chinook	Wenatchee	carcass	W	2009	2009	A	WDFW	09CL	144	144					
Summer Chinook	Wenatchee	Broodstock	U	2013	2013	A	WDFW	13NJ	135	135					
Summer Chinook	Wenatchee	hatchery sampling	HxW	2015	2015	A	WDFW	15IR	242	242					
Summer Chinook	Wenatchee	Carcass	W	1993	1993	A	WDFW	93DD	52	52	microsats	GAPS	51	Kassler et al.	
Summer Chinook	Wenatchee	Broodstock	W	1993	1993	A	WDFW	93DE	102	102	microsats	GAPS	88	Kassler et al.	

Species	Stock	Source	Origin	Brood	Run	Stage	Repository	Code	*N*	MGL N	genotyped	panel	report n	Report	Notes
Summer Chinook	Methow	Carcass	H	2006	2006	A	WDFW	06CS	63	63	microsats	GAPS	14	Kassler et al.	
Summer Chinook	Methow	Carcass	W	2006	2006	A	WDFW	06CT	136	136	microsats	GAPS	95	Kassler et al.	
Summer Chinook	Methow	Carcass	H	2008	2008	A	WDFW	08FX	50	51	microsats	GAPS	21	Kassler et al.	
Summer Chinook	Methow	Carcass	W	2008	2008	A	WDFW	08FY	102	118	microsats	GAPS	95	Kassler et al.	
Summer Chinook	Methow	carcass	W	2009	2009	A	WDFW	09CO	101	101	microsats	GAPS	91	Kassler et al.	
Summer Chinook	Methow	carcass	H	2009	2009	A	WDFW	09CP	64	64	microsats	GAPS	19	Kassler et al.	
Summer Chinook	Methow	smolt trap	W		2010	J	WDFW	10DY	392	392					
Summer Chinook	Methow	smolt trap	W		2011	J	WDFW	11CK	678	678					
Summer Chinook	Methow	smolt trap	W		2013	J	WDFW	13IH	180	180					
Summer Chinook	Methow	Broodstock	U	2013	2013	U	WDFW	13NI	101	101					
Summer Chinook	Methow	hatchery sampling	HxW	2015	2015	A	WDFW	15IS	98	98					
Summer Chinook	Methow	Carcass	W	1993	1993	A	WDFW	93EC	37	37	microsats	GAPS	27	Kassler et al.	
Summer Chinook	Methow	Carcass	M	1994	1994	A	WDFW	94EJ	88	88					

Species	Stock	Source	Origin	Brood	Run	Stage	Repository	Code	*N*	MGL N	genotyped	panel	report n	Report	Notes
Summer Chinook	Okanogan	Carcass	H	2006	2006	A	WDFW	06CU	75	75	microsats	GAPS	58	Kassler et al.	
Summer Chinook	Okanogan	Carcass	W	2006	2006	A	WDFW	06CV	130	130	microsats	GAPS	95	Kassler et al.	
Summer Chinook	Okanogan	Carcass	H	2008	2008	A	WDFW	08FZ	143	143	microsats	GAPS	19	Kassler et al.	
Summer Chinook	Okanogan	Carcass	W	2008	2008	A	WDFW	08GA	134	143	microsats	GAPS	95	Kassler et al.	
Summer Chinook	Okanogan	carcass	H	2009	2009	A	WDFW	09CM	143	143	microsats	GAPS	117	Kassler et al.	
Summer Chinook	Okanogan	carcass	W	2009	2009	A	WDFW	09CN	144	144	microsats	GAPS	133	Kassler et al.	
Summer Chinook	Okanogan		W		1992	A	WDFW	92FM		NA	microsats	GAPS	49	Kassler et al.	
Summer Chinook	Similkameen	Carcass	W	1993	1993	A	WDFW	93ED	124	124	microsats	GAPS	103	Kassler et al.	

Species	Stock	Source	Origin	Brood	Run	Stage	Repository	Code	*N*	MGL N	genotyped	panel	report n	Report	Notes
Summer Chinook	Chelan				2006	A	WDFW	06KN		NA	microsats	GAPS	70	Kassler et al.	
Summer Chinook	Methow/Okanogan	hatchery sampling			2008	A	WDFW	08MO		NA	microsats	GAPS	95	Kassler et al.	
Summer Chinook	Methow/Okanogan	hatchery sampling			1992	A	WDFW	92FO		NA	microsats	GAPS	36	Kassler et al.	
Summer Chinook	Methow/Okanogan	hatchery sampling			1993	A	WDFW	93DF		101	microsats	GAPS	90	Kassler et al.	
Summer Chinook	Wells	Broodstock	H	2006	2006	A	WDFW	06DM	142	142	microsats	GAPS	95	Kassler et al.	
Summer Chinook	Wells	Broodstock	H	2008	2008	A	WDFW	08HY	144	143	microsats	GAPS	95	Kassler et al.	
Summer Chinook	Wells	adult trap	W	2011	2011	A	WDFW	11GC	39	39					
Summer Chinook	Wells	adult trap	W	2012	2012	A	WDFW	12FR	46	46					
Summer Chinook	Wells	hatchery sampling			1991	A	WDFW	91FL		NA	microsats	GAPS	68	Kassler et al.	
Summer Chinook	Wells	hatchery sampling			1992	A	WDFW	92FK		NA	microsats	GAPS	25	Kassler et al.	
Summer Chinook	Wells	hatchery sampling			1993	A	WDFW	93DG		102	microsats	GAPS	11	Kassler et al.	
Summer Chinook	Eastbank	hatchery sampling			2008	A	WDFW	08MN		NA	microsats	GAPS	95	Kassler et al.	

Species	Stock	Source	Origin	Brood	Run	Stage	Repository	Code	*N*	MGL N	genotyped	panel	report n	Report	Notes
Sockeye	Wenatchee	Broodstock	U		2001	A	WDFW	01AAS	53	53	microsats	NA	53	Blankenship et al.	May not have tissue samples. May only have DNA.
Sockeye	Wenatchee	Tumwater Dam	W	2003	2003	A	WDFW	03AZ	100	100					
Sockeye	Wenatchee	Broodstock	U		2004	A	WDFW	04AAV	163	163	microsats	NA	43	Blankenship et al.	May not have tissue samples. May only have DNA.
Sockeye	Wenatchee	Broodstock	H	2006	2006	A	WDFW	06CN	38	36	microsats	NA	38	Blankenship et al.	
Sockeye	Wenatchee	Broodstock	W	2006	2006	A	WDFW	06CO	144	144	microsats	NA	96	Blankenship et al.	
Sockeye	Wenatchee	Broodstock	H	2007	2007	A	WDFW	07EE	18	18	microsats	NA	18	Blankenship et al.	
Sockeye	Wenatchee	Broodstock	W	2007	2007	A	WDFW	07EF	144	144	microsats	NA	96	Blankenship et al.	
Sockeye	Wenatchee	Broodstock	U		2000	A	WDFW	00AAE			microsats	NA	96	Blankenship et al.	

Species	Stock	Source	Origin	Brood	Run	Stage	Repository	Code	*N*	MGL N	genotyped	panel	report n	Report	Notes
Sockeye	Okanogan	Wells Dam	W	2003	2003	A	WDFW	03AY	58	58					
Sockeye	Okanogan	unknown	U		2011	A	WDFW	11GT	100	100					

Stock	Stock	Source	Origin	Brood	Run	Stage	Location	Code	*N*	MGL N	genotyped	panel	report n	Report	Notes

waiting to hear back from CRITFC

USFWS Genetic Archive List: 2001 - 2015

Mid-Columbia Fish and Wildlife Conservation Office
U.S. Fish & Wildlife Service
7501 Icicle Road
Leavenworth, WA 98826
(509) 548-7573
Contact Person: Matt Cooper (matt_cooper@fws.gov)

Update List in "N: Genetics: Genetic Sample Information: Genetic Sample Inventory List"

Year	Location	Species	Life Stage	Capture Type	Collection Dates	Total #	Data	Comments	Send Location/Date
2015	Icicle Creek	Spring	Adult	Spawning Ground		43	Genetics data	Females 28 / Males 11 / Unk 4	USFWS - Abernathy FTC,
2015	Winthrop/Methow	Steelhead	Adut	Hatchery			Genetics data		USFWS - Abernathy FTC,
2015	Winthrop/Methow	Steelhead	Adut	Hatchery			Genetics data		USFWS - Abernathy FTC,
2015	Winthrop	Spring	Adult	Hatchery		384	Genetics data	200 Females / 184 Males genetic vial samples	USFWS - Abernathy FTC
2015	Leavenworth	Spring	Adult	Hatchery		100	Genetics data	1 box of broodstock	USFWS - Abernathy FTC
2015	Leavenworth	Spring	Adult	Hatchery		949	Genetics data	477 Females / 472 Males PBT genetic samples	CRITFC
2015	Entiat	Summer	Adult	Hatchery		99	Genetics data	1 box of broodstock	USFWS - Abernathy FTC,
2015	Entiat	Summer	Adult	Hatchery		301	Genetics data	150 Females / 151 Males PBT genetic samples	CRITFC
2015	Entiat SGS SCS	Spring	Adult	Spawning Ground		134	Genetics data	2 boxes	USFWS - Abernathy FTC
2015	Entiat SGS SUS	Summer	Adult	Spawning Ground		201	Genetics data	2+boxes	USFWS - Abernathy FTC
2014	Winthrop/Methow	Steelhead	Adut	Hatchery		36	Genetics data	Males 36 collected/ 22 used for brood stock	USFWS - Abernathy FTC,
2014	Winthrop/Methow	Steelhead	Adut	Hatchery		33	Genetics data	Females 33 collected/ 29 used for brood stock	USFWS - Abernathy FTC,
2014	Winthrop	Spring	Adult	Hatchery		426	Genetics data	5+ boxes of broodstock	USFWS - Abernathy FTC
2014	Leavenworth	Spring	Adult	Hatchery		100	Genetics data	1 box of broodstock	USFWS - Abernathy FTC
2014	Leavenworth	Spring	Adult	Hatchery		1100	Genetics data	572 Females / 528 Males PBT genetic samples	CRITFC
2014	Entiat	Summer	Adult	Hatchery		100	Genetics data	1 box of broodstock	USFWS - Abernathy FTC
2014	Entiat	Summer	Adult	Hatchery		311	Genetics data	155 Females / 156 Males PBT genetic samples	CRITFC
2014	Entiat SGS SCS	Spring	Adult	Spawning Ground			Genetics data		USFWS - Abernathy FTC
2014	Entiat SGS SUS	Summer	Adult	Spawning Ground			Genetics data		USFWS - Abernathy FTC
2013	Winthrop/Methow	Steelhead	Adut	Hatchery		32	Genetics data	combo box 32 brood stock / 30 collected not used	USFWS - Abernathy FTC, 2/2014
2013	Winthrop/Methow	Steelhead	Adut	Hatchery		30	Genetics data	combo box 32 brood stock / 30 collected not used	USFWS - Abernathy FTC, 2/2014
2013	Winthrop	Spring	Adult	Hatchery		505	Genetics data	5+ boxes of broodstock	USFWS - Abernathy FTC, 2/2014
2013	Leavenworth	Spring	Adult	Hatchery		100	Genetics data	1 box of broodstock	USFWS - Abernathy FTC, 2/2014
2013	Leavenworth	Spring	Adult	Hatchery		794	Genetics data	407 Females / 387 Males PBT genetic samples	USFWS - Abernathy FTC, 2/2014
2013	Entiat	Summer	Adult	Hatchery		100	Genetics data	1 box of broodstock	USFWS - Abernathy FTC, 2/2014
2013	Entiat	Summer	Adult	Hatchery		303	Genetics data	152 Females / 151 Males PBT genetic samples	USFWS - Abernathy FTC, 2/2014
2013	Entiat SGS SCS	Spring	Adult	Spawning Ground		19	Genetics data	1 box	USFWS - Abernathy FTC, 2/2014
2013	Entiat SGS SUS	Summer	Adult	Spawning Ground		100	Genetics data	1 box	USFWS - Abernathy FTC, 2/2014
2012	Winthrop/Methow	Steelhead	Adut	Hatchery		42	Genetics data		USFWS - Abernathy FTC, 2/2013
2012	Winthrop	Spring	Adult	Hatchery		100	Genetics data	1 box of broodstock	USFWS - Abernathy FTC, 2/2013
2012	Leavenworth	Spring	Adult	Hatchery		100	Genetics data	1 box of broodstock	USFWS - Abernathy FTC, 2/2013
2012	Entiat	Summer	Adult	Hatchery		100	Genetics data	1 box of broodstock	USFWS - Abernathy FTC, 2/2013
2012	Entiat SGS SCS	Spring	Adult	Spawning Ground		142	Genetics data	2 boxes	USFWS - Abernathy FTC, 2/2013
2012	Entiat SGS SUS	Summer	Adult	Spawning Ground		200	Genetics data	2 boxes	USFWS - Abernathy FTC, 2/2013
2011	Winthrop/Methow	Steelhead	Adut	Angling/Hatchery	3/29 - 4/14/11	29	Genetics data	1 bag of vials collected from all broodstock	NOAA (Chris Tatara) Manchester 6/2011
2011	Winthrop	Spring	Adult	Hatchery	8/17-8/31/11	100	Genetics data	1 box of broodstock	USFWS - Abernathy FTC, 2/2012
2011	Leavenworth	Spring	Adult	Hatchery	8/30-9/6/11	100	Genetics data	1 box of broodstock	USFWS - Abernathy FTC, 2/2012
2011	Entiat	Summer	Adult	Hatchery	10/19-10/26/11	100	Genetics data	1 box of broodstock	USFWS - Abernathy FTC, 2/2012
2011	Entiat SGS SCS	Spring	Adult	Spawning Ground	8/12-9/20/11	158	Genetics data	2 boxes	USFWS - Abernathy FTC, 2/2012
2011	Entiat SGS SUS	Summer	Adult	Spawning Ground	10/8-11/4/11	136	Genetics data	2 boxes	USFWS - Abernathy FTC, 2/2012
2010	Winthrop	Chinook	Adult	Hatchery	8/19-9/2-2009	98	Genetics data	1 box of broodstock	USFWS - Abernathy FTC, 2/2011
2010	Winthrop	Steelhead	Adult	Hat/ Methow River	4/16-4/27/2009	24	Genetics data	1 box of broodstock	USFWS - Abernathy FTC, 2/2011
2010	Leavenworth	Chinook	Adult	Hatchery	8/18-9/1/2009	100	Genetics data	1 box of broodstock	USFWS - Abernathy FTC, 2/2011
2010	Entiat	SCS	Adult	Spawning Ground	9/1-9/23/2009	85	Genetics data	1 box	USFWS - Abernathy FTC, 2/2011

Year	Location	Species	Life Stage	Capture Type	Collection Dates	Total #	Data	Comments	Send Location/Date
2010	Entiat	SUS	Adult	Spawning Ground	9/25-11/12/2009	73	Genetics data	1 box	USFWS - Abernathy FTC, 2/2011
2010	Entiat	SUS	Adult	Wells Hatchery	10/21-10/28/2009	100	Genetics data	1 box of broodstock	USFWS - Abernathy FTC, 2/2011
2009	Winthrop	Chinook	Adult	Hatchery	8/19-9/2-2009	100	Genetics data	1 box of broodstock	USFWS - Abernathy FTC, 2/2010
2009	Winthrop	Steelhead	Adult	Hat/ Methow River	4/16-4/27/2009	13	Genetics data	1 box of broodstock	USFWS - Abernathy FTC, 2/2010
2009	Leavenworth	Chinook	Adult	Hatchery	8/18-9/1/2009	100	Genetics data	1 box of broodstock	USFWS - Abernathy FTC, 2/2010
2009	Entiat	SCS	Adult	Spawning Ground	9/1-9/23/2009	75	Genetics data	1 box	USFWS - Abernathy FTC, 2/2010
2009	Entiat	SUS	Adult	Spawning Ground	9/25-11/12/2009	78	Genetics data	1 box	USFWS - Abernathy FTC, 2/2010
2009	Entiat	SUS	Adult	Wells Hatchery	10/21-10/28/2009	88	Genetics data	Wells SUS brood stock Female (44) Male (44)	USFWS - Abernathy FTC, 2/2010
2009	Entiat	Steelhead/RT	Juvenile	Screw Trap	3/20-5/18/2009	75	Genetics data	1 box Vial# 1-75	USFWS - Abernathy FTC, 2/2010
2009	Entiat	Cutthroat	Juvenile	Screw Trap	7/19-11/3/2009	19	Genetics data	1 box Vial# 1-19	USFWS - Abernathy FTC, 2/2010
2009	Entiat	Bull trout	Juvenile	Screw Trap	3/9-11/16/2009	96	Genetics data	1 box Vials# 1-96	USFWS - Abernathy FTC, 2/2010
2009	Entiat	SUS	Juvenile	Screw Trap	7/8-8/24/2009	100	Genetics data	1 box	USFWS - Abernathy FTC, 2/2010
2009	Entiat	Chinook	Juvenile	Screw Trap	9/27-11/16/2009	83	Genetics data	1 box Vial# 091-173	USFWS - Abernathy FTC, 2/2010
2009	Entiat	Chinook	Juvenile	Screw Trap	3/17-5/18/09	89	Genetics data	1 box Vials# 002-90	USFWS - Abernathy FTC, 2/2010
2008	Winthrop	Chinook	Adult	Hatchery	8/13/08-9/3/08	100	Genetics data	1 box of broodstock	USFWS - Abernathy FTC, 5/27/09
2008	Leavenworth	Chinook	Adult	Hatchery	8/19/08-9/2/08	100	Genetics data	1 box of broodstock	USFWS - Abernathy FTC, 5/27/09
2008	Entiat	Chinook	Juvenile	Screw Trap	3/13/08-3/28/08	100	Genetics data	1 box	USFWS - Abernathy FTC, 5/27/09
2008	Entiat	Chinook	Juvenile	Screw Trap	3/28/08-4/9/08	100	Genetics data	1 box	USFWS - Abernathy FTC, 5/27/09
2008	Entiat	Chinook	Juvenile	Screw Trap	4/13/2008-7/14/2008	100	Genetics data	1 box	USFWS - Abernathy FTC, 5/27/09
2008	Entiat	SUS	Juvenile	Screw Trap	8/3/08-8/15/2008	100	Genetics data	1 box	USFWS - Abernathy FTC, 5/27/09
2008	Entiat	Cutthroat	Juvenile	Screw Trap	8/3/08-11/14/08	38	Genetics data	1 box	USFWS - Abernathy FTC, 5/27/09
2008	Entiat	SCS	Adult	Spawning Ground	8/25/2008-9/14/2008	67	Genetics data	1 box	USFWS - Abernathy FTC, 5/27/09
2008	Entiat	SUS	Adult	Spawning Ground	9/14/08-11/5/2008	77	Genetics data	1 box	USFWS - Abernathy FTC, 5/27/09
2007	Winthrop	Chinook	Adult	Hatchery	8/15/07-9/5/07	100	Genetics data	1 box of broodstock	USFWS - Abernathy FTC,
2007	Leavenworth	Chinook	Adult	Hatchery	8/14/07-8/28/07	100	Genetics data	1 box of broodstock	USFWS - Abernathy FTC,
2007	Entiat	Chinook	Adult	Spawning Ground	8/31/07-9/18/07	41	Genetics data	1 box	USFWS - Abernathy FTC,
2007	Entiat	Chinook	Juvenile	Screw Trap	3/21/07 - 5/07/07	100	Genetics data	35 from upper and 65 from lower trap, spring yearlings	USFWS - Abernathy FTC, sent 1/31/08
2007	Entiat	Steelhead/RT	Juvenile	Screw Trap	3/14/07 - 4/28/07	144	Genetics data	two boxes provided by state, tissue filled and returned	WDFW - Wenatchee (T. Miller - July 2007)
2006	Winthrop	Chinook	Adult	Hatchery	8/16/06 - 9/6/06	100	Genetics data	Box of 1	USFWS - Abernathy FTC, 7/18/06
2006	Leavenworth	Chinook	Adult	Hatchery	8/22/06 - 9/05/06	100	Genetics data	Box of 1	USFWS - Abernathy FTC, 7/18/06
2006	Entiat	Chinook	Adult	Spawning Ground	9/1/06 - 9/20/06	27	Genetics data	Box of 1	USFWS - Abernathy FTC, 7/18/06
2006	Entiat	Chinook	Adult	Hatchery	8/21/06 - 8/31/06	98	Genetics data	Box of 1	USFWS - Abernathy FTC,
2006	Entiat	Steelhead/RT	Juvenile	Screw Trap	3/17/06 - 4/25/06	100	RST data		USFWS - Abernathy FTC, 7/18/06
2006	Entiat	Chinook	Yearling	Screw Trap	3/3/06 - 4/2/06	100	RST data		USFWS - Abernathy FTC, 7/18/06
2005	Winthrop	Chinook	Adult	Hatchery	8/17/05 - 9/7/05	100	Genetics data		USFWS - Abernathy FTC, 7/18/06
2005	Peshastin	Steelhead/RT	Juvenile	Screw Trap	3/28/05 - 9/10/05	96	RST data	Box 1 of 2	USFWS - Abernathy FTC, 7/18/06
2005	Peshastin	Steelhead/RT	Juvenile	Screw Trap	9/11/05 - 11/3/05	100	RST data	Box 2 of 2	USFWS - Abernathy FTC, 7/18/06
2005	Peshastin	Chinook	Yearling	Screw Trap	3/11/05 - 11/22/05	58	RST data		USFWS - Abernathy FTC, 7/18/06
2005	Leavenworth	Chinook	Adult	Hatchery	8/16/05 - 8/30/05	100	Genetics data		USFWS - Abernathy FTC, 7/18/06
2005	Entiat	Steelhead/RT	Juvenile	Screw Trap	3/6/05 - 4/25/05	100	RST data	Box 1 of 2	USFWS - Abernathy FTC, 7/18/06
2005	Entiat	Steelhead/RT	Juvenile	Screw Trap	4/25/05 - 5/3/05	100	RST data	Box 2 of 2	USFWS - Abernathy FTC, 7/18/06
2005	Entiat	Chinook	Adult	Hatchery	8/27/05 - 9/1/05	100	Genetics data		USFWS - Abernathy FTC, 7/18/06
2005	Entiat	Chinook	Adult	Spawning Ground	9/6/05 - 9/22/05	33	Genetics data	Boxed with 2003 summer Chinook	USFWS - Abernathy FTC, 7/18/06
2005	Entiat	Chinook	Sub-Yearling	Screw Trap	9/13/05 - 10/3/05	100	RST data		USFWS - Abernathy FTC, 7/18/06
2005	Entiat	Chinook	Yearling	Screw Trap	3/2/05 - 4/5/05	96	RST data	Box 1 of 2	USFWS - Abernathy FTC, 7/18/06
2005	Entiat	Chinook	Yearling	Screw Trap	4/5/06 - 4/14/06	100	RST data	Box 2 of 2	USFWS - Abernathy FTC, 7/18/06
2004	Winthrop	Chinook	Adult	Hatchery	8/18/04 - 9/1/04	100	Genetics data		USFWS - Abernathy FTC, 7/18/06
2004	Peshastin	Steelhead/RT	Juvenile	Screw Trap	5/4/04 - 8/25/04	100	RST data		USFWS - Abernathy FTC, 7/18/06
2004	Peshastin	Chinook	Sub-Yearling	Screw Trap	3/25/04 - 9/4/04	100	RST data	Box 1 of 3	USFWS - Abernathy FTC, 7/18/06
2004	Peshastin	Chinook	Sub-Yearling	Screw Trap	9/4/04 - 9/10/04	100	RST data	Box 2 of 3	USFWS - Abernathy FTC, 7/18/06
2004	Peshastin	Chinook	Sub-Yearling	Screw Trap	9/23/04 - 11/12/04	28	RST data	Box 3 of 3	USFWS - Abernathy FTC, 7/18/06
2004	Leavenworth	Chinook	Adult	Hatchery	8/9/04 - 8/31/04	100	Genetics data		USFWS - Abernathy FTC, 7/18/06
2004	Leavenworth	Chinook	Adult	Hatchery	7/12/2004	100	Genetics data	Peshastin Outplants Box 1 of 4	USFWS - Abernathy FTC, 7/18/06
2004	Leavenworth	Chinook	Adult	Hatchery	7/12/04 - 7/13/04	100	Genetics data	Peshastin Outplants Box 2 of 4	USFWS - Abernathy FTC, 7/18/06
2004	Leavenworth	Chinook	Adult	Hatchery	7/13/04 - 7/14/04	100	Genetics data	Peshastin Outplants Box 3 of 4	USFWS - Abernathy FTC, 7/18/06
2004	Leavenworth	Chinook	Adult	Hatchery	7/14/2004	50	Genetics data	Peshastin Outplants Box 4 of 4	USFWS - Abernathy FTC, 7/18/06
2004	Entiat	Steelhead/RT	Juvenile	Screw Trap	5/3/04 - 10/6/02	17	RST data		USFWS - Abernathy FTC, 7/18/06
2004	Entiat	Steelhead/RT	Juvenile	Screw Trap	4/8/04 - 4/9/04	31	RST data	Fish Health samples, otoliths boxed separately	USFWS - Abernathy FTC, 7/18/06

Year	Location	Species	Life Stage	Capture Type	Collection Dates	Total #	Data	Comments	Send Location/Date
2004	Entiat	Chinook	Adult	Hatchery	8/23/04 - 9/2/04	100	Genetics data		USFWS - Abernathy FTC, 7/18/06
2004	Entiat	Chinook	Adult	Spawning Ground	9/7/04 - 9/22/04	34	Genetics data		USFWS - Abernathy FTC, 7/18/06
2004	Entiat	Chinook	Sub-Yearling	Screw Trap	6/4/04 - 10/17/04	61	RST data	Box 1 of 2, sample contains springs and summers	USFWS - Abernathy FTC, 7/18/06
2004	Entiat	Chinook	Sub-Yearling	Screw Trap	10/24/04 - 11/21/04	71	RST data	Box 2 of 2, sample contains springs and summers	USFWS - Abernathy FTC, 7/18/06
2004	Entiat	Chinook	Yearling	Screw Trap	unknown	38	RST data		NOAA (Mike Ford) 6/25/04
2004	Entiat	Chinook	Yearling	Hatchery	unknown	100	no data		NOAA (Mike Ford) 6/25/04
2003	Winthrop	Chinook	Adult	Hatchery	8/13/03 - 9/3/03	100	Genetics data		USFWS - Abernathy FTC, 7/18/06
2003	Leavenworth	Chinook	Adult	Hatchery	8/12/03 - 8/29/03	100	Genetics data		USFWS - Abernathy FTC, 7/18/06
2003	Leavenworth	Chinook	Adult	Hatchery	7/15/2003	100	Genetics data	Peshastin Outplants Box 1 of 4	USFWS - Abernathy FTC, 7/18/06
2003	Leavenworth	Chinook	Adult	Hatchery	7/15/03 - 7/16/03	100	Genetics data	Peshastin Outplants Box 2 of 4	USFWS - Abernathy FTC, 7/18/06
2003	Leavenworth	Chinook	Adult	Hatchery	7/16/2003	100	Genetics data	Peshastin Outplants Box 3 of 4	USFWS - Abernathy FTC, 7/18/06
2003	Leavenworth	Chinook	Adult	Hatchery	7/16/2003	50	Genetics data	Peshastin Outplants Box 4 of 4	USFWS - Abernathy FTC, 7/18/06
2003	Entiat	Steelhead/RT	Juvenile	Screw Trap	4/13/03 - 8/29/03	100	Genetics data	Box 1 of 3	USFWS - Abernathy FTC, 7/18/06
2003	Entiat	Steelhead/RT	Juvenile	Screw Trap	9/3/03 - 10/20/03	100	Genetics data	Box 2 of 3	USFWS - Abernathy FTC, 7/18/06
2003	Entiat	Steelhead/RT	Juvenile	Screw Trap	10/27/03 - 11/20/03	26	Genetics data	Box 3 of 3	USFWS - Abernathy FTC, 7/18/06
2003	Entiat	Chinook	Adult	Spawning Ground	10/16/03 - 11/6/03	20	Genetics data	Summer Chinook boxed with 2005 spring Chinook	USFWS - Abernathy FTC, 7/18/06
2003	Entiat	Chinook	Adult	Hatchery	unknown	100	no data		NOAA (Mike Ford) 6/25/04
2003	Entiat	Chinook	Sub-Yearling	Screw Trap	unknown	254	RST data		NOAA (Mike Ford) 6/25/04
2003	Entiat	Chinook	Sub-Yearling	Screw Trap	unknown	165	RST data		NOAA (Mike Ford) 6/25/04
2003	Entiat	Chinook	Yearling	Screw Trap	unknown	81	RST data		NOAA (Mike Ford) 6/25/04
2003	Entiat	Chinook	Yearling	Hatchery	unknown	100	no data		NOAA (Mike Ford) 6/25/04
2002	Winthrop	Chinook	Adult	Hatchery	8/14/02 - 9/10/02	100	Genetics data		USFWS - Abernathy FTC, 7/18/06
2002	Leavenworth	Chinook	Adult	Hatchery	8/13/02 - 8/27/02	100	Genetics data		USFWS - Abernathy FTC, 7/18/06
2002	Leavenworth	Chinook	Adult	Hatchery	7/8/2002	100	Genetics data	Peshastin Outplants Box 1 of 4	USFWS - Abernathy FTC, 7/18/06
2002	Leavenworth	Chinook	Adult	Hatchery	7/8/02 - 7/9/02	100	Genetics data	Peshastin Outplants Box 2 of 4	USFWS - Abernathy FTC, 7/18/06
2002	Leavenworth	Chinook	Adult	Hatchery	7/9/02 - 7/10/02	100	Genetics data	Peshastin Outplants Box 3 of 4	USFWS - Abernathy FTC, 7/18/06
2002	Leavenworth	Chinook	Adult	Hatchery	7/10/2002	50	Genetics data	Peshastin Outplants Box 4 of 4	USFWS - Abernathy FTC, 7/18/06
2002	Entiat	Chinook	Yearling	Hatchery	unknown	100	no data		USFWS - Abernathy FTC, 7/18/06
2001	Leavenworth	Chinook	Adult	Hatchery	8/21/01 - 8/28/01	100	Genetics data		USFWS - Abernathy FTC, 7/18/06

*Genetics data indicates data has been summarized specific to the box of tissue samples and is readily available in electronic form.
Tissue is primarily fin clips (~2mm2) preserved in 90%+ ethanol in 20 ml vials or placed on whatman paper to dry (ie. CRITFC PBT samples).

Species	Stock	Life Stage	Location	Last Analyses	Samples Needed	Analyses Year	Reporting
Spring Chinook	Wenatchee	Adult	brood, Tumwater	2004	(in hand) 2016, 2017	2017	2018
	Entiat	Adult	brood, spawning grounds	2006	2017, 2018	2018	2019
	Methow	Adult	brood, spawning grounds	2006	2017, 2018	2018	2019
	Okanogan	Adult	none for now, spawning grounds	none	2017, 2018	2018	2019
Steelhead	Wenatchee	Adult	brood, Tumwater	2010	2017, 2018	2018	2019
	Entiat	Adult/Smolt	brood, screw trap	2010	2017, 2018	2018	2019
	Methow	Adult	brood, weir	2008	2017, 2018	2018	2019
	Okanogan	Adult/Smolt	brood, weir	none	2017, 2018	2018	2019
Sockeye	Wenatchee	Adult	spawning grounds	2007	2018, 2019	2019	2020
	Okanogan	Adult	brood, spawning grounds	none	2018, 2019	2019	2020
Summer Chinook	Wenatchee	Adult	brood, spawning grounds	2010	2019, 2020	2020	2021
	Methow	Adult	brood, spawning grounds	2010	2019, 2020	2020	2021
	Okanogan	Adult	brood, spawning grounds, weir	2010	2019, 2020	2020	2021
	Chief Joseph [1]	Adult	brood, netting	none	2019, 2020	2020	2021
Fall Chinook	Hanford [2]	Adult	brood, spawning ground	2010	2019, 2020	2020	2021

[1] working with CCT

[2] waiting on CRITFC

Attachment F

MONITORING AND EVALUATION PLAN FOR PUD HATCHERY PROGRAMS

2017 UPDATE

July 19, 2017

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Citation: Hillman, T., T. Kahler, G. Mackey, Andrew Murdoch, K. Murdoch, T. Pearsons, M. Tonseth, and C. Willard. 2017. Monitoring and evaluation plan for PUD hatchery programs: 2017 update. Report to the HCP and PRCC Hatchery Committees, Wenatchee and Ephrata, WA.

TABLE OF CONTENTS

SECTION 1: INTRODUCTION 1

SECTION 2: ADULT PRODUCTIVITY 9
2.1 Natural Replacement Rates of Supplemented Populations 9
2.2 Natural-Origin Recruits of Supplemented Populations 11

SECTION 3: JUVENILE PRODUCTIVITY 13
3.1 Freshwater Juvenile Productivity 13

SECTION 4: NATURAL ENVIRONMENT MONITORING INDICATORS 17
4.1 Hatchery Replacement Rates (HRRs) 17
4.2 Proportion of Hatchery-Origin Spawners (pHOS or PNI) 18
4.3 Run Timing, Spawn Timing, and Spawning Distribution 19
4.4 Stray Rates 22
4.5 Population Genetics 26
4.6 Phenotypic Traits 28

SECTION 5: HATCHERY ENVIRONMENT MONITORING INDICATORS 33
5.1 Release Targets 33

SECTION 6: HARVEST MONITORING INDICATORS 37
6.1 Harvest Rates 37

SECTION 7: REGIONAL OBJECTIVES 39
7.1 Incidence of Disease 39
7.2 Non-Target Taxa of Concern (NTTOC) 40

SECTION 8: ADAPTIVE MANAGEMENT 41

SECTION 9: REFERENCES 43

APPENDIX 1: ESTIMATION OF CARRYING CAPACITY 45

APPENDIX 2: HATCHERY REPLACEMENT RATES 47

APPENDIX 3: PNI AND PHOS TARGETS AND SLIDING SCALES 49

APPENDIX 4: SPATIAL DISTRIBUTION OF SPAWNERS OR REDDS 53

APPENDIX 5: WITHIN HATCHERY REARING TARGETS 55

APPENDIX 6: IDENTIFYING AND ANALYZING REFERENCE POPULATIONS 57

LIST OF APPENDICES

Appendix 1: **Estimation of Carrying Capacity.**

Appendix 2: **Hatchery Replacement Rates.**

Appendix 3: **PNI and pHOS Management Targets and Sliding Scales.**

Appendix 4: **Spatial Distribution of Spawners or Redds.**

Appendix 5: **Within Hatchery Rearing Targets.**

Appendix 6: **Identifying and Analyzing Reference Populations.**

GLOSSARY

Adult-to-Adult survival (Ratio)	The number of parent broodstock relative to the number of returning adults.
Age at maturity	The age of fish at the time of spawning (hatchery or naturally)
Augmentation	A hatchery strategy where fish are released for the sole purpose of providing harvest opportunities.
Broodstock	Adult salmon and steelhead collected for hatchery fish egg harvest and fertilization.
Donor population	The source population for supplementation programs before hatchery fish spawned naturally.
Effective population size (Ne)	The number of reproducing individuals in an ideal population (i.e., Ne = N) that would lose genetic variation due to genetic drift or inbreeding at the same rate as the number of reproducing adults in the real population under consideration (Hallerman 2003).
ESA	Endangered Species Act passed in 1973. The ESA-listed species refers to fish species added to the ESA list of endangered or threatened species and are covered by the ESA.
Expected value	The number of smolts or adults derived from survival rates agreed to in the Biological Assessment and Management Plan (BAMP 1998).
Extraction rate	The proportion of the spawning population collected for broodstock.
Genetic diversity	All the genetic variation within a species of interest, including both within and between population components.
Genetic stock structure	A type of assortative mating, in which the gene pool of a species is composed of a group of subpopulations, or stocks, that mate panmictically within themselves.
Genetic variation	All the variation due to different alleles and genes in an individual, population, or species.
HCP	Habitat Conservation Plan is a plan that enables an individual or organization to obtain a Section 10 Permit which outlines what will be done to “minimize and mitigate” the impact of the permitted take on a listed species.
HCP-HC	Habitat Conservation Plan Hatchery Committee is the committee that directs actions under the hatchery program section of the HCP’s for Chelan and Douglas PUDs.
HRR	Hatchery Replacement Rate is the ratio of the number of returning hatchery adults relative to the number of adults taken as broodstock, both hatchery and naturally produced fish (i.e., adult-to-adult replacement rate).
Long-term fitness	Long-term fitness is the ability of a population to self-perpetuate over successive generation.
Naturally produced	Progeny of fish that spawned in the natural environment, regardless of the origin of the parents.

Mean Ratio	The ratio between a treatment and control population, with the mean taken across a time period, such as years. Used in analysis in Before-After-Control-Impact studies.
Ne	Effective population size
Non-target taxa of concern (NTTOC)	Species, stocks, or components of a stock with high value (e.g., stewardship or utilization) that may suffer negative impacts as a result of a hatchery program.
NRR	Natural replacement rate is the ratio of the number of returning naturally produced adults relative to the number of adults that naturally spawned, both hatchery and naturally produced.
NTTOC	Non-target taxa of concern.
pHOS	Proportion of Hatchery Origin Spawners
PNI	Proportionate Natural Influence
pNOB	Proportion of Natural Origin Broodstock
Productivity	The capacity in which juvenile fish or adults can be produced.
Reference population	A population in which no directed artificial propagation is currently directed, although may have occurred in the past. Reference populations are used to monitor the natural variability in survival rates and out of basin impacts on survival.
SAR	Smolt-to-adult survival rate
SAR Smolt-to-adult survival rate (SAR)	Smolt-to-adult survival rate is a measure of the number of adults that return from a given smolt population.
Segregated	A type of hatchery program in which returning adults are spatially or temporally isolated from other populations.
Size-at-maturity	The length or weight of a fish at a point in time during the year in which spawning will occur.
Smolts per redd	The total number of smolts produced from a stream divided by the total number of redds from which they were produced.
Spawning Escapement	The number of adult fish that survive to spawn.
Stray rate	The rate at which fish spawn outside of natal rivers or the stream in which they were released.
Supplementation	A hatchery strategy where the main purpose is to increase the relative abundance of natural spawning fish without reducing the long-term fitness of the population.
Target population	A specific population in which management actions are directed (e.g., artificial propagation, harvest, or conservation).

SECTION 1: INTRODUCTION

This document is an update of the monitoring and evaluation (M&E) plan of the salmon and steelhead hatchery programs funded by Douglas, Chelan, and Grant County Public Utility Districts (PUDs). Programmatic changes, evaluation of data collection methods, and M&E results from the past several years, along with shifting management paradigms affect M&E needs, all of which have occurred under advancing fish culture and monitoring techniques. As required by the programs, this document is a result of a five-year review intended to expand on and coalesce previous M&E documents (BAMP 1998; Cates et al. 2005; Murdoch and Peven 2005; Hays et al. 2006; Pearsons and Langshaw 2009a, 2009b; Hillman et al. 2013) with inclusion of new information.

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Fishery management agencies developed the following general goal statements for hatchery programs, which were adopted by the HCPs Hatchery Committees and PRCC Hatchery Sub-Committee (hereafter, Hatchery Committees):

1. Support the recovery of ESA-listed species by increasing the abundance of the natural adult population, while ensuring appropriate spatial distribution, genetic stock integrity, and adult spawner productivity.
2. Increase the abundance of the natural adult population of unlisted plan species, while ensuring appropriate spatial distribution, genetic stock integrity, and adult spawner productivity. In addition, provide harvest opportunities in years when spawning escapement is sufficient to support harvest.
3. Provide salmon for harvest and increase harvest opportunities, while segregating returning adults from natural tributary spawning populations.

Following the development of Hatchery and Genetic Management Plans (HGMPs), artificial supplementation programs are now characterized into three categories. The first type, integrated conservation programs, are intended to support or restore natural populations. These programs focus on increasing the natural production of targeted fish populations. A fundamental assumption of this strategy is that hatchery fish returning to the spawning grounds are reproductively similar to naturally produced fish. The second type, safety-net programs, are extensions of conservation programs, but are intended to function as reserve capacity for conservation programs in years of low returns. The safety-net provides a demographic and genetic reserve for the natural population. That is, in years of abundant returns they function like segregated programs, and in low return years they can be managed as conservation programs. Lastly harvest augmentation programs are intended to increase harvest opportunities while limiting interactions with wild-origin counterparts.

Monitoring is needed to determine if the hatchery programs are meeting the intended management objectives of conservation, safety-net, or harvest augmentation programs. Objectives for hatchery programs are generally grouped into three categories of performance indicators:

1. In-Hatchery: Is the program meeting the hatchery production objectives?
2. In-Nature: How do fish from the program perform after release?
    a. Conservation Program:

- How does the program affect target population abundance and productivity?
- How does the program affect target population long-term fitness?

b. Safety-Net Program:

- How does the program affect target population long-term fitness?

c. Harvest Augmentation Program:

- Does the program provide harvest opportunities?

3. Risk Assessment: Does the program pose risks to other populations?

Objectives in this plan have been organized in a hierarchy where productivity indicators are the primary metrics used to assess if conservation and safety-net program goals have been met; harvest rates and effects on non-targeted populations are used for harvest programs. In cases where productivity indicators are not available or results are equivocal, monitoring indicators may be used to help evaluate the performance of the program. Evaluations of monitoring indicators may not provide sufficiently powerful conclusions on which to base management actions, although they may provide insight as to why a productivity indicator did or did not meet the program goal. Therefore, the relationship between hatchery programs and indicators can be viewed in a chain-of-causation: management actions within the hatchery programs affect the status of monitoring indicators, which in turn influence productivity indicators (Figure 1).

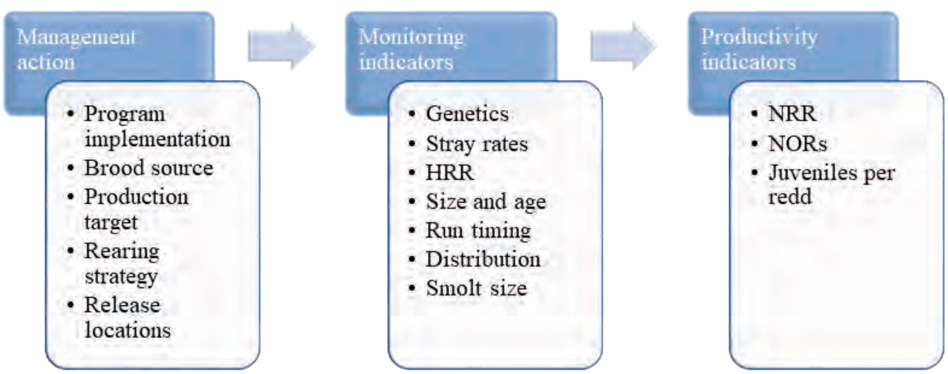

Figure 1. **Relationship of indicators to the assessment of supplementation programs. Management actions affect monitoring indicators, which influence productivity indicators. Monitoring indicators may be used to hypothesize the magnitude of influence on productivity.**

The primary goal of a conservation program is to contribute to the rebuilding and recovery of naturally reproducing populations within their native habitat. In this plan, natural replacement rates (NRR), recruitment of naturally-produced fish (NOR), and juvenile productivity (juveniles per redd) are important indicators for assessing the success of supplementation. These indicators are difficult to measure precisely and are quite variable in space and time. Therefore, monitoring indicators can be evaluated to help assess if productivity was related to the hatchery programs or other factors (Table 1).

Table 1. Program objectives, indicators, and goals for conservation hatchery programs including productivity and monitoring indicators (also applies to safety-net programs when used to support a conservation program).

	Objective	Indicator	Target	Program goals: Rebuild natural populations	Program goals: Maintain genetic diversity	Program goals: Opportunity for harvest
Productivity indicators	Determine if the program has increased the number of naturally spawning adults	Abundance of natural spawners	Increase	✓		✓
		Adult productivity (NRR)	No decrease	✓		
	Determine if the proportion of hatchery fish affects freshwater productivity	Residuals vs. pHOS	No relationship	✓		
		Juveniles per redd vs. pHOS	No relationship	✓		
Monitoring indicators	Determine if run timing and distribution meets objectives	Migration timing	No difference	✓	✓	
		Spawn timing[1]	No difference	✓	✓	
		Redd distribution[2]	No difference	✓	✓	
	Determine if program has affected genetic diversity and population structure	Allele frequency (hatchery vs. wild)	No difference		✓	
		Genetic distance between populations	No difference		✓	
		Effective population size	Increase		✓	
		Age and size at maturity	No difference		✓	
	Determine if hatchery survival meets expectations	HRR	HRR > NRR	✓		
		HRR	HRR ≥ Goal[3]	✓		
	Determine if recipient stray rate of hatchery fish is acceptable	Out of basin	≤ 5%	✓	✓	
		Within basin	≤ 10%	✓	✓	
	Determine if hatchery fish were released at program targets	Size and number	= Target[4]	✓		
	Provide harvest opportunities when appropriate	Harvest	Escapement goals			✓

[1] Hatchery and natural-origin fish should spawn at the same time across the range of elevations within the spawning distribution of each stock.

[2] Hatchery and natural-origin fish should spawn in the same locations. Exceptions are the Carlton and Dryden Summer Chinook programs (see Appendix 4).

[3] HRR targets are identified in Appendix 2.

[4] Number and size targets are identified in Table 3 and Appendix 5.

A flow of information following sequential, logical steps will be employed to evaluate supplementation programs, consistent with the indicators described in Table 1. For example, a hatchery program, at a minimum, must be able to produce more adults per spawner than would occur in the natural environment. Should the program fail this test, hatchery operations should be evaluated to determine if improvements can correct the problem. If a program successfully replaces the required number of adults, it is then evaluated against a reference population or condition, if available, to determine if it has increased the overall number of naturally spawning fish (including both hatchery- and natural-origin adults), increased the number of natural-origin spawners, and to test if productivity of the natural population has changed. When these goals are met, the program is considered successful. When these goals are not met, monitoring indicators may infer why the program is not achieving its goals

If suitable reference populations are not available, other comparisons can be used to help evaluate treatment responses. Evaluation of programs may pursue the following approaches:

- Comparison to reference population(s) that do not contain pre-treatment data.
- Before treatment and after treatment comparisons.
- Comparison to standard(s).
- Comparison to other suitable reference conditions.

Methodologies for selecting reference streams, analyzing data from treatment and reference stream comparisons, and other comparisons are presented in Hillman et al. (2012) (see Appendix 6).

The primary goals of a safety-net program are to provide demographic and genetic reserves for a population that is supplemented by a conservation program (Table 2). Harvest and adult management may be used to control escapement of spawners when appropriate. Monitoring focuses on estimating the number of fish that escape to spawn naturally and stray rates and in-hatchery performance evaluation.

Table 2. Program objectives, indicators, and goals for segregated harvest augmentation hatchery programs including monitoring indicators.

				Program goals		
	Objective	**Indicator**	**Target**	**Rebuild natural populations**	**Maintain genetic diversity**	**Opportunity for harvest**
Monitoring indicators	Determine if hatchery survival meets expectations	HRR	HRR > NRR			✓
		HRR	HRR ≥ Goal[1]			✓
	Determine if stray rate of hatchery fish is acceptable	Out of basin	≤ 5%		✓	
		Within basin	≤ 10%		✓	
	Determine if hatchery fish were released at program targets	Size and number	= Target[2]			✓
	Provide harvest opportunities when appropriate	Harvest	Escapement goals			✓

[1] HRR targets are identified in Appendix 2.
[2] Number and size targets are identified in Table 3 and Appendix 5.

The primary goal of a harvest augmentation program is to increase harvest opportunities, while segregating adults from natural spawning populations. In this plan, harvest opportunity, survival rates, and stray rates are important indicators for assessing the success of harvest augmentation. These indicators are more readily quantified compared to productivity indicators (Table 2). A flow of information will be employed to evaluate harvest augmentation programs. Since harvest augmentation programs are typically segregated, monitoring indicators will be used to determine the success of a program.

Both monitoring and productivity indicators will be used to evaluate the success of hatchery programs. In the event that the statistical power of tests that involve productivity indicators is insufficient to inform sound management decisions, some of the monitoring indicators may be used to guide management. Figure 2 show the categories of indicators associated with each component of monitoring.

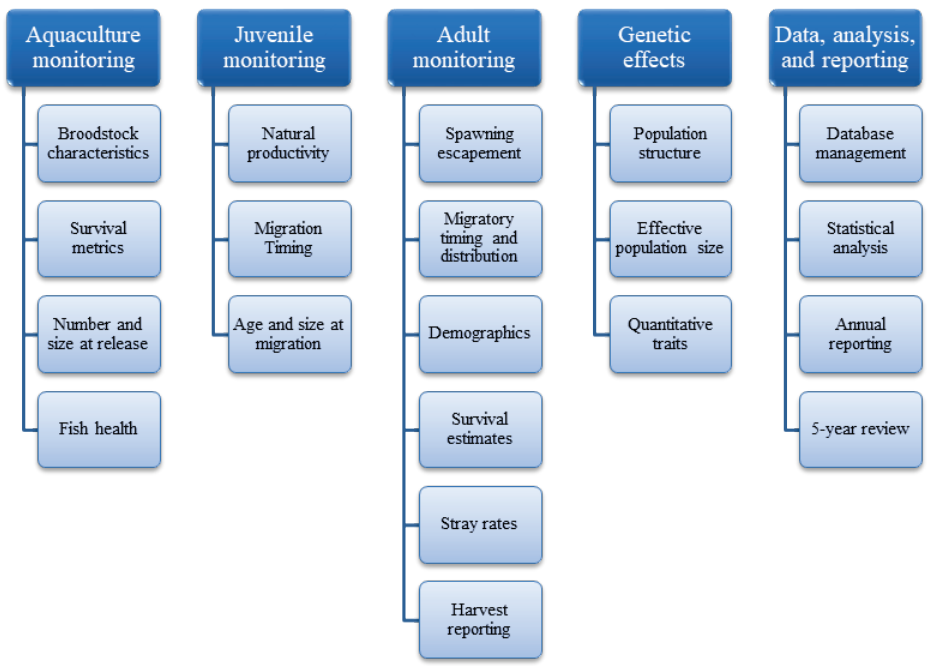

Figure 2. Overview of Monitoring and Evaluation Plan Categories and Components (not including regional objectives).

The overarching goals of conservation, safety-net, and harvest augmentation programs, as described above, are shown in detail in Figure 3. The flow chart (Figure 3) shows the relationship of overarching program goals, the strategies used to meet the goals, the monitoring and evaluation objectives used to evaluate the strategies and determine if goals are being met, and the adaptive management cycle associated with the programs (see Tables 1 and 2 for the indicators under each objective). The logic depicted in this flow chart shall be used to assess M&E results and apply

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those results to management decisions. Table 3 presents the current hatchery programs releasing fish in the Upper Columbia Basin.

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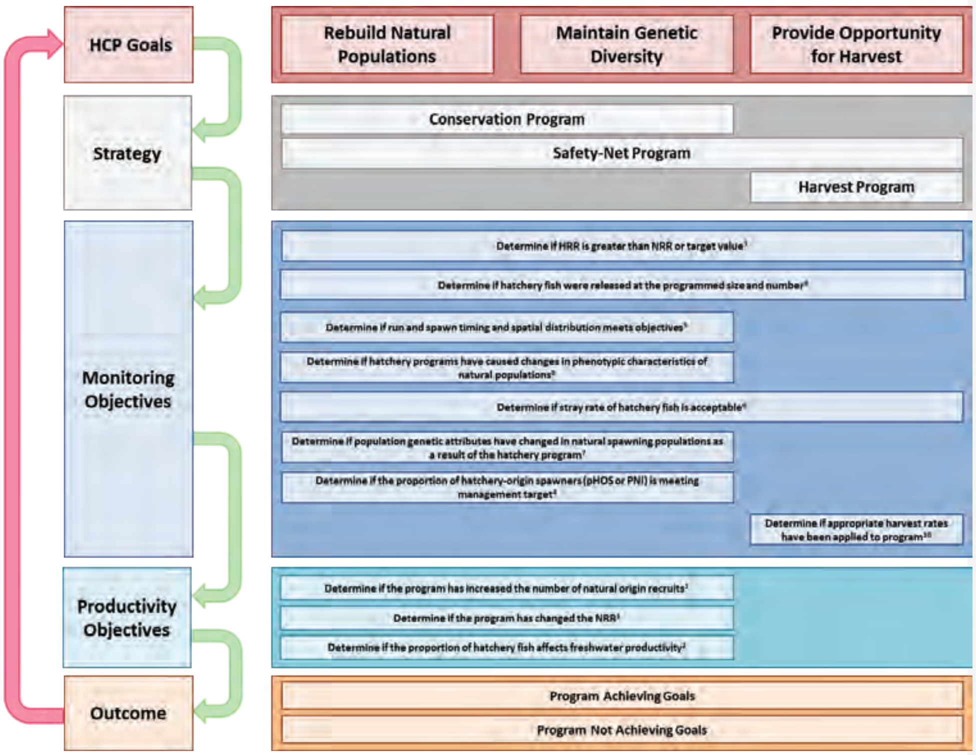

Figure 3. Adaptive management flow chart depicting HCP goals, associated strategies to meet the goals, the monitoring and evaluation objectives (indicated in superscript), and the adaptive management feedback cycle. The strategies, objectives, and outcomes are aligned vertically under the corresponding goals.

Table 3. Hatchery programs in the mid-Columbia River Basin, 2012. Funding entities included Douglas PUD (D), Chelan PUD (C), Grant PUD (G), Bonneville Power Administration (B), Bureau of Reclamation (O), and Army Corps of Engineers (A) and are listed in order of contribution. Total artificial production targets in the mid-Columbia River exceeds 20 million juveniles annually.

Program	Species	Basin	Purpose	Funding Entity	Production
Methow[5]	Spring Chinook [1]	Methow	NNI/Conservation	G, C, D	223,765
Chief Joseph[7]	Spring Chinook	Okanogan	Reintroduction/Harvest	B, G, C, D	900,000
Chiwawa[5]	Spring Chinook [1]	Wenatchee	NNI/Conservation	C	144,026
White[5]	Spring Chinook [1]	Wenatchee	NNI/Conservation	G	74,556
Nason[5]	Spring Chinook [1]	Wenatchee	NNI/Conservation	G	149,114
Winthrop[7]	Spring Chinook [2]	Methow	Safety-Net	O	400,000
Leavenworth	Spring Chinook [2]	Wenatchee	Harvest	O	1,200,000
Wells[5]	Steelhead [1]	Columbia	Inundation/Safety-Net	D	160,000
Winthrop[7]	Steelhead [1]	Methow	Conservation	O	100,000-200,000
Wells[5]	Steelhead [1]	Methow	Inundation/Safety-Net	D	100,000
Wells/Omak[5, 6]	Steelhead [1]	Okanogan	NNI/Conservation	G	100,000
Wells[5]	Steelhead [1]	Twisp	Inundation/Conservation	D	40,000
Wells[5]	Steelhead [1]	Twisp	NNI/Conservation	D	8,000
Chiwawa[5]	Steelhead [1]	Wenatchee	NNI/Conservation	C	22,000
Chiwawa[5]	Steelhead [1]	Wenatchee	Inundation/Harvest	C	165,000
Chiwawa[5]	Steelhead [1]	Wenatchee	Species trade	C	60,300
Wells[5]	Summer Chinook [2, 3]	Columbia	Inundation/Harvest	D	484,000
Chief Joseph[7]	Summer Chinook [3]	Okanogan	NNI/Cons./Harvest	B, G, C, D	700,000
Chelan Falls[5]	Summer Chinook [2]	Chelan	Inundation/Harvest	C	400,000
Chelan Falls[5]	Summer Chinook [2]	Chelan	NNI/Conservation	C	176,000
Wells[5]	Summer Chinook [2]	Columbia	Inundation/Harvest	D	320,000
Entiat	Summer Chinook	Entiat	Harvest	O	400,000
Carlton[5]	Summer Chinook	Methow	NNI/Conservation	G	200,000
Chief Joseph[7]	Summer Chinook	Okanogan	NNI/Cons./Harvest	B, G, C, D	1,300,000
Dryden[5]	Summer Chinook	Wenatchee	NNI/Conservation	C, G	500,000
Priest[5]	Fall Chinook[3]	Columbia	Inundation/Harvest	G	5,000,000
Priest[5]	Fall Chinook[3]	Columbia	NNI/Harvest	G	325,543
Priest[5]	Fall Chinook[4]	Columbia	Fry loss/Harvest	G	1,000,000
Priest[5, 7]	Fall Chinook[3]	Columbia	Harvest	A	1,700,000
Ringold[7]	Fall Chinook[3]	Columbia	Harvest	A	3,000,000
Yakama Nation	Coho	Wenatchee	Reintroduction/Harvest	B, G, C, D	1,000,000
Yakama Nation[8]	Coho	Methow	Reintroduction/Harvest	B, G, C, D	500,000
Skaha	Sockeye	Okanogan	Reintroduction/Harvest	C, G	≤ 5 M eggs

[1] Species listed under the Endangered Species Act.
[2] Segregated program.
[3] Sub-yearling production.
[4] Fry production.
[5] Program covered by this M&E Plan.
[6] Program also partially covered by CCT M&E Plan.
[7] Program affects PUD-funded programs covered by this plan.
[8] Planned to increase within the next 5 years.

SECTION 2: ADULT PRODUCTIVITY

2.1 Natural Replacement Rates of Supplemented Populations[1]

Objective 1: Determine if conservation programs have increased the number of naturally spawning and naturally produced adults of the target population and if the program has reduced the natural replacement rate (NRR) of the supplemented population.

At the core of a conservation program is the objective of increasing the number of spawning adults (i.e., the combined number of naturally produced and hatchery fish) in order to affect a subsequent increase in the number of returning naturally produced fish or natural-origin recruits (NOR). In order for the natural population to remain stable or to increase, the Natural Replacement Rate (NRR), or the ratio of NORs to the parent spawning population, must be at a level where parents are being replaced by their offspring as spawners in the next generation. It is possible to affect an increase in natural-origin spawners through supplementation with a stable or decreasing NRR. However, if the NRR is below replacement (NRR<1.0), termination of the supplementation program will result in a declining natural population should that state of NRR persist. The proportion of the hatchery-origin spawners (pHOS) that will increase natural production without creating adverse effects to the genetic diversity or reproductive success rate of the natural population is unknown, and may be dependent on how individual hatchery programs are operated, as well as available spawning and rearing habitat. Some programs may restrict pHOS to reduce the risk to the natural population with the intent of optimizing productivity, concomitantly reducing the overall number of spawners. All other objectives of the M&E Plan either directly support this objective or seek to minimize negative effects of the conservation programs on non-target stocks of concern.

Differences in carrying capacities of supplemented and non-supplemented streams can confound the analysis of the effects of supplementation on total number of spawners returning to the streams. For example, if the supplemented population is at carrying capacity and the non-supplemented population is not, the total number of spawners returning to the non-supplemented population may show an increasing trend over time, while the supplemented population would show no increasing trend. To avoid concluding that the supplementation program has no effect or perhaps a negative effect on total spawners, density corrections should be included in the analyses. Hypotheses that may require density corrections are noted under each monitoring question. Appendix 1 describes methods for estimating carrying capacities.

Monitoring Questions:

Q1.1.1 Has the supplementation program changed the adult productivity (NRRs) of the supplemented populations?[2]

Target Species/Populations:

[1] Supplementation programs may include a safety-net component.

[2] Because adult productivity is affected by the abundance of the population (i.e., productivity decreases with increasing abundance), the goal of supplementation is to increase or maintain productivity, but not decrease it.

- Q1.1.1 applies to all conservation and safety-net stocks.

Statistical Hypotheses 1.1.1[3]:

- $Ho_{1.1.1.1}$: Slope in NRRs before supplementation ≤ slope in NRRs after supplementation.
- $Ho_{1.1.1.2}$: Differences in slopes in NRRs between supplemented and reference populations before supplementation ≤ differences in slopes in NRRs between supplemented and reference populations after supplementation.
- $Ho_{1.1.1.3}$: Mean NRRs before supplementation ≤ mean NRRs after supplementation.
- $Ho_{1.1.1.4}$: Mean ratio scores in NRRs before supplementation ≤ Mean ratio scores in NRRs during supplementation.
- $Ho_{1.1.1.5}$: Mean ratio scores in NRRs (adjusted for density dependence) before supplementation ≤ Mean ratio scores in NRRs (adjusted for density dependence) during supplementation. [This hypothesis adjusts NRRs for density-dependent effects (see Hillman et al. 2012 for details; Appendix 6).]
- $Ho_{1.1.1.6}$: There is no association between the proportion of hatchery-origin spawners (pHOS) and the residuals from the smooth hockey stick stock-recruitment curve; rho = 0. [If there is a significant negative association between pHOS and the residuals, then hatchery fish may be reducing the productivity of the wild population.]

Measured Variables:

- Number of hatchery and naturally produced fish on spawning grounds
- Number of naturally produced fish harvested

Derived Variables:

- Number of naturally produced recruits by brood year for both naturally produced parents and hatchery parents (≥age-3).
- NRRs (calculated as NORs/spawner).
- Stock-recruit models, parameters, and residuals.
- Includes ratio scores of NRRs (requires reference population[s]).
- Includes calculation of ratios NORs (requires reference population).
- Appendix 1: Spawning escapement and carrying capacity information (as applicable)

Spatial/Temporal Scale:

- Calculated annually based on brood year.
- Time series.

Possible Statistical Analysis:

[3] Quality and quantity of data will determine which hypotheses are evaluated. See Hillman et al. 2012 (Appendix 6) for details.

- These analyses shall be performed every 5-years. Use graphic analyses, trend analyses, t-tests, Aspin-Welch tests, and randomization tests to evaluate the statistical hypotheses (see Hillman et al. 2012; Appendix 6). The specific analysis used will depend on the availability of reference conditions.
- Correlation analysis will examine associations between hatchery adult composition and NRRs.
- On a five-year period, correlate productivity with extraneous factors such as ocean productivity indices.

Analytical Rules:

- This is a productivity indicator that will be used to assess the success of the supplementation program.
- Type I Error of 0.05.

2.2 Natural-Origin Recruits of Supplemented Populations

Monitoring Questions:

Q1.2.1: Has the supplementation program changed the abundance of NORs within the supplemented population?

Target Species/Populations:

- Q1.2.1 applies to all supplemented or safety net stocks.

Statistical Hypotheses 1.2.1[4]:

- $Ho_{1.2.1.1}$: Slope in NORs[5] before supplementation ≥ slope in NORs after supplementation.
- $Ho_{1.2.1.2}$: Differences in slopes in NORs between supplemented and reference populations before supplementation ≥ differences in slopes in NORs between supplemented and reference populations after supplementation.
- $Ho_{1.2.1.3}$: Mean NORs before supplementation ≥ mean NORs after supplementation.
- $Ho_{1.2.1.4}$: Mean ratio scores in NORs before supplementation ≥ Mean ratio scores in NORs during supplementation.
- $Ho_{1.2.1.5}$: Mean ratio scores in NORs/Maximum Recruitment before supplementation ≥ Mean ratio scores in NORs/Maximum Recruitment during supplementation. [This hypothesis adjusts NORs for the capacity of the habitat; it tests the fraction of the habitat saturated with NORs (see Hillman et al. 2012 for details).]
- $Ho_{1.2.1.6}$: There is no association between the proportion of hatchery-origin spawners (pHOS) and NORs; rho = 0. [If there is a significant negative association between

[4] Quality and quantity of data will determine which hypotheses are evaluated. See Hillman et al. 2012 (Appendix 7) for details.

[5] "Slope in NORS" refers to abundance of NORs across time (years).

pHOS and NORs, then hatchery fish may be reducing the reproductive success of the wild population.]

Measured Variables:

- Number of hatchery and naturally produced fish on spawning grounds.
- Number of hatchery and naturally produced fish taken for broodstock.
- Number of hatchery and naturally produced fish taken in harvest (if recruitment is to the Columbia).

Derived Variables:

- NORs (number of naturally produced recruits (total recruits) by brood year for both naturally produced parents and hatchery parents [≥age-3]).
- Stock-recruit models, parameters, and residuals.
- Includes ratio scores of NORs (requires reference population[s]).
- Estimates of carrying capacity (see Appendix 1).

Spatial/Temporal Scale:

- Calculate annually based on brood year.
- Time series.

Possible Statistical Analysis:

- These analyses shall be performed every 5-years. Use graphic analyses, trend analyses, t-tests, Aspin-Welch tests, and randomization tests to evaluate the statistical hypotheses (see Hillman et al. 2012). The specific analysis used will depend on the availability of reference conditions.
- Correlation analysis will examine associations between hatchery adult composition and NORs.
- On a five-year period, correlate NORs with extraneous factors such as ocean productivity indices.

Analytical Rules:

- This is a productivity indicator that will be used to assess the success of the supplementation program.
- Type I Error of 0.05.

SECTION 3: JUVENILE PRODUCTIVITY

3.1 Freshwater Juvenile Productivity

Objective 2: Determine if the proportion of hatchery fish on the spawning grounds affects the freshwater productivity of supplemented stocks.

Out-of-basin effects (e.g., smolt passage through the hydro system, harvest, and ocean productivity, etc.) influence the survival of smolts after they migrate from the tributaries. These effects introduce substantial variability into the adult-to-adult survival rates (NRRs and HRRs) and may mask in-basin effects (e.g., habitat quality, density-dependent mortality, and differential reproductive success of hatchery and naturally produced fish). Therefore, an estimate of freshwater productivity may help inform the performance of hatchery and natural-origin spawners.

The objective of estimating freshwater productivity in the Upper Columbia ESU/DPS is to estimate the survival from egg to a critical juvenile life stage(s) of target stocks. Smolt or juvenile production models generated from the information obtained through these programs will provide a level of predictability with greater sensitivity to in-basin effects than spawner-recruitment models that consider all effects.

Differences in the current carrying capacities of supplemented and non-supplemented streams can confound the effects of supplementation on numbers of juveniles per redd. For example, if the supplemented population is at or above carrying capacity and the non-supplemented population is not, numbers of juveniles per redd in the non-supplemented population may be significantly greater than the number of juveniles per redd in the supplemented population. In addition, pHOS may be correlated with overall spawner abundance. In these cases, it is difficult or impossible to separate density-dependent effects from the influence of pHOS on freshwater productivity. To avoid concluding that the supplementation program has no effect or perhaps a negative effect on juveniles per redd, the capacity of the habitats must be included in the analyses. The Supplementary Hypotheses presented below are designed to address the confounding effects of different densities on the analyses.

Monitoring Questions:

Q2.1.1: Has the supplementation program changed the number of juveniles (smolts, parr, and/or emigrants) per redd within the supplemented population?

Q2.2.1: Does the number of juveniles per redd decrease as the proportion of hatchery spawners increases?[6]

Target Species/Populations:

- Both Q2.1.1 and Q2.2.1 apply to all conservation stocks.

Statistical Hypotheses for 2.1.1[7]:

6 Information is needed to estimate the effects of density dependence on these questions. Consider spatial distribution of redds.

7 Quality and quantity of data will determine which hypotheses are evaluated. See Hillman et al. (2012) for details.

- $Ho_{2.1.1.1}$: Slope in juveniles/redd before supplementation ≤ slope in juveniles/redd after supplementation.
- $Ho_{2.1.1.2}$: Differences in slopes in juveniles/redd between supplemented and reference populations before supplementation ≤ differences in slopes in juveniles/redd between supplemented and reference populations after supplementation.
- $Ho_{2.1.1.3}$: Mean juveniles/redd before supplementation ≤ mean juveniles/redd after supplementation.
- $Ho_{2.1.1.4}$: Mean ratio scores in juveniles/redd before supplementation ≤ Mean ratio scores in juveniles/redd during supplementation.
- $Ho_{2.1.1.5}$: Mean ratio scores in juveniles/redd (adjusted for density dependence) before supplementation ≤ Mean ratio scores in juveniles/redd (adjusted for density dependence) during supplementation. [This hypothesis adjusts juveniles/redd for density-dependent effects (see Hillman et al. 2012 for details; Appendix 6).]
- $Ho_{2.1.1.6}$: There is no association between the proportion of hatchery-origin spawners (pHOS) and the residuals from the smooth hockey stick stock-recruitment curve; rho = 0. [If there is a significant negative association between pHOS and the residuals, then hatchery fish may be reducing the productivity of the wild population.]

Statistical Hypotheses for 2.2.1:

- $Ho_{2.2.1.1}$: There is no association between the proportion of hatchery-origin spawners (pHOS) and the residuals from the smooth hockey stick stock-recruitment curve; rho = 0. [If there is a significant negative association between pHOS and the residuals, then hatchery fish may be reducing the productivity of the wild population.]
- $Ho_{2.2.1.2}$: The slope between proportion of hatchery spawners and juveniles/redd is ≥ 0.

Measured Variables:

- Number of hatchery and naturally produced fish on spawning grounds.
- Numbers of redds.
- Number of juveniles (smolts, parr [where appropriate], and emigrants).

Derived Variables:

- Number of juveniles per spawner.
- Number of juveniles per redd.
- Carrying capacity (see Appendix 1).

Spatial/Temporal Scale:

- Calculate annually based on brood year.
- Time series.

Possible Statistical Analysis:

- These analyses shall be performed every five-years. Use graphic analyses, trend analyses, t-tests, Aspin-Welch tests, and randomization tests to evaluate the statistical hypotheses (see Hillman et al. 2012; Appendix 6). The specific analysis used will depend on the availability of reference conditions.
- Correlation analysis will examine associations between hatchery adult composition and juveniles/redd.

Analytical Rules:

- This is a productivity indicator that will be used to assess the success of the supplementation program.
- Type I Error of 0.05.

SECTION 4: NATURAL ENVIRONMENT MONITORING INDICATORS

4.1 Hatchery Replacement Rates (HRRs)

<u>Objective 3</u>: **Determine if the hatchery adult-to-adult survival (i.e., hatchery replacement rate, HRR) is greater than the natural adult-to-adult survival (i.e., natural replacement rate, NRR) and the target hatchery survival rate.**

The survival advantage from the hatchery (i.e., egg-to-smolt) must be sufficient to produce a greater number of returning adults than if broodstock were left to spawn naturally. If a hatchery program cannot produce a greater number of adults than naturally spawning fish, then the program should be modified or discontinued. Production levels were initially developed using historical run sizes and smolt-to-adult survival rates (BAMP 1998). Using the stock specific NRR and agreed upon target values (see Appendix 2), comparisons to actual survival rates will be made to ensure the expected level of survival has been achieved.

Deleted: e.g. values listed in the BAMP or derived from other sources

Monitoring Questions:

Q3.2.1: Is the adult-to-adult survival rate of hatchery fish (HRR) greater than or equal to the adult-to-adult survival rate (NRR) of naturally produced fish?

Q3.2.2: Is the adult-to-adult survival rate of hatchery fish (HRR) greater than or equal to the Target Value identified in Appendix 2[8]?

Target Species/Populations:

- Q3.2.1 applies to all conservation stocks.
- Q3.2.2 applies to all stocks.

Statistical Hypothesis 3.2.1:

- $Ho_{3.2.1.1}$: $HRR_{\text{Year } x} \geq NRR_{\text{Year } x}$

Statistical Hypothesis 3.2.2:

- $Ho_{3.2.2.1}$: HRR ≥ Target Value identified in Appendix 2

Measured Variables:

- Number of hatchery and naturally produced fish on spawning grounds.
- Number of hatchery and naturally produced fish harvested.
- Number of hatchery and naturally produced fish collected for broodstock.
- Number of broodstock used by brood year (hatchery and naturally produced fish).

Derived Variables:

- Number of hatchery and naturally produced adults by brood year (≥age-3).

[8] Target values may be adjusted by the hatchery committees.

- HRR (number of returning adults per brood year/broodstock)
- NRR (from Objective 1)
- Appendix 2: HRR targets identified in Appendix 2

Spatial/Temporal Scale:

- Calculate annually based on brood year.
- Time series.

Possible Statistical Analysis:

- For Q3.2.1 use graphic analysis and paired-sample quantile tests to compare HRR to NRR
- For Q3.2.2 use graphic analysis and one-sample quantile tests to compare HRR to the target value.
- On a five-year period, correlate HRRs with extraneous factors such as ocean productivity indices.

Analytical Rules:

- This is a monitoring indicator that will be used to support management decisions.
- Type I Error of 0.05.

4.2 Proportion of Hatchery-Origin Spawners (pHOS or PNI)

Objective 4: Determine if the proportion of hatchery-origin spawners (pHOS or PNI) is meeting management target.

Certain hatchery programs have pHOS or PNI targets, while other do not. HGMPs and permits inform the selection of targets, which are identified in Appendix 3.

Monitoring Questions:

Q4.1.1: Is the estimated proportion of hatchery-origin spawners (pHOS) less than or equal to the management target, and/or, is the estimated Percent Natural Influence (PNI) greater than or equal to the management target identified in Appendix 3?

Target Species/Populations:

- Q4.1.1 applies to all conservation and safety-net stocks that have a defined pHOS or PNI target or sliding scale (see Appendix 3).

Statistical Hypothesis 4.1.1:

- $Ho_{4.1.1.1}$: pHOS > target value or $PNI_{Supplemented\ population}$ < target value identified in Appendix 3

Measured Variables:

- Number of hatchery and naturally produced fish on spawning grounds

Derived Variables:

- pHOS or PNI
- Appendix 3: PNI and pHOS targets and sliding scales identified in Appendix 3

Spatial/Temporal Scale:

- Calculate annually.
- Analyzed as time series.

Possible Statistical Analysis:

- Use graphic analysis and summary statistics to compare pHOS or PNI to the target value in Appendix 3.

Analytical Rules:

- This is a monitoring indicator that will be used to support management decisions.

4.3 Run Timing, Spawn Timing, and Spawning Distribution

Objective 5: Determine if the run timing, spawn timing, and spawning distribution of the hatchery component is similar to the natural component of the target population or is meeting program-specific objectives.

Strategies for conservation programs typically intend that hatchery and natural-origin fish spawn together and in similar locations. However, in some cases, strategies may differ from this paradigm (e.g., summer Chinook salmon in the Wenatchee and Methow rivers; see Appendix 4). Phenotypic plasticity or selection resulting from the hatchery environment (i.e., domestication) may affect run (migration) timing, spawn timing, and spawning distribution. If conservation programs do not adequately represent the genetic diversity of the natural population, and if phenotypic traits in supplementation fish related to fitness deviate from the naturally produced spawning population, the goals of supplementation may not be achieved. Hatchery adults that migrate and/or spawn at different times or are spatially segregated from natural-origin fish may be subject to reduced fitness. Hatchery adults that spawn at different times or locations than natural-origin fish would be reproductively isolated from the natural population. The extent of such isolation, ranging from no isolation to substantial isolation, may be exploited for management purposes in some cases.

Migration Timing

Monitoring Questions:

Q5.1.1: Is the migration timing of hatchery and natural-origin fish from the same age class similar?

Target Species/Populations:

- Q5.1.1 applies to all conservation stocks.

Statistical Hypotheses 5.1.1:

- $Ho_{5.1.1.1}$: Migration timing $_{\text{Hatchery Age X}}$ = Migration timing $_{\text{Naturally produced Age X}}$

- $Ho_{5.1.1.2}$: The cumulative frequency of migration timing of hatchery-origin fish = the cumulative frequency of migration timing of natural-origin fish.
- $Ho_{5.1.1.3}$: The 10th percentile, 50th percentile (mode), 90th percentile, and mean migration timing of hatchery-origin fish = the 10th percentile, 50th percentile (median), 90th percentile, and mean migration timing of natural-origin fish.

Measured Variables:

- Ages of hatchery and natural-origin fish sampled via pit tags or stock assessment monitoring.
- Time (Julian date) of arrival at mainstem projects and within tributaries (e.g., traps, PIT arrays) with the intent to identify biologically significant differences.

Derived Variables:

- Mean Julian date for a given age class.

Spatial/Temporal Scale:

- Calculate annually based on return year and age class.
- Time series.

Possible Statistical Analysis:

- Use graphic analyses (cumulative frequency polygons), paired t-tests, Aspin-Welch tests, and randomization tests.

Analytical Rules:

- This is a monitoring indicator that will be used to support management decisions.
- Type I Error of 0.05.

Spawn Timing

Monitoring Questions:

Q5.2.1: Is the timing of spawning similar for conservation hatchery and natural-origin fish?

Deleted: ly produced

Target Species/Populations:

- Q5.2.1: Applies to all semelparous species and populations supplemented by conservation programs. Steelhead can only be assessed for natural spawning in situations where hatchery and natural-origin fish can be appropriately marked and detected.

Deleted:

Statistical Hypotheses 5.2.1:

- $Ho_{5.2.1.1}$: The cumulative frequency of spawn timing of hatchery-origin fish = the cumulative frequency of spawn timing of natural-origin fish.
- $Ho_{5.2.1.2}$: The 10th percentile, 50th percentile (mode), 90th percentile, and mean spawn timing of hatchery-origin fish = the 10th percentile, 50th percentile (mode), 90th percentile, and mean spawn timing of natural-origin fish.

- Ho$_{5.2.1.3}$: The relationship between elevation and spawn timing of hatchery-origin fish = the relationship between elevation and spawn timing of natural-origin fish.

Measured Variables:

- Time (Julian date) and elevation (m) of hatchery and natural-origin salmon carcasses or marked steelhead detected on spawning grounds within defined reaches.
- Time (Julian date) of ripeness of hatchery and natural-origin steelhead captured for broodstock.

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Derived Variables:

- Mean Julian date.

Spatial/Temporal Scale:

- Calculate annually based on return year.
- Time series.

Possible Statistical Analysis:

- Use graphic analyses (cumulative frequency polygons), paired t-tests, Aspin-Welch tests, and randomization tests.
- Use graphic analyses, ANCOVA, and regression analysis to assess relationships between elevation and spawn timing.

Deleted: ANCOVA with elevation as a covariate

Analytical Rules:

- This is a monitoring indicator that will be used to support management decisions.
- Type I Error of 0.05.

Spatial Distribution of Redds

Monitoring Questions:

Q5.3.1: Is the distribution of redds similar for conservation hatchery and natural-origin fish?

Q5.3.2: Is the distribution of redds similar to defined management targets (see Appendix 4)?

Target Species/Populations:

- Q5.3.1 applies to all conservation program stocks.
- Q5.3.2 applies only to conservation program stocks with specific spawning distribution targets (Carlton and Dryden summer Chinook programs; Appendix 4).

Deleted: Table 5.3.1

Statistical Hypothesis 5.3.1:

- Ho$_{5.3.1.1}$: The distribution of hatchery-origin redds (hatchery females) = the distribution of natural-origin redds (natural-origin females).

Statistical Hypothesis 5.3.2:

- $Ho_{5.3.2.1}$: The distribution of hatchery-origin redds (hatchery females) = the target distribution identified in Appendix 4.

Measured Variables:

- Location (GPS coordinate) of female salmon carcasses observed on spawning grounds. The distribution of hatchery and naturally produced steelhead redds may be evaluated if marking or tagging efforts provide reasonable results.

Derived Variables:

- Location of female salmon carcass at the historic reach scale and at the 0.1 km scale.
- Calculate percent overlap in distribution across available spawning habitat or historical reaches.
- Appendix 4: Management targets for spatial distribution of spawners or redds (as applicable).

Spatial/Temporal Scale:

- Calculate annually based on return year.
- Time series.

Possible Statistical Analysis:

- Use graphic analysis and Yates' Chi-square analysis for both Q5.3.1 and Q5.3.2.

Analytical Rules:

- This is a monitoring indicator that will be used to support management decisions.
- Type I Error of 0.05.

4.4 Stray Rates

Objective 6: Determine if the recipient stray rate of hatchery fish is below the acceptable levels to maintain genetic variation among stocks.

Maintaining locally adapted traits among independent fish populations requires that returning hatchery fish have a high rate of site fidelity to the target population or stream. Hatchery practices (e.g., imprinting on water sources at key life history stages, release methodology, release location, age at return, and environmental conditions) are the main variables thought to affect stray rates. Regardless of the magnitude of homing of adult returns, if adult hatchery fish do not contribute to the natural population, the program will not meet the basic condition of a supplementation program.

Independent populations are populations that are genetically differentiated from other populations. In some cases, genetic differentiation may be assumed based on phenotypic traits or geographic isolation when molecular genetics analyses are not available. When populations are not independent, straying among them does not pose a risk of genetic homogenization. In addition, stray rates of hatchery-origin fish cannot be expected to be lower than for natural-origin fish. When estimates of stray rates for natural-origin fish are available and if they exceed the 5% among population stray rate or 10% within population stray rate thresholds identified in this plan, analysis

and interpretation of stray rates must take into account the concept that hatchery programs may be held to unattainable standards based on the natural stray rate. Current criteria established by the ICBTRT (2005) and the Upper Columbia Spring Chinook Salmon and Steelhead Recovery Plan (2007) indicate that fish that do stray to other non-target populations should not comprise greater than 5% of the non-target spawning population. Likewise, fish that stray into non-target spawning areas within an independent population should not comprise greater than 10% of the non-target spawning aggregate (see Tables 6.1 and 6.2).

This plan identifies three stray rate metrics; brood-year stray rate, among population return-year stray rate, and within population return-year stray rate. The return-year stray rates have specific targets that are from the ICBTRT (2005) and Upper Columbia Spring Chinook Salmon and Steelhead Recovery Plan (2007), and are linked to extinction risk. That is, hatchery strays from other populations cannot make up more than 5% of the spawning escapement within a non-target, recipient population. In addition, hatchery strays from other spawning aggregations within a population (e.g., Chiwawa spring Chinook) cannot make up more than 10% of the spawning escapement within a non-target, recipient spawning aggregate (e.g., Peshastin Creek). Brood-year stray rate, on the other hand, is not discussed in the Upper Columbia Spring Chinook Salmon and Steelhead Recovery Plan (2007) or ICBTRT (2005) and therefore has no specific target. Nevertheless, it is important to track brood-year stray rates to determine if hatchery operations affect the homing and straying of specific brood years. These data support the return-year stray metrics and are used to explain possible changes in genetic variation among stocks.

Brood-Year Stray Rates

Monitoring Questions:

Q6.1.1: What is the brood-year stray rate of hatchery fish?

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Deleted: less than 5% for the total brood return

Target Species/Populations:

- Q6.1.1 applies to all hatchery stocks.

Statistical Hypothesis 6.1.1:

- $Ho_{6.1.1.1}$: None.

Deleted: Stray rate of hatchery fish ≥ 5% of total hatchery brood return

Measured Variables:

- Number of hatchery carcasses found in non-target and target spawning areas or number of returning spawners counted via PIT-tag detection or at weirs in close temporal proximity to spawning areas.
- Number of hatchery fish collected for broodstock.
- Number of hatchery fish taken in fishery.
- Locations of live and dead strays (used to tease out overshoot).

Derived Variables:

- Total number of hatchery carcasses and take in fishery estimated from expansion analysis.
- Percent of the total brood return that strays.

Spatial/Temporal Scale:

- Calculate annually based on brood year.
- Time series.

Possible Statistical Analysis:

- Use graphical analysis to track brood-year stray rates over time.

Analytical Rules:

- This is a monitoring indicator that will be used to support management decisions.

Among-Population Return-Year Stray Rates

Monitoring Questions:

Q6.2.1: Do hatchery strays make up less than 5% of the spawning escapement within ther non-target independent populations?

Target Species/Populations:

- Q6.2.1 applies to all hatchery stocks.

Statistical Hypothesis 6.2.1:

- $Ho_{6.2.1.1}$: Stray hatchery fish make up ≥ 5% of the spawning escapement (based on run year) within other independent populations [9]

Measured Variables:

- Number of hatchery carcasses (PIT-tagged steelhead) found in non-target and target spawning areas or number of returning spawners counted via PIT-tag detection or at weirs in close temporal proximity to spawning areas.

Derived Variables:

- Total number of hatchery salmon carcasses (PIT-tagged steelhead, spawners counted at weirs) estimated from expansion analysis.
- Percent of the non-target population that is made up of hatchery strays.

Spatial/Temporal Scale:

- Calculate annually based on return year.
- Time series.

Possible Statistical Analysis:

[9] This stray rate is suggested based on a literature review and recommendations by the ICBTRT (2005) and is identified in the Upper Columbia Spring Chinook Salmon and Steelhead Recovery Plan (2007). It can be re-evaluated as more information on naturally-produced Upper Columbia salmonids becomes available. This will be evaluated on a species and program specific basis and decisions made by the HCP HC. It is important to understand the actual spawner composition of the population to determine the potential effect of straying.

Deleted: <#>Appendix 5: Reciprocal stray rates¶

Deleted: and one-sample quantile tests to compare the estimated stray rate with the target (5%) stray rate.

Deleted: <#>Type I Error of 0.05.¶

- Use graphical analysis and one-sample quantile tests to compare the estimated stray rate with the target (5%) stray rate.

Analytical Rules:

- This is a monitoring indicator that will be used to support management decisions.
- Type I Error of 0.05.

Within-Population Return-Year Stray Rates

Monitoring Questions:

Q6.3.1: Do hatchery strays make up less than 10% of the spawning aggregate within non-target spawning areas within the target population?[10]

Target Species/Populations:

- Q6.3.1 applies to all hatchery stocks.

Statistical Hypothesis 6.3.1:

- $Ho_{6.3.1}$: Stray hatchery fish make up ≥ 10% of spawning escapement (based on run year) within non-target spawning areas within the target population

Measured Variables:

- Number of hatchery carcasses (possibly PIT-tagged steelhead) found in non-target and target spawning aggregates or number of returning spawners counted via PIT-tag detection or at weirs in close temporal proximity to spawning areas.

Derived Variables:

- Total number of hatchery salmon carcasses (possibly PIT-tagged steelhead or spawners counted at weirs) estimated from expansion analysis.
- Percent of the non-target spawning aggregate that is made up of hatchery strays.

Spatial/Temporal Scale:

- Calculate annually based on return year.
- Time series.

Possible Statistical Analysis:

- Use graphical analysis and one-sample quantile tests to compare the estimated stray rate with the target (10%) stray rate.

Analytical Rules:

- This is a monitoring indicator that will be used to support management decisions.
- Type I Error of 0.05.

[10] The value of 10% should be reviewed by the Hatchery Committee. See footnote 3 for additional information.

4.5 Population Genetics

Objective 7: Determine if genetic diversity, population structure, and effective population size have changed in natural spawning populations as a result of the hatchery program.

The genetic component of the M&E Plan specifically addresses the potential for changes in genetic diversity in natural populations as a result of a hatchery program(s). The long-term fitness of populations is assumed to be related to maintaining the genetic diversity of natural populations. However, hatchery programs select a subset of individuals from the population to pass on genetic material to the next generation. This is often a relatively small number of individuals that produce a large number of offspring, and can result in changes in allele frequencies and reductions of effective population size. Therefore, it is important to monitor the genetic status of the natural populations to determine if there are signs of changes in genetic distance among populations, changes in allele frequencies, and to estimate effective population size. Assessing the genetic effects of the hatchery program does not require annual sampling. Meeting stray-rate targets (hypotheses tested under Objective 5) should reduce significant changes in population genetics. Stray rates may inform population genetic analyses. Testing statistical hypotheses associated with genetic components (Hypotheses 3.1, 3.2, and 3.3) should be conducted every ten years or two generations.

Allele Frequency

Monitoring Questions:

Q7.1.1: Is the allele frequency of hatchery fish similar to the allele frequency of naturally produced and donor fish?

Target Species/Populations:

- Q7.1.1 applies to all conservation stocks.

Statiscial Hypotheses 7.1.1:

- $Ho_{7.1.1.1}$: Allele frequency $_{\text{Hatchery}}$ = Allele frequency $_{\text{Naturally produced}}$ = Allele frequency $_{\text{Donor pop.}}$
- $Ha_{7.1.1.1}$: Allele frequency $_{\text{Hatchery}}$ ≠ Allele frequency $_{\text{Naturally produced}}$ = Allele frequency $_{\text{Donor pop.}}$ or
- $Ha_{7.1.1.1}$: Allele frequency $_{\text{Hatchery}}$ = Allele frequency $_{\text{Naturally produced}}$ ≠ Allele frequency $_{\text{Donor pop.}}$ or
- $Ha_{7.1.1.1}$: Allele frequency $_{\text{Hatchery}}$ ≠ Allele frequency $_{\text{Naturally produced}}$ ≠ Allele frequency $_{\text{Donor pop.}}$

Measured Variables:

- Microsatellite genotypes or SNP genotypes, as appropriate

Derived Variables:

- Allele frequency

Spatial/Temporal Scale:

- Analyze as a time series, initially comparing pre- and post-hatchery samples and thereafter every 10 years.
- Compare samples within drainages.

Possible Statistical Analysis:

- Population differentiation tests, analysis of molecular variance (AMOVA), and relative genetic distances.

Analytical Rules:

- This is a monitoring indicator that will be used to support management decisions.
- Type I Error of 0.05.

Genetic Distance Between Populations

Monitoring Questions:

Q7.2.1: Does the genetic distance among subpopulations within a supplemented population remain the same over time?

Target Species/Populations:

- Q7.2.1 applies to all conservation and safety-net stocks.

Statistical Hypothesis 7.2.1:

- $Ho_{7.2.1.1}$: Genetic distance between subpopulations $_{\text{Year x}}$ = Genetic distance between subpopulations $_{\text{Year y}}$

Measured Variables:

- Microsatellite genotypes or SNP genotypes

Derived Variables:

- Allele frequencies

Spatial/Temporal Scale:

- Analyze as a time series, initially comparing pre- and post-hatchery samples and thereafter every 10 years.
- Compare samples among spawning aggregates.

Possible Statistical Analysis:

- Population differentiation tests, AMOVA, and relative genetic distances.

Analytical Rules:

- This is a monitoring indicator that will be used to support management decisions.
- Type I Error of 0.05.

Effective Spawning Population

Monitoring Questions:

Q7.3.1: Is the ratio of effective population size (N_e) to spawning population size (N) constant over time?

Target Species/Populations:

- Q7.3.1 applies to all supplemented stocks.

Statistical Hypothesis 3.3:

- $Ho_{7.3.1.1}$: $(N_e/N)_{t0} = (N_e/N)_{t1}$ for each population

Measured Variables:

- Microsatellite genotypes or SNP genotypes

Derived Variables:

- Allele frequencies

Spatial/Temporal Scale:

- Analyze as a time series, initially comparing pre- and post-hatchery samples and thereafter every 10 years.

Possible Statistical Analysis:

- Population differentiation tests, relative genetic distances, statistics to calculate effective population size (e.g., harmonic means).

Analytical Rules:

- This is a monitoring indicator that will be used to support management decisions.
- Type I Error of 0.05.

4.6 Phenotypic Traits

Objective 8: Determine if hatchery programs have caused changes in phenotypic characteristics of natural populations.

Fitness, or the ability of individuals to survive and pass on their genes to the next generation in a given environment, includes genetic, physiological, and behavioral components.[11] Maintaining the long-term fitness of supplemented populations requires a comprehensive evaluation of genetic and phenotypic characteristics. Evaluation of some phenotypic traits (i.e., run timing, spawn timing, spawning location, and stray rates) is addressed under Objective 5. Objective 8 assess the potential effects of domestication, including size at maturity, age at maturity, sex ratio, and fecundity. Age and size at maturity shall be assessed for both fish arriving in the Columbia system, and those recovered on the spawning grounds. Size (or age) selective mortality during migration through the Columbia system, such as through fisheries, could alter the age and size of fish on the spawning grounds.

[11] These metrics are difficult to measure, and phenotypic expression of these traits may be all we can measure and evaluate.

Age at Maturity

Monitoring Questions:

Q8.1.1: Is the age at maturity of hatchery and natural-origin fish similar at the time they enter the Columbia River and when they spawn?

Target Species/Populations:

- Q8.1.1 applies to all conservation program stocks.

Statistical Hypotheses 8.1.1:

- $Ho_{8.1.1.1}$: Age at Maturity $_{\text{Hatchery produced spawners Gender X}}$ = Age at Maturity $_{\text{Naturally produced spawners Gender X}}$
- $Ho_{8.1.1.2}$: Age at Maturity $_{\text{All hatchery produced adults Gender X}}$ = Age at Maturity $_{\text{All naturally produced adults Gender X}}$

Measured Variables:

- Total and salt (ocean) age of hatchery and natural-origin salmon carcasses collected on spawning grounds.
- Total and salt age of broodstock.
- Total and salt age of fish at stock assessment locations (e.g., Dryden, Tumwater, Wells, Priest Rapids).
- Whenever possible, age at maturity will be measured at weirs or dams near the spawning stream to avoid the size-related carcass recovery bias on spawning grounds (carcass sampling).
- Assess age of fish, including harvested fish.

Derived Variables:

- Total age and saltwater age
- Age of fish entering the Columbia River.

Spatial/Temporal Scale:

- Calculate annually based on brood year.
- Time series.

Possible Statistical Analysis:

- Use graphic analysis and Yates' Chi-square.

Analytical Rules:

- This is a monitoring indicator that will be used to support management decisions.
- Type I Error of 0.05.

Size at Maturity

Monitoring Questions:

Q8.2.1: Is the size (length) at maturity of a given age and sex of hatchery fish similar to the size at maturity of a given age and sex of natural-origin fish?

Target Species/Populations:

- Q8.2.1 applies to all conservation and safety-net stocks.

Statistical Hypothesis 8.2.1:

- $Ho_{8.2.1.1}$: Size (length) at Maturity $_{\text{Hatchery Age X and Gender Y}}$ = Size (length) at Maturity $_{\text{Naturally produced Age X and Gender Y}}$
- $Ho_{8.2.1.2}$: Size (length) at Maturity $_{\text{All hatchery adults Gender X}}$ = Size (length) at Maturity $_{\text{All naturally produced adults Gender X}}$

Measured Variables:

- Size (length), age, and gender of hatchery and natural-origin salmon carcasses collected on spawning grounds.
- Size (length), age, and gender of broodstock.
- Size (length), age, and gender of fish at stock assessment locations (e.g., Priest Rapids, Dryden, Tumwater, Wells, Twisp Weir).
- Whenever possible size at maturity will be measured at weirs or dams near the spawning stream to avoid the size-related carcass recovery bias on spawning grounds (carcass sampling).

Derived Variables:

- Total age and saltwater age

Spatial/Temporal Scale:

- Calculate annually based on brood year.
- Time series.

Possible Statistical Analysis:

- Use graphic analysis and three-way ANOVA by origin, gender, and age

Analytical Rules:

- This is a monitoring indicator that will be used to support management decisions.
- Type I Error of 0.05.

Fecundity at Size[12]

Monitoring Questions:

Q8.3.1: Is the fecundity vs. size relationship of hatchery and natural-origin fish similar?

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12 May not apply to all programs.

Q8.3.2: Is the gonadal mass vs. size relationship of hatchery and natural-origin fish similar?

Target Species/Populations:

- Both Q8.3.1 and Q8.3.2 apply to all conservation stocks using both natural- and hatchery-origin broodstock.

Statistical Hypothesis 8.3.1:

- $Ho_{8.3.1.1}$: Slope of Fecundity vs. Size $_{\text{Hatchery}}$ = Slope of Fecundity vs. Size $_{\text{Naturally produced}}$

Statistical Hypothesis 8.3.2:

- $Ho_{8.3.2.1}$: Gonadal Mass vs. Size $_{\text{Hatchery}}$ = Gonadal Mass vs. Size $_{\text{Naturally produced}}$

Measured Variables:

- Length, weight, and age (covariate) of hatchery and natural-origin broodstock after eggs have been removed.
- Number and weight of eggs

Derived Variables:

- Total age and saltwater age.
- Mean weight per egg.

Spatial/Temporal Scale:

- Calculate annually based on brood year.
- Time series.

Possible Statistical Analysis:

- Use graphic analysis, regression, t-test, and ANCOVA.

Analytical Rules:

- This is a monitoring indicator that will be used to support management decisions.
- Type I Error of 0.05.

Sex Ratio

Monitoring Questions:

Q8.4.1: Is the sex ratio of hatchery and natural-origin fish similar?

Target Species/Populations:

- Q8.4.1 applies to all conservation stocks.

Statistical Hypothesis 8.4.1:

- $Ho_{8.4.1.1}$: Sex Ratio $_{\text{Hatchery}}$ = Sex Ratio $_{\text{Naturally produced}}$

Measured Variables:

- Age and sex of hatchery and natural-origin salmon carcasses collected on spawning grounds or sampled at dams or weirs.
- Whenever possible sex ratio will be measured at weirs or dams near the spawning stream to avoid the size-related carcass recovery bias on spawning grounds (carcass sampling or ultrasound on live fish).

Derived Variables:

- Ratio of sexes based on brood year returns

Spatial/Temporal Scale:

- Calculate annually based on brood year.
- Time series.

Possible Statistical Analysis:

- Use graphic analysis and Yates'Chi-square.

Analytical Rules:

- This is a monitoring indicator that will be used to support management decisions.
- Type I Error of 0.05.

SECTION 5: HATCHERY ENVIRONMENT MONITORING INDICATORS

5.1 Release Targets

Objective 9: **Determine if hatchery fish were released at the programmed size and number.**

The HCP outlines the number and size of fish that are to be released to meet NNI and inundation compensation levels. The size of the fish at release may be altered according to an adaptive management process in the Hatchery Committee(s), and the number of fish can be altered by survival study results and adjustment of hatchery production for population dynamics. Size of fish at release can affect survival, sex ratios, age at return, stray rate, and fecundity. In addition, the variation in size at release may affect performance of the fish.

The coefficient of variation (CV) will be evaluated to ascertain if program performance is related to variation in size at release. Note also that variation in a population is a natural condition and striving to control this variation could result in directional or stabilizing artificial selection that could have unforeseen long-term consequences. Attaining uniform or multi-modal growth in a hatchery environment may not be adaptive for fitness in the wild. Therefore, pursuit of a CV target should be seen as an informative exercise, but is not in itself indicative of success or failure of a hatchery program. Furthermore, growth regimes may prove to be important in affecting adult returns and age structure. Although many factors can influence both the size and number of fish released, past hatchery cultural experience with these stocks should assist in meeting program production levels. Appendix 5 presents the target size at release and CVs for the programs. These targets shall be assessed annually to ensure they are optimized to inform management decisions.

Size at Release of Hatchery Fish

Monitoring Questions:

Q9.1.1: Is the size (fish per pound; fpp) of hatchery fish released equal to the program goal identified in Appendix 5?

Deleted: length and weight

Target Species/Populations:

- Q9.1.1 applies to all hatchery stocks.

Statistical Hypothesis 9.1.1:

- $Ho_{9.1.1}$: Hatchery fish $fpp_{\text{at release}}$ = Programmed $fpp_{\text{at release}}$ (see Appendix 5)

Deleted: Size

Deleted: Size

Measured Variables:

- Fork length and weights of random samples of hatchery juveniles at release.

Derived Variables:

- Mean length (FL), mean weight, and fish per pound
- Appendix 5: Rearing targets

Deleted: and

Deleted: 6

Spatial/Temporal Scale:

- Calculate annually.
- Time series.

Possible Statistical Analysis:

- Use graphic analysis and descriptive statistics to compare the estimated fpp of hatchery fish at time of release with the program goal.

Deleted: size

Analytical Rules:

- This is a monitoring indicator that will be used to support management decisions.

Coefficient of Variation (CV) of Hatchery Fish Released

Monitoring Questions:

Q9.2.1: Is the CV of hatchery fish released equal to the program target identified in Appendix 5?

Target Species/Populations:

- Q9.2.1 applies to all hatchery stocks.

Statistical Hypothesis 9.2.1:

- $Ho_{9.2.1.1}$: Hatchery fish $CV_{\text{at release}}$ = Programmed CV in Appendix 5

Measured Variables:

- Length and weights of random samples of hatchery smolts.

Derived Variables:

- Coefficient of Variation: $cv = (1 + 1/4n) \times (s/x)$ (where s = standard deviation, x = estimated mean, n = sample size)
- Appendix 5: Rearing targets

Deleted: 6

Spatial/Temporal Scale:

- Calculate annually.
- Time series.

Possible Statistical Analysis:

- Use graphic analysis and descriptive statistics to compare the estimated CV of size of hatchery fish released with the program goal.

Analytical Rules:

- This is a monitoring indicator that will be used to support management decisions.

Condition Factor (K) of Hatchery Fish Released

Monitoring Questions:

Q9.3.1: Is the K of hatchery fish released equal to the program target identified in Appendix 5?

Target Species/Populations:

- Q9.3.1 applies to all hatchery stocks.

Statistical Hypothesis 9.3.1:

- $Ho_{9.3.1.1}$: Hatchery fish $K_{\text{at release}}$ = Programmed K identified in Appendix 5

Measured Variables:

- Monthly individual lengths and weights of random samples of hatchery juveniles.

Derived Variables:

- Condition Factor: $K = W/L^3 \times 10^5$

Spatial/Temporal Scale:

- Calculate annually.
- Time series.

Possible Statistical Analysis:

- Use graphic analysis and descriptive statistics to compare the estimated K of released hatchery fish with the program goal.

Analytical Rules:

- This is a monitoring indicator that will be used to support management decisions.
- Type I Error of 0.05.

Number of Hatchery Fish Released

Monitoring Questions:

Q9.4.1: Is the number of hatchery fish released equal to the program goal identified in Appendix 5?

Target Species/Populations:

- Q9.4.1 applies to all hatchery stocks.

Statistical Hypothesis 9.4.1:

- $Ho_{9.4.1.1}$: Hatchery Fish Number = Programmed Number identified in Appendix 5

Measured Variables:

- Numbers of smolts released from the hatchery.

Derived Variables:

- Appendix 5: Rearing targets

Deleted: 6

Spatial/Temporal Scale:

- Calculate annually.

- Time series.

Possible Statistical Analysis:

- Use graphic analysis and one-sample quantile tests to compare the estimated number of hatchery fish released with the program goal.

Analytical Rules:

- This is a monitoring indicator that will be used to support management decisions.
- Type I Error of 0.05.

SECTION 6: HARVEST MONITORING INDICATORS

6.1 Harvest Rates

<u>Objective 10</u>: Determine if appropriate harvest rates have been applied to conservation, safety-net, and segregated harvest programs to meet the HCP/SSSA goal of providing harvest opportunities while also contributing to population management and minimizing risk to natural populations.

Harvest will be applied to different types of programs in an effort to achieve the management objectives of those programs. Programs designed to augment harvest should routinely contribute to harvest at a rate that greatly reduces the incidence of straying to natural spawning grounds, but also allows the program to be sustained. Safety-net programs may be harvested as part of an adult management strategy to minimize excessive escapement of hatchery-origin fish to spawning grounds. Similarly, conservation programs may undergo harvest to manage returning adults, but the emphasis for these programs should be to achieve escapement goals. In all cases, harvest effort should not have the unintended consequence of removing excessive numbers of conservation or natural-origin fish. In years when the expected returns of hatchery adults are above the level required to meet program goals (i.e., supplementation of spawning populations and/or brood stock requirements), surplus fish may be available for harvest. The M&E Plan specifically addresses harvest and harvest opportunities upstream of Priest Rapids Dam. Harvest or removal of surplus hatchery fish from the spawning grounds may assist in reducing potential adverse ecological and genetic impacts to natural populations (e.g., loss of genetic variation within and between populations, loss of fitness, reduced effective population size, and density-dependent effects).

Monitoring Questions:

Q10.1.1: Conservation Programs: Is the harvest on conservation hatchery fish at an appropriate level to manage natural spawning of conservation hatchery fish but low enough to sustain the hatchery program?

Q10.1.2: Safety-Net Programs: Is the harvest on conservation hatchery fish at an appropriate level to manage natural spawning of safety-net hatchery fish but low enough to sustain the hatchery program?

Q10.1.3: Is the harvest on hatchery fish produced from harvest-augmentation programs high enough to manage natural spawning but low enough to sustain the hatchery program?

Q10.1.4: Is the escapement of fish from conservation and safety-net programs in excess of broodstock and natural production[13] needs to provide opportunities for terminal harvest?

Target Species/Populations:

- Q10.1.1 applies to conservation programs.
- Q10.1.2 applies to safety-net programs.

[13] The current best estimates of carrying capacity (maximum recruits) will be used, as available.

- Q10.1.3 applies harvest augmentation programs.
- Q10.1.4 applies to conservation and safety-net programs.

Statistical Hypothesis 10.1.1:

- $Ho_{10.1.1.1}$: Harvest rate ≤ Maximum level to meet program goals

Statistical Hypothesis 10.1.2:

- $Ho_{10.1.2.1}$: Harvest rate ≤ Maximum level to meet program goals

Statistical Hypothesis 10.1.3:

- $Ho_{10.1.3.1}$: Escapement ≤ Maximum level to meet supplementation goals

Statistical Hypothesis 10.1.4:

- $Ho_{10.1.4.1}$: Harvest rate ≤ Maximum level to meet program goals

Measured Variables:

- Numbers of hatchery fish taken in harvest.
- Numbers of natural-origin fish taken in harvest.

Derived Variables:

- Total harvest by fishery estimated from expansion analysis.

Spatial/Temporal Scale:

- Calculated annually.
- Time series.

Possible Statistical Analysis:

- Use graphic analysis and one-sample quantile tests to compare the estimated harvest of hatchery fish with the program goal.

Analytical Rules:

- This is a monitoring indicator that will be used to support management decisions.
- Type I Error of 0.05.

SECTION 7: REGIONAL OBJECTIVES

Hatchery programs have the potential to increase diseases that typically occur at low levels in the natural environment (Objective 9). In addition, hatchery fish can reduce the abundance, size, or distribution of non-target taxa through ecological interactions (Objective 10). These are important objectives that will be monitored at a later time. Analytical rules will be established for these objectives before monitoring activities begin.

7.1 Incidence of Disease

Objective 11: Determine if the incidence of disease has increased in the natural and hatchery populations.

The hatchery environment has the potential to amplify diseases that are typically found at low levels in the natural environment. Amplification could occur within the hatchery population (i.e., vertical and horizontal transmission) or indirectly from the hatchery effluent or commingling between infected and non-infected fish (i.e., horizontal transmission). Potential impacts to natural populations have not been extensively studied, but should be considered for programs in which the hatchery fish are expected to commingle with natural fish. This is particularly important for supplementation type programs. Specifically, the causative agent of bacterial kidney disease (BKD), *Renibacterium salmoninarum* (Rs), could be monitored at selected acclimation ponds, both in the water and fish, in which the risk and potential for transmission from the hatchery is highest. Although it is technologically possible to measure the amount of Rs in water or Rs DNA in smolts and adults non-lethally sampled, the biological meaning of these data are uncertain. Currently, the only metric available for M & E purposes is measuring the antigen level from kidney/spleen samples (i.e., ELISA, PCR). When available, non-lethal sampling may replace or be used in concert with lethal sampling.

Implementation of this objective will be conducted in a coordinated approach within the hatchery and natural environment. BKD management within the hatchery population (e.g., broodstock or juveniles) has the potential to reduce the prevalence of disease through various actions (e.g., culling or reduced rearing densities). BKD management must also take into account and support other relevant objectives of the M & E program (e.g., Hatchery Return Rate [HRR], number of smolts released). Hence, the goal of BKD management is to decrease the prevalence of disease and maintain hatchery production objectives (i.e., number and HRR).

As previously discussed, disease transmission from hatchery to naturally produced fish may occur at various life stages and locations. Of these, horizontal transmission from hatchery effluent, vertical transmission on the spawning grounds, and horizontal transmission in the migration corridor have been identified as disease interactions that could be examined under this objective, although others may also be relevant. Experimental designs addressing this objective may require technology not yet available, although in some instances samples may be collected, but not analyzed until a link can be established between bacteria levels in samples and disease prevalence.

Developing a complete set of questions and hypotheses statements for this objective may not be practical at this time, because there is currently no BKD Management Plan. However, while developing experimental designs for this objective, it may be feasible to incorporate both hatchery and natural environment monitoring under a single study design. Integration of the different aspects of the objective would likely result in a more robust approach into understanding the effectiveness of disease management strategies.

Proposed Tasks:

T1: Assemble fish health data for fish used as brood (e.g., ELISA results).

T2: Conduct data exploration exercise to identify potential relationships between pathogen profiles and likely causative variables (e.g., rearing conditions and management actions).

T3: Develop hypotheses for potential testing to meet objective.

7.2 Non-Target Taxa of Concern (NTTOC)

<u>Objective 12</u>: Determine if the release of hatchery fish affects non-target taxa of concern (NTTOC) within acceptable limits.

Ecological risks of Pacific salmon (spring, summer, and fall run Chinook, coho, and sockeye salmon) and steelhead trout hatchery programs operated between 2013 and 2023 in the Upper Columbia Watershed will be assessed using Delphi and modeling approaches. Committees composed of resource managers and public utility districts identified non-target taxa of concern (i.e., taxa that are not the target of supplementation), and acceptable hatchery impacts (i.e., change in population status) to those taxa. Biologists assembled information about hatchery programs, non-target taxa, and ecological interactions and this information will be provided to expert panelists in the Delphi process to facilitate assessment of risks and also used to populate the Predation, Competition, and Disease (PCD) Risk 1 model. Delphi panelists will independently estimate the proportion of a non-target taxa population that will be affected by each individual hatchery program. Estimates from each of the two approaches will be independently averaged, a measure of dispersion calculated (e.g., standard deviation), and subsequently compared to the acceptable hatchery impact levels that were determined previously by committees of resource managers and public utility districts. Measures of dispersion will be used to estimate the scientific uncertainty associated with risk estimates. Delphi and model results will be compared to evaluate the qualities of the two approaches. Furthermore, estimates of impacts from each hatchery program will be combined together to generate an estimate of cumulative impact to each non-target taxa.

The Hatchery Evaluation Technical Team (HETT) is currently addressing this objective. Work has been underway for several years. The study is expected to provide risk assessment using both an ecological modeling approach and a panel of expert opinion. These two methods will be compared to establish the potential to use modeling in place of expert panels to conduct such risk assessments in the future.

SECTION 8: ADAPTIVE MANAGEMENT

Because of naturally large variation in productivity indicators, several years of data may be required before statistical inferences can be made regarding the effects of hatchery fish on productivity of naturally produced fish. Furthermore, given the large natural variation of productivity indicators, productivity could increase or decrease as a result of the hatchery programs before a difference is detected statistically. In the interim, risk associated with supplementation programs and the productivity of naturally produced fish can be quantified based on observed natural variation in the indicator of interest (Table 1). If large differences in rates of change between supplemented and reference populations are observed, management actions may be required.

Assuming hatchery programs do not negatively affect the productivity of naturally produced fish, the observed difference in rates of change between the supplemented and reference populations should decrease over time as more of the natural variation within and between populations is incorporated into these data. More simply, as the number of years increases, the acceptable observed difference in the indicator(s) decreases. The value of the difference at any point in time would determine if management actions are warranted.

SECTION 9: REFERENCES

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APPENDIX 1: ESTIMATION OF CARRYING CAPACITY

APPENDIX 2: HATCHERY REPLACEMENT RATES

Based on ideas developed by the HETT, in February 2016, the HCP Hatchery Committees and PRCC Hatchery Subcommittee agreed to the following rules and HRR targets:

1. Use the estimated 40% HRR Target during 5-year statistical evaluation periods.
2. Use varying degrees of action depending on the numbers of years that annual HRR deviates from Target.
   a. Green Light (below Target for ≤ 2 years.
   b. Red Light (below Target for > 2 years.
3. Each program will have its own HRR target with the following exceptions.
   a. Nason Creek spring Chinook will use the Chiwawa Target (there are currently no data to calculate a target for Nason Creek spring Chinook).
   b. Methow and Chewuch spring Chinook will use the greater of their two Targets (they are MetComp stock and evaluated similarly).

Table 1. Release numbers and 5-year hatchery replacement rates (HRR) targets for Upper Columbia River Hatchery Programs.

Species	Owner	Program (Hatchery)	Basin (Purpose)	Smolts released[1]	5-Year HRR[2]
Steelhead	CPUD	Eastbank (Chiwawa)	Wenatchee (Conservation)	123,650	6.9
Steelhead	CPUD	Eastbank (Chiwawa)	Wenatchee (Safety Net)	123,650	6.9
Steelhead	DPUD	Wells (Wells)	Columbia (Safety Net)	160,000	26.5
Steelhead	DPUD	Wells (Wells)	Methow (Safety Net)	100,000	26.5
Steelhead	DPUD	Wells (Wells)	Twisp (Conservation)	48,000	26.5
Steelhead	GPUD	Wells (Omak)	Okanogan (Conservation)	100,000	7.3 [3]
SUM Chinook	CPUD	Eastbank (Chelan Falls)	Chelan (Conservation)	176,000	5.7
SUM Chinook	CPUD	Eastbank (Chelan Falls)	Chelan (Harvest)	400,000	5.7
SUM Chinook	CPUD, GPUD	Eastbank (Dryden)	Wenatchee (Conservation)	500,000	5.7
SUM Chinook	DPUD	Wells (Wells)	Columbia (Harvest)	320,000	3.0
SUM Chinook	GPUD	Eastbank (Carlton)	Methow (Conservation)	200,000	3.0
SUM Chinook	CCT	Chief Joseph	Okanogan (Harvest)	1,100,000	8.6
SPR Chinook	CPUD	Eastbank (Chiwawa)	Wenatchee (Conservation)	144,026	6.7
SPR Chinook	CPUD, DPUD, GPUD	Wells (Methow)	Methow (Conservation)	193,765	3.8
SPR Chinook	DPUD, GPUD	Wells (Twisp)	Methow (Conservation)	30,000	2.7
SPR Chinook	GPUD	Eastbank (Nason)	Wenatchee (Conservation)	149,114	6.7

[1] Release goal established by HCPs and adjusted by HC.
[2] Derived from Annual Reports.
[3] Harvest not included.

APPENDIX 3: PNI and pHOS Targets and Sliding Scales

Select CPUD, DPUD, and GPUD funded hatchery mitigation programs have PNI management targets, while others do not. Table 1 summarizes management strategies by species and population. Detailed information can be found in the sections that follow. Descriptions provided in the following sections are taken directly from HGMPs and/or issued and draft permits.

Table 1. Summary of management strategies by species and population.

Species	Population	Management Strategy	Comments
Spring Chinook	Wenatchee	Sliding Scale of PNI management	Details can be found in Section 2.0
	Methow	Two—population sliding scale PNI management	Details can be found in Section 3.0
	Okanogan	None Currently	Details can be found in Section 4.0
Steelhead	Wenatchee	Two-zone management.	Details can be found in 5.0
	Methow	In-development	Details forthcoming; Section 6.0
	Okanogan	None Currently	Details can be found in Section 7.0
Summer Chinook	Wenatchee	None Currently	Details can be found in Section 9.0
	Methow	None Currently	Details can be found in Section 10.0
	Okanogan	0.67; pHOS 0.30	Details can be found in Section 11.0
	Upper Columbia River	None Currently	Details can be found in Section 12.0
Fall Chinook	Hanford Reach	0.67	Details can be found in Section 13.0

2.0 Wenatchee Spring Chinook

Wenatchee spring Chinook will be managed according to the sliding scale identified in the Wenatchee Spring Chinook Management Plan (2010) and Permit Numbers 18118 and 18121. The sliding scale is based upon the estimated number of natural origin spring Chinook over Tumwater Dam. As more information becomes available the sliding scale may be adjusted as a result of gaining a better understanding of the pre-spawn mortality rate and carrying capacity.

Table 2. Sliding scale of PNI goals based on natural origin spring Chinook run size expected to the Wenatchee River basin. Percentiles are based on adult returns observed between 1999 and 2008.

Percentile	NOR Run Size				PNI
	Chiwawa	Nason Creek	White	Wenatchee River (above TWD)	
>75th	>372	>350	>87	>910	≥ 0.80
50% - 75%	278-372	259-349	68-86	631-909	≥ 0.67
25% - 50%	209-277	176-258	41-67	525-630	≥ 0.50
10%-25%	176-208	80-175	20-40	400-524	≥ 0.40
<10th	<175	<80	<20	<400	Any PNI

3.0 Methow/ Chewuch Spring Chinook

The following sliding scale (Table 3) is presented in the April 14, 2016 draft Methow Hatchery Spring Chinook Section 10-Draft. It is anticipated that no further changes will be made to the sliding scale prior to issuance of the final permits.

Table 3. PUD PNI sliding scale calculations for a range of natural run sizes.

Natural Origin Returns	PUD pHOS	WNFH pHOS	PUD pNOB	2-pop PNI	PUD PNI (equation)
<300	Ensure minimum of 500 total spawners				
300	0.40	0.2	0.75	0.67	0.67
500	0.40	0.2	0.80	0.68	0.76
900	0.30	0.15	1.00	0.78	0.80
1500	0.25	0.1	1.00	0.8	0.80
2000	0.25	0.1	1.00	0.8	0.80
2500	0.25	0.1	1.00	0.8	0.80

4.0 Okanogan Spring Chinook

The Okanogan spring Chinook program is a re-introduction effort implemented as a non-essential experimental population under ESA Section 10j to re-introduced spring Chinook into the Okanogan River. As a non-essential experimental population targeting re-introduction and establishment of a local population of spring Chinook, the Okanogan spring Chinook program will not conduct adult management actions to reduce the proportion of 10j hatchery fish on the spawning grounds or conduct broodstocking efforts in the Okanogan for a 10-year period (2014 – 2023), as such, no PNI or pHOS objectives have been identified for this program in this 10-year period.

CJH Program segregated production released into the mainstem Columbia River are non-listed Leavenworth stock released reared/acclimated/released at CJH. Although no PNI or pHOS targets are identified for the Okanogan 10j population, minimizing strays from the CJH segregated spring Chinook program is a program objective, as such, returning segregated program fish will be subject to directed harvest and aggressive adult surplusing at CJH to minimize straying to the Okanogan River Basin as well as other extant upper Columbia River spring Chinook populations. Stray targets for the segregated program are 5% or less stray rate (i.e. spawning contribution to other upper Columbia River spring Chinook populations).

5.0 Wenatchee Steelhead

Interim escapement goal for Wenatchee River steelhead will be 1,500 spawners with an additional goal of attaining an average PNI of 0.67 for the Wenatchee River basin population as a whole. To achieve the stated goal, the Wenatchee steelhead program will use a two-zone management approach wherein the upper basin (above TWD) will be managed for recovery using an integrated recovery program, a separate spawning escapement goal, and a PNI standard to achieve the overall basin goal of an average PNI over time of 0.67 (Table 4). Areas below TWD will be managed to minimize hatchery supplementation with a pHOS goal of < 0.10.

Steelhead returning upstream of TWD will be managed as an integrated recovery program with a pNOB goal of 1.0. The above TWD escapement goal will be 1,094 spawners. Working within this framework, pNOB will be maximized above TWD while pHOS will be minimized.

Table 4. Wenatchee steelhead two-zone management and PNI targets.

Location	Run Escapement Goal	pNOB Conservation Program	pNOB Safety Net Program	pHOS	PNI
Above TWD	1,094	1.0	0.0	Varies	Varies
Below TWD	406	N/A	N/A	< 0.10	< 0.67
Basin Total	1,500	N/A	N/A	Minimal	Average = 0.67

6.0 Methow Steelhead

Methow steelhead PNI targets are currently in development.

7.0 Okanogan Steelhead

Current program has no PNI goal. CTCR submitted an Okanogan steelhead HGMP to NOAA Fisheries on February 4, 2014. Within the HGMP provisions were included to allow a greater collection of natural-origin broodstock and multiple adult management strategies to address over-escapement of hatchery-origin steelhead to the spawning grounds. The HGMP also identified a near-term (1-4 years) and a long-term PNI objectives of 0.50 and > 0.67, respectively. Once NOAA has completed the consultation and issued a new permit, providing the opportunity to increase the proportion of natural-origin fish in the broodstock and additional adult management strategies, the program will adopt the PNI objectives and this Appendix can be amended accordingly.

8.0 Wells Columbia Mainstem Safety-net Steelhead

The Safety-Net Mainstem Columbia component released below Wells Dam will be managed primarily at the Wells Hatchery volunteer channel. The objective of the adult management of the Safety-Net Mainstem Columbia component is to prevent runs of this component from moving into natural spawning areas. This will be accomplished through in-river harvest and removal of volunteers at the Wells Hatchery outfall. There are no PNI goals for this component.

9.0 Wenatchee Summer Chinook

No PNI goals are established.

10.0 Methow Summer Chinook

No PNI goals are established.

11.0 Okanogan Summer Chinook

Okanogan summer/fall Chinook will be managed to achieve a 5-year rolling average PNI of 0.67 and pHOS of 0.30. Strategies to achieve that PNI target include up to 100% pNOB, aggressive removal of hatchery-origin Chinook in selective fisheries, at the Okanogan weir, and during surplusing at CJH ladder. Reduction in the number of juveniles released in the Okanogan River Basin (integrated program) is also a management option, should adult management actions be unable to control the proportion of hatchery fish on the spawning grounds to achieve that PNI target.

CJH segregated summer/fall Chinook program rears/acclimates/releases smolts into the mainstem Columbia River at CJH. Broodstock are 100% hatchery-origin, as such no PNI target for this production component. Stray rate (i.e. contribution to upper Columbia summer/fall Chinook

populations) is 5% or less. Adult management on returning adults from the segregated program include fisheries, removal at the Okanogan weir, and removal at the CJH ladder.

12.0 Upper Columbia Summer Chinook (Chelan Falls and Wells) Summer Chinook

No PNI goals are established. Chelan Falls and Wells FH summer Chinook programs are segregated harvest programs designed to provide opportunity for harvest. Adult returns are not intended to spawn naturally; therefore, there is no escapement goal for natural spawning areas. Adult returns will be managed to meet program objectives. Chelan Falls and Wells Hatchery summer Chinook are available for harvest in the ocean and Columbia River commercial, tribal, and recreational fisheries.

13.0 Priest Rapids Fall Chinook

The Hanford Reach fall Chinook population is intentionally supplemented by Grant PUD at the Priest Rapids Hatchery and the ACOE at the Priest Rapids and Ringold Springs hatcheries. Managers desire to achieve a population level PNI that includes all hatchery programs of $\geq$0.67. Grant PUD and the HSC do not have control over operation or expansion of the ACOE program and therefore will strive to operate the Priest Rapids Hatchery fall Chinook program in a way that does its fair share of achieving a population level PNI of 0.67.

APPENDIX 4: SPATIAL DISTRIBUTION OF SPAWNERS OR REDDS

Strategies for conservation programs typically intend that hatchery and naturally produced fish spawn together and in similar locations. However, in some cases, strategies may differ from this paradigm. In Table 1, conservation programs that have a spatial distribution management plan that deviates from similar to the natural spawning spatial distributions are presented. Otherwise, conservation programs are intended to have a spawning distribution similar to the natural origin spawning spatial distributions, as described by M&E Objective 5.3.

Table 1. Management targets for the spatial distribution of hatchery-origin redds for conservation programs that deviate from Objective 5.3.

Program	Target	Rational	Source
Carlton Summer Chinook	The observed spawning distribution of hatchery origin Methow summer Chinook from 2005-2010 represents the base-line spawner distribution for evaluating the performance of the hatchery program (i.e., M&E plan check-ins). It is acknowledged that this distribution is lower in the River than the spawning distribution of natural origin summer Chinook salmon.	Based upon an assessment of summer Chinook and ESA-listed spring Chinook abundance and spawner distribution, it was determined that an increase in summer Chinook spawning abundance in the upper most range of natural origin summer Chinook distribution or potentially above the current range may pose an unknown and potentially adverse impact to ESA listed spring Chinook. Due to the concern for spring Chinook, the HSC has endorsed an acclimation site in the Methow Basin that is lower in the basin than may be required to attain exact replication of natural and hatchery origin summer Chinook spawner distribution.	SOA 2011-02 Priest Rapids Coordinating Committee Hatchery Subcommittee Statement of Agreement on Monitoring & Evaluation (M&E) Objective for Spawning Distribution of Hatchery-Origin Summer Chinook
Dryden Summer Chinook	The observed spawning distribution of hatchery origin Wenatchee summer Chinook from 2008-2013 (previous 5 years to the current M&E check-in cycle) represents the base-line spawner distribution for evaluating the performance of the hatchery program (i.e., M&E plan check-ins).	The primary site endorsed by the HSC for Grant PUD overwinter acclimation of summer Chinook is the Dryden Pond, and is the current acclimation and release site for the existing summer Chinook supplementation program funded and owned by Chelan PUD. Because current data indicates that spawning distribution of hatchery summer Chinook from the existing program is lower in the Wenatchee River than natural origin spawners, expectations are that acclimation of Grant PUD's summer Chinook at Dryden Pond would continue to return hatchery origin summer Chinook that result in different spawning distributions for hatchery and natural summer Chinook.	Adapted from SOA 2011-02 Priest Rapids Coordinating Committee Hatchery Subcommittee Statement of Agreement on Monitoring & Evaluation (M&E) Objective for Spawning Distribution of Hatchery-Origin Summer Chinook

APPENDIX 5: WITHIN HATCHERY REARING TARGETS

Rearing Targets for Upper Columbia River Hatchery Programs. K-factor or fork length targets will be determined based on data from the pending "Five-Year Report."

Table 1. Numbers, fish per pound (fpp), coefficient of variation (CV), and condition factor (K) targets at release of Upper Columbia River Hatchery Programs.

Hatchery	Species	Life Stage	Basin	Release number	FPP	CV	K-factor
Methow	Spring Chinook	Yearling	Methow	193,765[1]	15	<10	TBD
Methow	Spring Chinook	Yearling	Twisp	30,000	15	<10	TBD
Chief Joseph	Spring Chinook	Yearling	Columbia	700,000	15	<10	TBD
Chief Joseph	Spring Chinook	Yearling	Okanogan	200,000	15	<10	TBD
Chiwawa	Spring Chinook	Yearling	Wenatchee	144,026	18	<10	TBD
Nason	Spring Chinook	Yearling	Wenatchee	223,670[2]	18-24	<10	TBD
Winthrop	Spring Chinook	Yearling	Methow	400,000	17	<10	TBD
Leavenworth	Spring Chinook	Yearling	Wenatchee	1.2 M	17	<10	TBD
Wells	Steelhead	Yearling	Columbia	160,000	6	<10	TBD
Wells	Steelhead	Yearling	Methow	100,000	6	<10	TBD
Wells	Steelhead	Yearling	Twisp	48,000	6	<10	TBD
Wells	Steelhead	Yearling	Omak	~100,000[3]	5-8	<10	TBD
Wells	Steelhead	Yearling	Okanogan	~100,000[3]	5-8	<10	TBD
Winthrop	Steelhead	Two year	Methow	200,000	4-6	<10	TBD
Chiwawa	Steelhead	Yearling	Wenatchee	247,300[4]	6	9.0	TBD
Wells	Summer Chinook	Subyearling	Columbia	480,000	50	<7	TBD
Wells	Summer Chinook	Yearling	Columbia	320,000	10	<7	TBD
Chief Joseph	Summer Chinook	Subyearling	Columbia	400,000	50	<7	TBD
Chief Joseph	Summer Chinook	Subyearling	Okanogan	300,000	50	<7	TBD
Chelan Falls	Summer Chinook	Yearling	Chelan	576,000	13	9.0	TBD
Entiat	Summer Chinook	Yearling	Entiat		17	<10	TBD
Carlton	Summer Chinook	Yearling	Methow	200,000	13-17	<12	TBD
Chief Joseph	Summer Chinook	Yearling	Columbia	500,000	10	<7	TBD
Chief Joseph	Summer Chinook	Yearling	Okanogan	799,998[6]	10	<7	TBD
Dryden	Summer Chinook	Yearling	Wenatchee	500,001	18	9.0	TBD
Priest	Fall Chinook	Subyearling	Columbia	7.3 M[7]	50	<10	TBD
Ringold	Fall Chinook	Subyearling	Columbia	3.5 M	50	<10	TBD

[1] The total release includes the release of 108,249 into the Methow River at the Methow Fish Hatchery, 25,000 into the Methow River at the Goat Wall site, and 60,516 into the Chewuch River at the Chewuch Acclimation Facility.

[2] The total release includes 125,000 conservation fish and 98,670 safety net fish.

[3] The combined Okanogan and Omak steelhead release number is 100,000.

[4] The total release includes 66,771 fish into Nason Creek, 53,170 into the Chiwawa River, 102,359 into the Wenatchee River, and 25,000 into Blackbird Pond.

[5] The Wells subyearling Chinook are not reared to achieve a specific size target. The fish are released on a date to optimize survival and are grown to the largest size possible before release.

[6] The total release is divided equally among the Omak, Riverside, and Similkameen Acclimation Ponds.

[7] The total release consists of 5.6 m fall Chinook for the Grant PUD program and 1.7 M fall Chinook for the Army Corps of Engineers program.

APPENDIX 6: IDENTIFYING AND ANALYZING REFERENCE POPULATIONS

An important goal of supplementation is to increase spawning abundance and natural-origin recruitment of the supplemented population, and not reduce the productivity of the supplemented population. Indeed, a successful supplementation program must increase spawning abundance and natural-origin recruitment to levels above those that would have occurred without supplementation. There are several methods that can be used to test the effects of supplementation programs on these population metrics. One important method is to compare the performance of population metrics (e.g., spawning abundance, natural-origin recruitment, and productivity) in the supplemented population to those in un-supplemented (reference) populations. By comparing supplemented populations to reference populations, one can determine if the supplementation programs benefit, harm, or have no effect on the supplemented populations. These comparisons, however, are only valid if the performance of the reference populations is similar to the performance of the supplemented population prior to the period of supplementation. If the performance of the two populations differs significantly before any supplementation occurs, then any results from comparing the two populations after supplementation will be suspect. It is therefore important to select reference populations that are as similar as possible to the supplemented populations.

One of the goals of the Conceptual Approach to Monitoring and Evaluating the Chelan County PUD Hatchery Programs (Murdoch and Peven 2005) is to use reference populations to analyze the potential effects of hatchery supplementation programs on natural-origin salmon and steelhead spawner abundance and productivity[14]. Murdoch and Peven (2005) identified specific objectives to evaluate the performance of the program. For example, Objective 1 determines if the supplementation programs have increased the number of naturally spawning and naturally produced adults of the target population (supplemented population) relative to a reference population. Objective 7 determines if the proportion of hatchery fish on the spawning grounds affects the freshwater productivity (e.g., number of juveniles per redd) of supplemented streams when compared to reference streams. The relevant questions tested under each objective are as follows:

Objective 1:

- Is the annual change in the number of natural-origin recruits produced from the supplemented populations greater than or equal to the annual change in natural-origin recruits in an un-supplemented population?
- Is the change in natural replacement rates within the supplemented population greater than or equal to the change in natural replacement rates in an un-supplemented population?

Objective 7:

[14] Productivity is defined as adult recruits per spawner, where recruits are the number of adults produced from a given brood year (i.e., spawners plus adults harvested).

- Is the change in numbers of juveniles (smolts, parr, or emigrants) per redd in the supplemented population greater than or equal to that in an un-supplemented population?[15]

In this paper, we describe methods used to identify suitable reference streams and statistical techniques that can be used to compare reference populations with supplemented populations. Although we apply the methods described in this paper to Chiwawa spring Chinook salmon (hereafter referred to as Chinook), the methods should also apply to steelhead and other supplemented salmon stocks in the Upper Columbia Basin.

Identification of Reference Populations

Reference populations are an important component of an effectiveness monitoring design because they provide the standard by which treatment conditions are compared (ISRP and ISAB 2005; Murdoch and Peven 2005; Galbreath et al. 2008). Selecting appropriate reference areas and maintaining them over long periods of time is needed to establish the effectiveness of supplementation programs.

We developed a three-step process for identifying suitable reference populations (Figure 1). Each step serves as a filter. That is, potential reference populations are evaluated based on specific criteria under each step. Populations that pass through each step are considered suitable reference populations for a specific supplemented population.

[15] In this paper we only address adult recruits, not juvenile recruits. This is because we were unable to find suitable reference populations for analysis of juveniles. However, the methods described in this paper would also apply to juveniles.

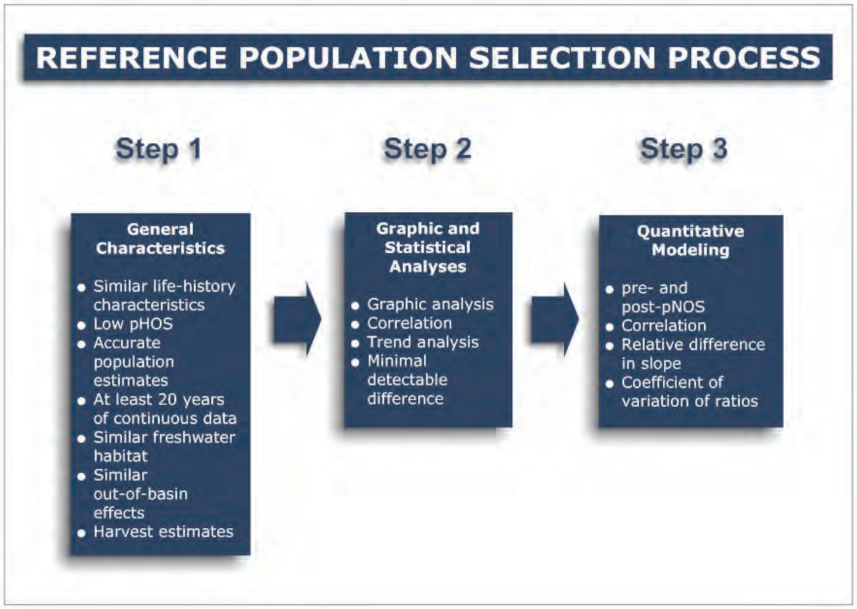

Figure 1. Criteria evaluated during each step in the process of identifying suitable reference populations.

Step 1: General Characteristics

Under step 1, potential reference populations are evaluated based on several general criteria. When compared to the supplemented population, potential reference populations should have:

- Similar life-history characteristics (e.g., run timing, migration characteristics, etc.).
- No or few hatchery fish in the reference area (pHOS < 10%).
- Accurate abundance estimates.
- Long time series of natural-origin abundance and productivity estimates (at least 20 years of continuous data).
- Similar trends in freshwater habitat.
- Similar out-of-basin effects (i.e., similar migration and ocean survivals).
- Harvest estimates for adjusting escapement estimates.

We used these criteria to begin the process of selecting suitable reference populations for the Chiwawa spring Chinook program. We began by identifying stream-type Chinook populations within the Columbia Basin. Galbreath et al. (2008; their Table 1) identified stream-type Chinook populations within the Columbia River Basin that may serve as suitable reference populations for hatchery programs. Supplementing their work with data from the NOAA Fisheries Salmon Population Summary Database, we identified 18 candidate stream-type Chinook populations that may serve as reference populations for the Chiwawa supplementation program (Table 1).

Table 1. Populations of stream-type Chinook salmon and their comparison to Chiwawa spring Chinook.

Population	Similar life-history	No or few hatchery fish	Accurate abundance estimates	Long time series (at least 20 years)	Similar freshwater habitat impairments	Similar out-of-basin effects	Comments
Deschutes River	Yes	Yes	Yes	Yes	No	No	
John Day mainstem	Yes	Yes	Yes	Yes	No	No	
Middle Fk John Day	Yes	Yes	Yes	Yes	No	No	
North Fk John Day	Yes	Yes	Yes	Yes	No	No	
Granite Creek	Yes	Yes	Yes	Yes	No	No	
Wenaha River	Yes	No	Yes	Yes	Yes	No	Hatchery strays (>10%)
Minam River	Yes	No	Yes	Yes	Yes	No	Hatchery strays (>10%)
Slate Creek	Yes	Yes	Yes	No	No	No	
Secesh River	Yes	Yes	Yes	Yes	Yes	No	
Middle Fk Salmon River	Yes	Yes	Yes	No	No	No	Fair productivity est.
Big Creek	Yes	Yes	Yes	Yes	No	No	
Camas Creek	Yes	Yes	Yes	Yes	No	No	Fair productivity est.
Loon Creek	Yes	Yes	Yes	Yes	No	No	Fair productivity est.
Sulphur Creek	Yes	Yes	Yes	Yes	No	No	
Bear Valley Creek	Yes	Yes	Yes	Yes	No	No	
Marsh Creek	Yes	Yes	Yes	Yes	Yes	No	
North Fk Salmon River	Yes	Yes	No	No	Yes	No	
Lemhi River	Yes	Yes	Yes	Yes	No	No	
East Fk Salmon River	Yes	No	Yes	Yes	No	No	Hatchery strays (>10%)
Valley Creek	Yes	No	Yes	Yes	No	No	Hatchery strays (>10%)
Chamberlain Creek	Yes	Yes	Yes	No	Yes	No	
Naches River	Yes	Yes	Yes	Yes	Yes	No	
Little Wenatchee River	Yes	No	Yes	Yes	Yes	Yes	Hatchery strays (>10%)
Entiat River	Yes	No	Yes	Yes	No	No	Hatchery release ending

We then assessed the accuracy and length of the series of abundance estimates. We assumed that abundance estimates generated from expanded redd counts or adjusted weir counts would compare well with estimates in the Chiwawa Basin, which were based on expanded redd counts. In addition, we looked for populations that had an abundance data series that extended from at least 1981 to present. Based on this analysis, we identified 18 populations with abundance estimates that could be compared to those from the Chiwawa Basin (Table 1).

Next, we determined if the potential reference populations came from watersheds with habitat conditions similar to those in the Chiwawa Basin. For this exercise, we searched recovery plans and draft recovery plans to identify tributary factors that limit Chinook abundance, productivity, and survival within the reference populations. We compared these factors with those limiting

Chinook salmon in the Chiwawa Basin. Based on this analysis, we identified eight populations with habitat impairments similar to those in the Chiwawa Basin (Table 1).

Finally, we examined the potential reference populations to see if they experienced out-of-basin effects similar to spring Chinook from the Chiwawa Basin. In this case, we compared the number of mainstem dams that each potential reference population passes during migration. Six of the potential reference populations pass less than six mainstem dams; the other populations pass eight mainstem dams (Table 1). Only the Little Wenatchee population passes seven dams, similar to the Chiwawa population.

In sum, there were no reference populations that matched the Chiwawa spring Chinook population on all the criteria identified above. Differential out-of-basin effects and freshwater habitat conditions prevented most reference populations from matching with Chiwawa spring Chinook. However, some of the potential reference populations were similar to the Chiwawa population on several criteria and warranted further investigation. We selected the following populations for further investigation: Sesech River, Marsh Creek, Naches River, Little Wenatchee, and Entiat River.

We included the Little Wenatchee because it is within the Wenatchee River basin and experiences similar out-of-basin effects and has the same climatic and environmental conditions as the Chiwawa. A confounding effect with the Little Wenatchee is that Chiwawa hatchery fish have strayed into the Little Wenatchee. However, straying of Chiwawa hatchery fish should decrease with the change in source water to the Chiwawa acclimation ponds in 2006. We also included the Entiat River because it is an adjacent basin to the Chiwawa and experiences similar climatic and environmental conditions. The spring Chinook hatchery program that has operated in the Entiat since 1975 has been discontinued. Therefore, this population offers a unique opportunity to compare the Chiwawa population to a population in which the hatchery program has been discontinued.

Step 2: Graphic and Statistical Analysis

Graphic Analysis

Although we were unable to find potential reference populations that matched with the Chiwawa population on all criteria considered under Step 1, spawner abundance, natural-origin recruits (NORs), and productivity of some of the potential reference populations may nevertheless track closely with the Chiwawa population. If the time series of abundance, NORs, and productivity of a potential reference population tracks closely with the abundance, NORs, and productivity of the Chiwawa population, the reference population may provide a reasonable reference condition for testing the effects of supplementation on the Chiwawa population.

Under Step 2, we used graphing techniques to examine the relationship of abundance, NORs, and productivity between the Chiwawa population and the five reference populations (Sesech River, Marsh Creek, Naches River, Little Wenatchee, and Entiat River). We compiled spawner abundance, NORs, and productivity data from local biologists and the NOAA Fisheries Salmon Population Summary Database. We then compared time series plots of spawner abundance, NORs, and productivity data of potential reference populations with the Chiwawa population (Figures 2, 3, and 4; plots on the left side of figures). The time series only included the period 1981 to 1992, which represented the period before supplementation of the Chiwawa population (pre-treatment period). We also plotted the relationship between the abundance, NORs, and productivity of each

potential reference population to the Chiwawa population (Figures 2, 3, and 4; plots on right side of figures). These plots show whether the reference populations closely tracked the Chiwawa population. As a point of reference, data points that fall along the dashed line would represent a perfect relationship between the two populations (i.e., both populations have identical abundance, NORs, and productivity estimates). While a perfect relationship between two independent populations is unrealistic, a strong linear relationship between the two populations indicates populations with similar trends.

Based on analysis of spawner abundance, the Naches River time series tracked more closely with the abundance of Chiwawa spring Chinook than did the other potential reference populations. The poor relationship with the other potential reference streams was largely because of the relatively high abundance of Chiwawa spring Chinook during the mid-1980s. As with spawner abundance, analyses of NORs indicated a close relationship between the Naches and Chiwawa populations. The other potential reference populations tracked poorly with the Chiwawa. The analyses of productivity indicated close relationships between potential reference populations and the Chiwawa population. The Naches, Sesech, and Little Wenatchee populations tracked the closest with the Chiwawa population.

When analyzing the potential effects of a supplementation program on fish performance, it is common to transform the data to meet various assumptions of statistical analysis. The most common transformation used to adjust abundance, NORs, and productivity data is the natural logarithm (LN or $\log_e$). We therefore transformed the spawner abundance, NORs, and productivity data using LN and re-plotted the relationships between the potential reference populations and the Chiwawa population (Figures 5, 6, and 7). We added 1 to each observation before taking its logarithm to avoid taking the logarithm of 0, which is undefined (note that the LN of 1 is 0).

By transforming spawner abundance, NORs, and productivity data, most of the potential reference populations tracked more closely with the Chiwawa population. The Naches, Entiat, and Little Wenatchee abundance data tracked the closest with the Chiwawa abundance data (Figure 5). For NORs, Marsh Creek and the Little Wenatchee populations tracked the closest with the Chiwawa (Figure 6). For productivity, the Naches, Sesech, and Little Wenatchee tracked the closest with the Chiwawa (Figure 7).

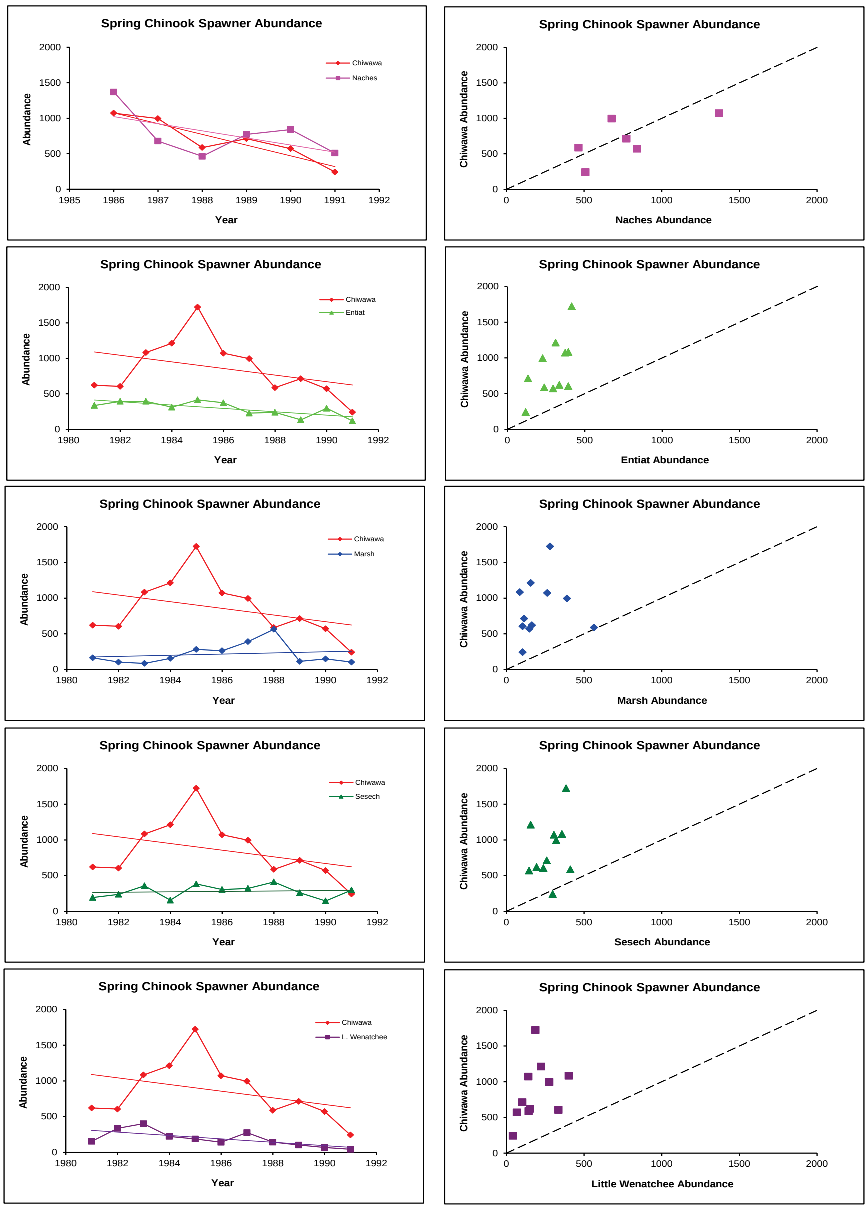

Figure 2. Time series of spawner abundance of potential reference populations and the Chiwawa spring Chinook population before the Chiwawa population was supplemented with hatchery fish.

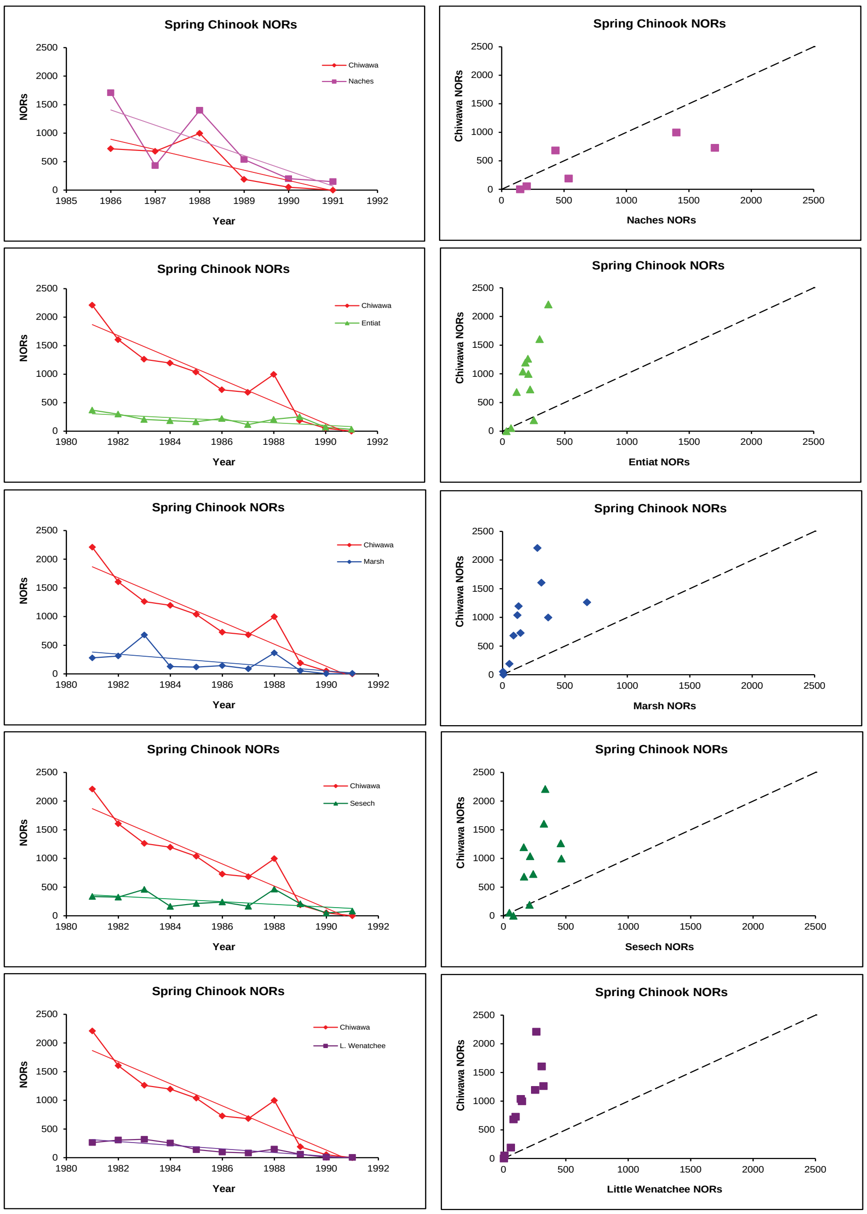

Figure 3. Time series of natural-origin recruits (NORs) of potential reference populations and the Chiwawa spring Chinook population before the Chiwawa population was supplemented with hatchery fish.

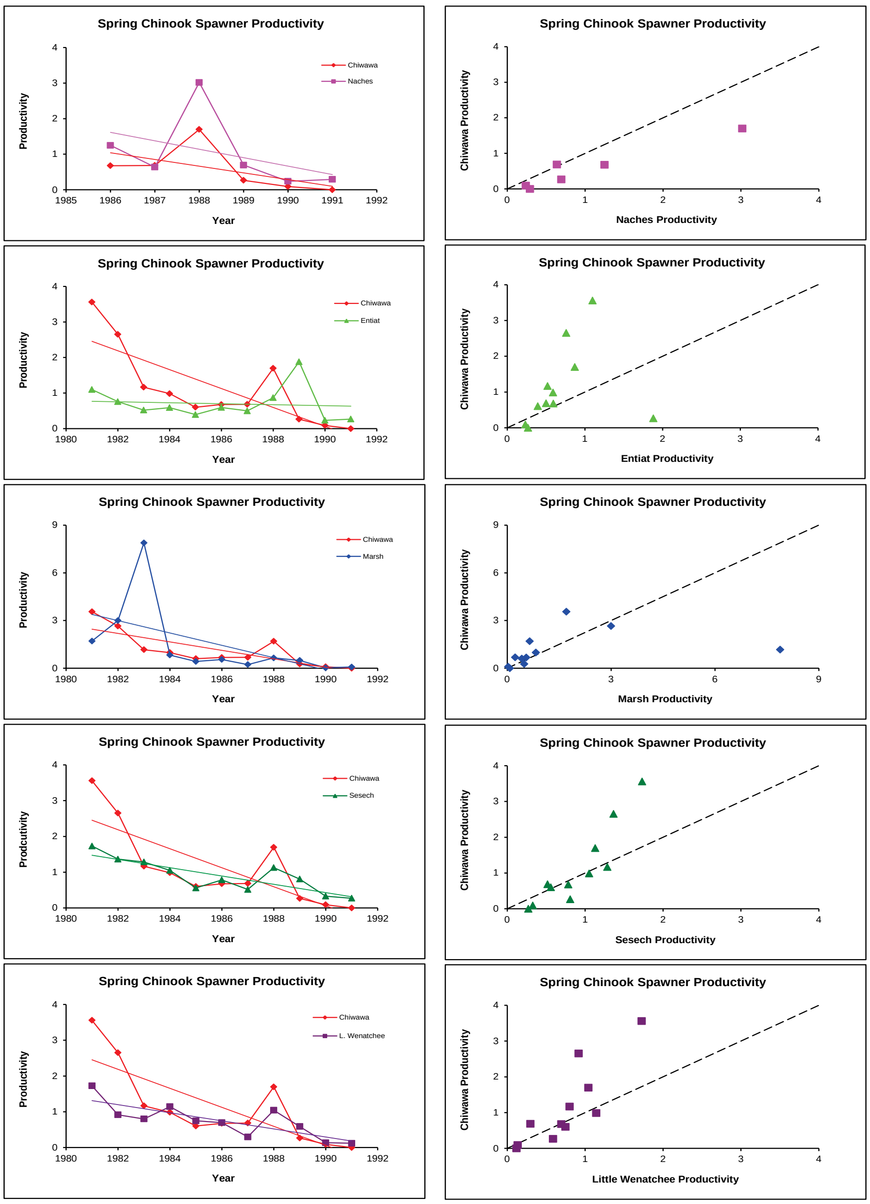

Figure 4. Time series of adult productivity of potential reference populations and the Chiwawa spring Chinook population before the Chiwawa population was supplemented with hatchery fish.

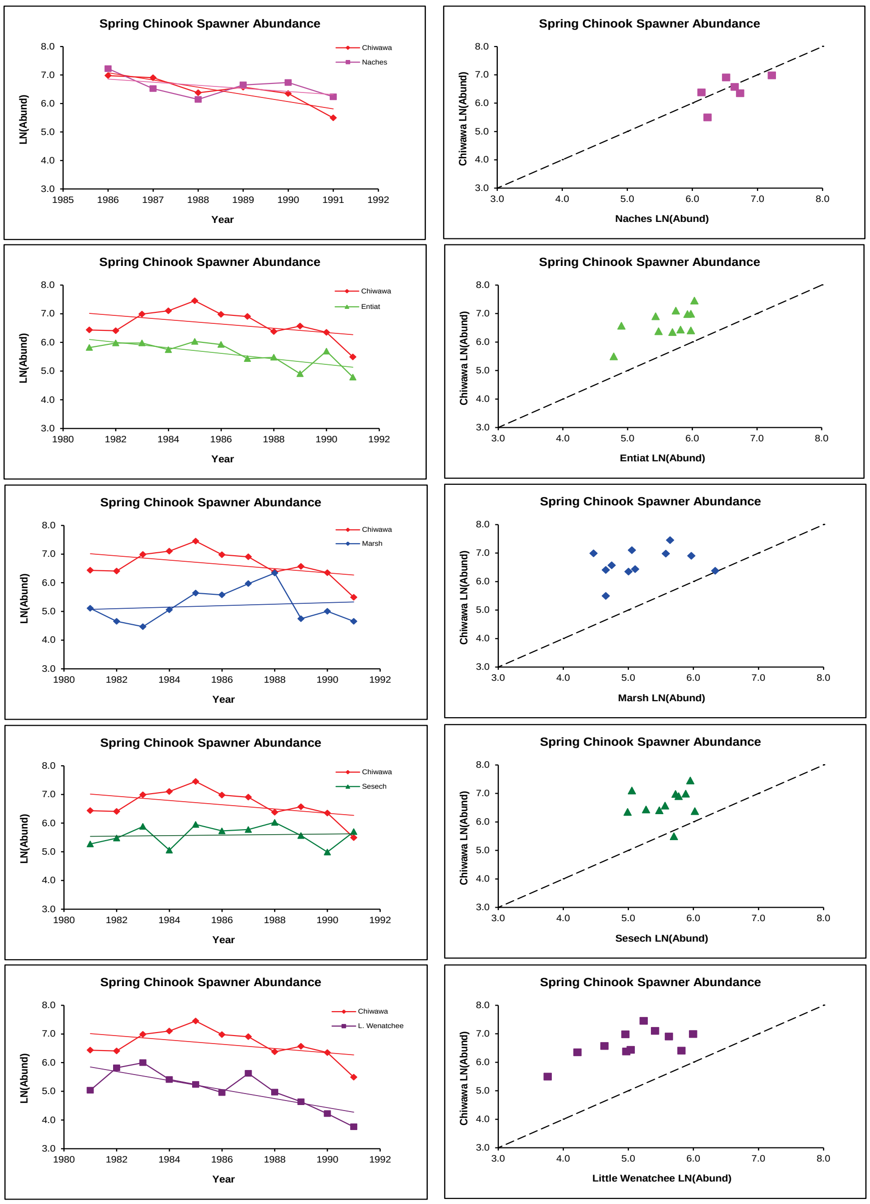

Figure 5. Time series of natural log spawner abundance of potential reference populations and the Chiwawa spring Chinook population before the Chiwawa population was supplemented with hatchery fish.

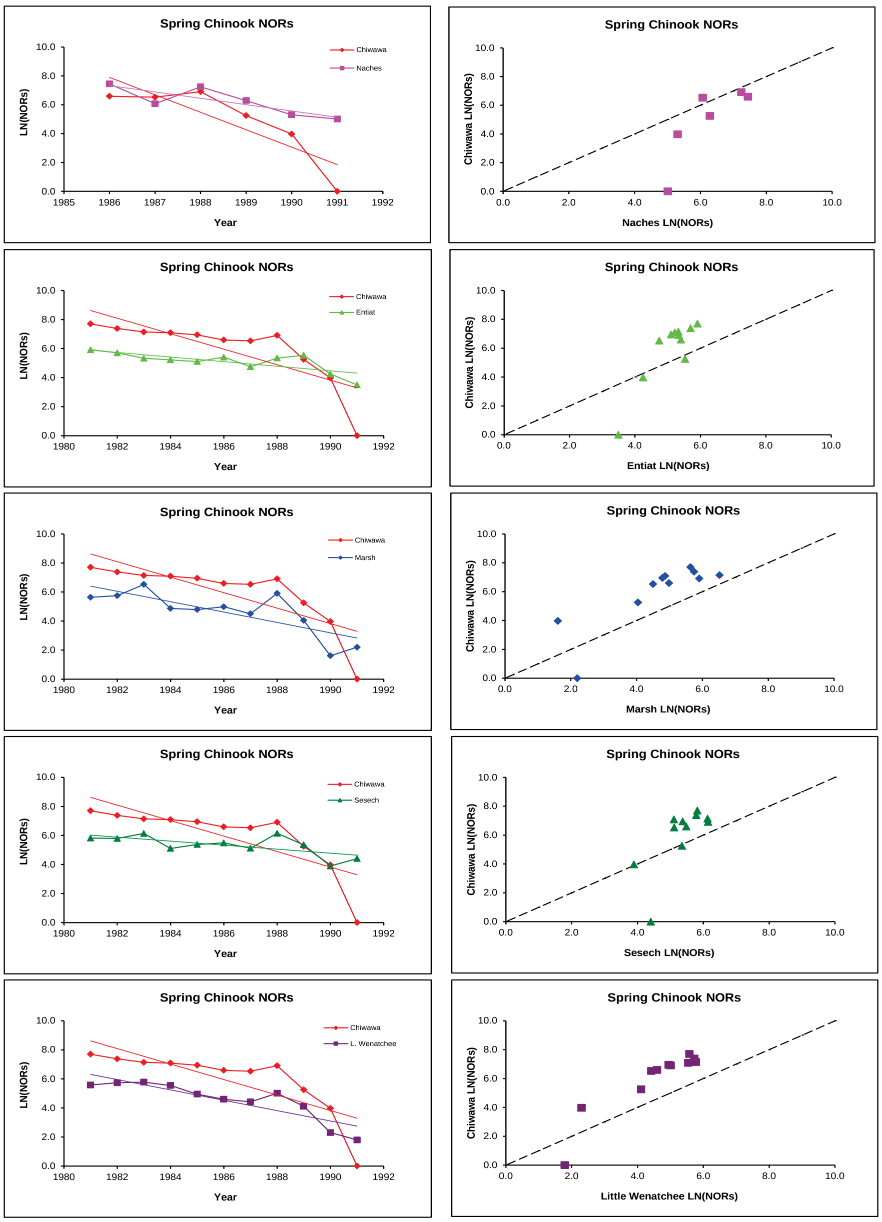

Figure 6. Time series of natural log natural-origin recruits (NORs) of potential reference populations and the Chiwawa spring Chinook population before the Chiwawa population was supplemented with hatchery fish.

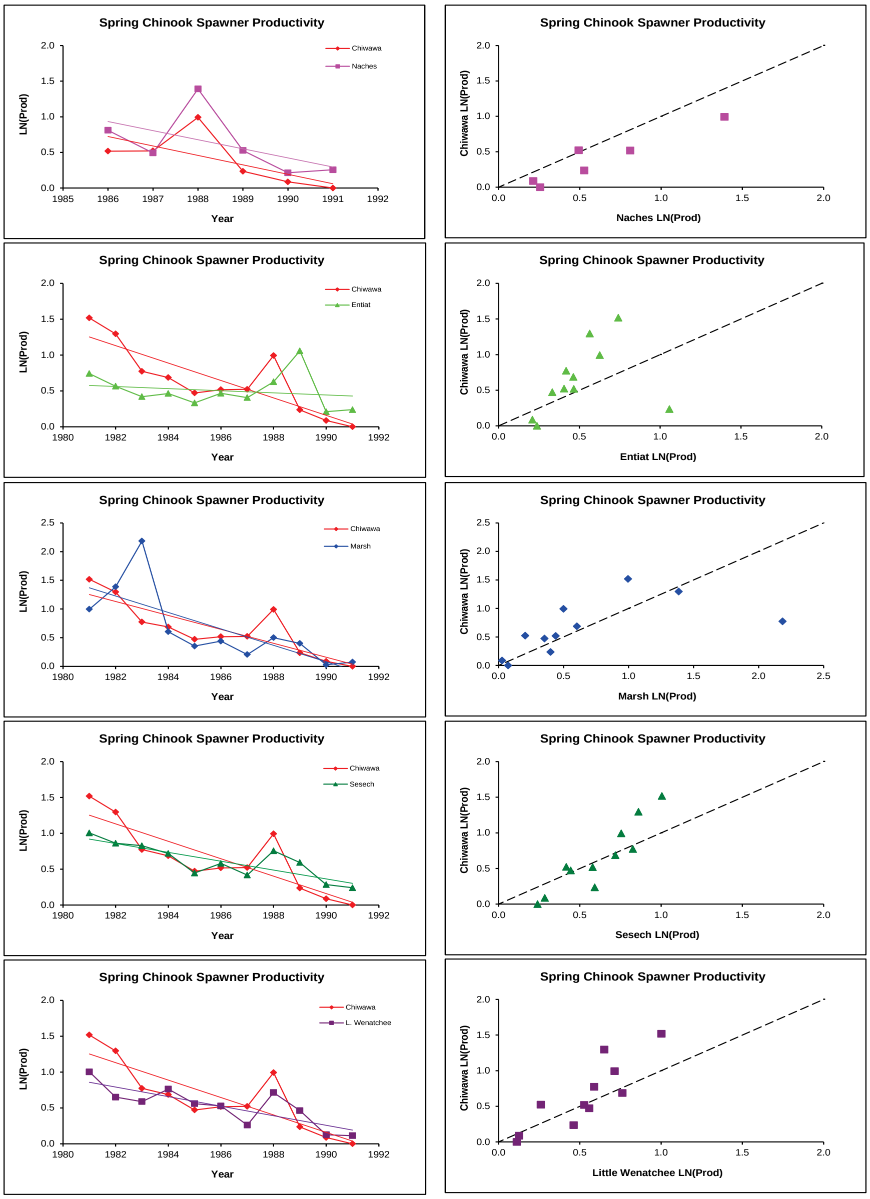

Figure 7. Time series of natural log adult productivity of potential reference populations and the Chiwawa spring Chinook population before the Chiwawa population was supplemented with hatchery fish.

Correlations and Trends

Other methods for evaluating the suitability of potential reference populations under Step 2 include correlation and trend analyses. For correlation analysis, we simply calculated the Pearson correlation coefficient, which is an index of the strength of the association between the potential reference populations and the Chiwawa population. The coefficient ranges from -1 to 1, where a value near 1 or -1 represents that strongest association between the populations. A value of 0 means no association. We used only spawner abundance, NORs, and productivity data during the pre-treatment period (1981-1992). We assumed that populations with coefficients greater than 0.6 represented reasonable reference conditions.

For trend analyses, we used least squares techniques to compute a straight-line trend through the spawner abundance and productivity data for the potential reference populations and the Chiwawa population. Trends were fit to the pre-treatment time series data (1981-1992). We then used t-tests to determine if the slopes of the trends between potential reference populations and the Chiwawa population differed significantly.

It is important to note that time-series trend analyses are susceptible to temporal correlations in the data. Autoregressive integrated moving average (ARIMA) models can be used to describe the correlation structure in temporal data (Gotelli and Ellison 2004). However, these models require a long time series (N > 40) and therefore we could not use them to model the spring Chinook data. As such, we were unable to correct for any temporal correlation that may exist within the time series.

Tests of correlation with spawner abundance data indicated that the Naches River closely correlated with the Chiwawa population (Table 2). There was no difference in abundance trends between the potential reference populations and the Chiwawa population (Table 2; Figure 2). For NORs, all potential reference populations correlated with the Chiwawa population (Table 2). However, trends in NORs of all reference populations, except Naches, differed significantly from the Chiwawa population (Table 2; Figure 3). For productivity, the Naches, Sesech, and Little Wenatchee correlated with the Chiwawa population (Table 2). Only the Entiat productivity trend differed significantly from the Chiwawa population trend (Table 2; Figure 4).

Table 2. Pearson correlation coefficients and t-test results comparing slopes of trends between potential reference populations and the Chiwawa spring Chinook population; d.f. = degrees of freedom and for correlation coefficients, an asterisk (*) indicates significance at P < 0.05.

Reference populations	Pearson correlation coefficient	t-test on slopes		
		t-value	d.f.	P-value
Spawner Abundance Data				
Naches	0.684*	-0.659	8	0.528
Entiat	0.598*	-0.596	18	0.559
Marsh	0.147	-1.341	18	0.197
Sesech	0.274	-1.265	18	0.222
Little Wenatchee	0.399	-0.591	18	0.562
Natural-Origin Recruits				
Naches	0.803*	0.666	8	0.524
Entiat	0.795*	-7.495	18	0.000

Reference populations	Pearson correlation coefficient	t-test on slopes		
		t-value	d.f.	P-value
Marsh	0.605*	-5.786	18	0.000
Sesech	0.648*	-6.874	18	0.000
Little Wenatchee	0.880*	-7.206	18	0.000
Productivity Data				
Naches	0.960*	0.169	8	0.870
Entiat	0.272	-3.057	18	0.007
Marsh	0.320	0.605	18	0.553
Sesech	0.903*	-2.059	18	0.054
Little Wenatchee	0.848*	-2.065	18	0.054

We also ran correlation and trend analyses on natural-log transformed spawner abundance, NORs, and productivity data. These analyses indicated that the Naches, Entiat, and Little Wenatchee abundance data correlated with the Chiwawa population data (Table 3). None of the abundance trends of the potential reference populations differed significantly from the Chiwawa population trend (Table 3; Figure 5). For NORs, all potential reference populations correlated with the Chiwawa population (Table 3). Only trends in NORs of the Entiat and Sesech differed significantly from the Chiwawa population (Table 2; Figure 6). For productivity, the Naches, Marsh, Sesech, and Little Wenatchee correlated with the Chiwawa population data (Table 3). Only the Entiat productivity trend differed significantly from the Chiwawa population trend (Table 3; Figure 7).

Table 3. Pearson correlation coefficients and t-test results comparing slopes of trends between potential reference populations and the Chiwawa spring Chinook population; d.f. = degrees of freedom and for correlation coefficients, an asterisk (*) indicates significance at $P < 0.05$. Analyses were conducted on natural-log transformed abundance and productivity data.

Reference populations	Pearson correlation coefficient	t-test on slopes		
		t-value	d.f.	P-value
LN Spawner Abundance Data				
Naches	0.642*	-1.323	8	0.222
Entiat	0.652*	0.412	18	0.685
Marsh	0.294	-1.324	18	0.202
Sesech	0.149	-1.431	18	0.170
Little Wenatchee	0.670*	1.325	18	0.202
LN Natural-Origin Recruits				
Naches	0.824*	-1.985	8	0.082
Entiat	0.886*	-2.563	18	0.019
Marsh	0.830*	-1.038	18	0.313
Sesech	0.730*	-2.664	18	0.016
Little Wenatchee	0.927*	-1.150	18	0.265
LN Productivity Data				

Reference populations	Pearson correlation coefficient	t-test on slopes		
		t-value	d.f.	P-value
Naches	0.944*	-0.042	8	0.968
Entiat	0.373	-3.043	18	0.007
Marsh	0.610*	0.428	18	0.674
Sesech	0.913*	-2.050	18	0.055
Little Wenatchee	0.862*	-1.811	18	0.087

In summary, based on correlation, trend, and graphic analyses, the Naches, Entiat, and Little Wenatchee populations appear to be reasonable reference populations for comparing spawner abundance data with Chiwawa data. For NORs, the Naches, Marsh, and Little Wenatchee appear to be reasonable reference populations. For productivity, the Naches, Marsh, Sesech, and Little Wenatchee populations appear to be reasonable reference populations for the Chiwawa population.

Minimal Detectable Differences (MDD)

Given a suite of potential reference populations, it is important to conduct power analyses to determine the minimum differences that can be detected when comparing the reference populations to the supplemented population. As a final exercise under Step 2, we examined potential reference populations for the smallest minimal detectable differences. Before conducting power analyses, several decisions needed to be made, including what statistical procedures will be used to analyze the data, the desired level of statistical power (probability of rejecting a false null hypothesis), the size of the type-I error (the probability of rejecting a true null hypothesis of no difference), and the number of samples (i.e., years) included in the analysis. In this case, the number of samples represents the number of treatment (supplementation) years. The number of pre-treatment years (1981-1992) was based on the number of years of quality data available for Chiwawa spring Chinook and potential reference populations.

We designed the study as a modified BACI (Before-After, Control-Impact) design, which includes replication before and after supplementation in both the treated (T) population and the reference (R) populations. A common approach used to analyze data from BACI designs includes analysis of difference scores (Stewart-Oaten et al. 1992; Smith et al. 1993). Differences are calculated between paired treatment and reference population scores (i.e., T-R). Another approach is to calculate ratios (treatment/reference; T/R) for paired treatment and reference population scores (Skalski and Robson 1992). Finally, differences in annual changes in paired treatment and reference population scores can be calculated (i.e., ΔT-ΔR) (Murdoch and Peven 2005; Hays et al. 2006).[16] These derived difference and ratio scores are then analyzed for a before-after treatment effect with a two-sample t-test, Aspin-Welch modification of the t-test, or a randomization test. For power analyses, we calculated minimal detectable differences assuming the use of an independent two-sample t-test with a type-I error rate of 0.05, power of 0.80 (beta or type-II error rate of 0.20), and sample sizes (treatment years) of 5, 10, 15, 20, 25, and 50 years.

16 The difference of annual difference scores was estimated by first subtracting the population parameter (e.g., spawner abundance) in year 2 from year 1. This continues for all years in the data series for both treatment ($T_{t+1} - T_t$) and reference populations ($R_{t+1} - R_t$). We then calculated differences between paired treatment and reference annual difference scores [$(T_{t+1} - T_t) - (R_{t+1} - R_t) = \Delta T - \Delta R$].

The power analysis calculated the minimal detectable difference between mean difference or ratio scores before and during supplementation. We used existing data to calculate variances for the pre-supplementation and supplementation periods. Thus, variances were known and unequal. For both spawner abundance and NORs, the null hypothesis tested was that the mean difference or ratio before supplementation equaled the mean difference or ratio during supplementation. The alternative hypothesis was that the mean difference or ratio before supplementation was less than the mean difference during supplementation (one-tail test; Difference < 0). For productivity, the null hypothesis tested was that the mean difference or ratio before supplementation equaled the mean difference or ratio during supplementation. The alternative hypothesis was that the mean difference or ratio before supplementation was greater than the mean difference during supplementation (one-tail test; Difference > 0).

Based on spawner abundance data, power analysis indicated that the Sesech-Chiwawa pairing consistently produced the smallest detectable differences (Table 4). However, when the abundance data were transformed using natural logs, the Entiat-Chiwawa pairing produced the smallest detectable difference (Table 5). Minimal detectable differences, based on mean difference scores on untransformed data and a treatment period of 20 years, ranged from 334 to 394 adult spawners; transformed data ranged from 0.479 to 1.010. These analyses indicate that the Naches, Entiat, Sesech, and Little Wenatchee populations appear to be reasonable reference populations for comparing spawner abundance data with Chiwawa data. The Marsh Creek population produced some of the largest detectable differences and based on these analyses may not be a reasonable reference population.

Table 4. Minimal detectable differences between mean difference and ratio scores before and during supplementation. Analyses were conducted on spawner abundance data.

Response variable	Treatment years	Minimal detectable differences by reference population				
		Naches	Entiat	Marsh	Sesech	Little Wenatchee
T-R	5	638	604	560	396	652
	10	464	448	444	354	481
	15	405	395	406	341	424
	20	376	368	387	334	394
	25	358	352	376	331	376
	50	322	319	354	323	340
T/R	5	0.600	2.084	39.251	1.569	5.498
	10	0.506	1.548	24.729	1.508	3.828
	15	0.478	1.367	19.646	1.490	3.256
	20	0.465	1.275	16.828	1.481	2.954
	25	0.458	1.219	14.974	1.475	2.765
	50	0.447	1.105	10.573	1.465	2.366
ΔT-ΔR	5	1,049	761	717	518	766
	10	750	542	539	411	547
	15	650	467	480	376	473
	20	598	429	450	359	434

Response variable	Treatment years	Minimal detectable differences by reference population				
		Naches	Entiat	Marsh	Sesech	Little Wenatchee
	25	567	405	431	348	410
	50	506	355	395	329	361

Table 5. Minimal detectable differences between mean difference and ratio scores before and during supplementation. Analyses were conducted on natural-log transformed spawner abundance data.

Response variable	Treatment years	Minimal detectable differences by reference population				
		Naches	Entiat	Marsh	Sesech	Little Wenatchee
T-R	5	0.975	0.871	2.061	0.828	1.013
	10	0.721	0.613	1.375	0.648	0.722
	15	0.637	0.525	1.138	0.588	0.623
	20	0.595	0.479	1.010	0.559	0.571
	25	0.569	0.450	0.928	0.541	0.539
	50	0.521	0.390	0.749	0.505	0.473
T/R	5	0.157	0.162	2.343	0.160	0.368
	10	0.116	0.115	1.474	0.125	0.247
	15	0.102	0.099	1.170	0.114	0.206
	20	0.095	0.090	1.001	0.108	0.183
	25	0.091	0.085	0.890	0.104	0.169
	50	0.082	0.075	0.625	0.098	0.138
ΔT-ΔR	5	1.261	1.288	3.076	1.160	1.467
	10	0.898	0.900	2.020	0.887	1.001
	15	0.776	0.768	1.653	0.797	0.840
	20	0.713	0.698	1.463	0.751	0.755
	25	0.675	0.655	1.325	0.724	0.701
	50	0.600	0.564	1.038	0.670	0.585

Based on NORs, power analysis indicated that the Entiat-Chiwawa, Marsh-Chiwawa, and Little Wenatchee-Chiwawa pairings produced the smallest detectable differences (Table 6). When NORs were transformed using natural logs, the Little Wenatchee-Chiwawa pairing produced the smallest detectable difference (Table 7). Minimal detectable differences, based on mean difference scores on untransformed data and a treatment period of 20 years, ranged from 483 to 640 NORs; transformed data ranged from 0.958 to 2.262. These analyses indicate that the Entiat, Marsh, and Little Wenatchee populations appear to be reasonable reference populations for comparing NORs with Chiwawa data.

Table 6. Minimal detectable differences between mean difference and ratio scores before and during supplementation. Analyses were conducted on natural-origin recruits.

Response variable	Treatment years	Minimal detectable differences by reference population				
		Naches	Entiat	Marsh	Sesech	Little Wenatchee
T-R	5	1,139	541	573	630	546
	10	809	511	515	550	503
	15	698	502	498	526	489
	20	640	497	489	514	483
	25	604	494	484	507	479
	50	534	489	474	493	472
T/R	5	0.469	2.538	5.196	1.976	6.973
	10	0.451	2.183	4.183	1.894	5.118
	15	0.446	2.072	3.854	1.869	4.492
	20	0.445	2.017	3.691	1.857	4.170
	25	0.444	1.986	3.594	1.850	3.973
	50	0.443	1.924	3.405	1.836	3.572
ΔT-ΔR	5	1,639	500	519	609	531
	10	1,239	386	409	433	396
	15	1,109	348	374	372	351
	20	1,046	329	356	341	328
	25	1,009	318	346	321	314
	50	943	295	325	281	285

Table 7. Minimal detectable differences between mean difference and ratio scores before and during supplementation. Analyses were conducted on natural-log transformed natural-origin recruits.

Response variable	Treatment years	Minimal detectable differences by reference population				
		Naches	Entiat	Marsh	Sesech	Little Wenatchee
T-R	5	2.380	1.646	1.967	2.247	1.174
	10	2.291	1.479	1.505	1.835	1.026
	15	2.270	1.428	1.351	1.702	0.980
	20	2.262	1.403	1.273	1.636	0.958
	25	2.258	1.389	1.227	1.597	0.945
	50	2.253	1.361	1.133	1.522	0.920
T/R	5	0.322	0.332	0.739	0.398	0.356
	10	0.301	0.289	0.581	0.334	0.322
	15	0.296	0.275	0.530	0.314	0.312
	20	0.294	0.269	0.504	0.305	0.307
	25	0.293	0.265	0.488	0.299	0.304

Response variable	Treatment years	Minimal detectable differences by reference population				
		Naches	Entiat	Marsh	Sesech	Little Wenatchee
	50	0.291	0.258	0.458	0.288	0.298
ΔT-ΔR	5	2.858	2.400	2.355	3.283	2.109
	10	2.560	1.714	1.881	2.311	1.552
	15	2.485	1.481	1.728	1.979	1.365
	20	2.456	1.360	1.652	1.805	1.269
	25	2.443	1.285	1.607	1.697	1.210
	50	2.430	1.130	1.519	1.471	1.092

Using untransformed productivity data, power analysis indicated that the Little Wenatchee-Chiwawa pairing consistently produced the smallest detectable differences (Table 8). The Marsh-Chiwawa pairings produced the largest detectable differences. When we analyzed natural-log transformed productivity data, the Naches-Chiwawa and Little Wenatchee-Chiwawa pairings produced the smallest detectable differences (Table 9). Minimal detectable differences, based on mean difference scores on untransformed data and a treatment period of 20 years, ranged from 0.754 to 1.839; transformed data ranged from 0.277 to 0.477. These analyses indicate that the Naches, Entiat, Sesech, and Little Wenatchee populations appear to be reasonable reference populations for comparing productivity data with Chiwawa data. The Marsh Creek population produced some of the largest detectable differences and based on these analyses may not be a reasonable reference population.

Table 8. Minimal detectable differences between mean difference and ratio scores before and during supplementation. Analyses were conducted on productivity data.

Response variable	Treatment years	Minimal detectable differences by reference population				
		Naches	Entiat	Marsh	Sesech	Little Wenatchee
T-R	5	2.181	1.382	2.033	3.517	1.192
	10	1.442	1.119	1.900	2.265	0.901
	15	1.186	1.033	1.859	1.828	0.804
	20	1.047	0.991	1.839	1.588	0.754
	25	0.959	0.966	1.828	1.432	0.724
	50	0.764	0.917	1.806	1.074	0.664
T/R	5	1.364	1.773	0.863	0.876	2.167
	10	1.095	1.359	0.831	0.687	1.587
	15	1.011	1.221	0.822	0.625	1.391
	20	0.971	1.152	0.817	0.594	1.290
	25	0.949	1.110	0.814	0.575	1.228
	50	0.910	1.027	0.908	0.538	1.102
ΔT-ΔR	5	3.298	1.864	3.211	4.420	1.942
	10	2.263	1.382	2.968	2.811	1.291

Response variable	Treatment years	Minimal detectable differences by reference population				
		Naches	Entiat	Marsh	Sesech	Little Wenatchee
	15	1.909	1.220	2.894	2.248	1.066
	20	1.723	1.137	2.859	1.938	0.944
	25	1.606	1.087	2.839	1.735	0.866
	50	1.365	0.986	2.800	1.259	0.695

Table 9. Minimal detectable differences between mean difference and ratio scores before and during supplementation. Analyses were conducted on natural-log transformed productivity data.

Response variable	Treatment years	Minimal detectable differences by reference population				
		Naches	Entiat	Marsh	Sesech	Little Wenatchee
T-R	5	0.540	0.551	0.674	0.890	0.585
	10	0.367	0.452	0.542	0.590	0.413
	15	0.308	0.421	0.499	0.486	0.355
	20	0.277	0.405	0.477	0.430	0.324
	25	0.257	0.396	0.465	0.393	0.305
	50	0.215	0.378	0.440	0.314	0.265
T/R	5	0.915	1.286	0.743	0.697	1.685
	10	0.744	0.973	0.704	0.541	1.227
	15	0.691	0.868	0.692	0.489	1.072
	20	0.666	0.815	0.687	0.463	0.993
	25	0.652	0.783	0.683	0.447	0.943
	50	0.628	0.719	0.677	0.416	0.843
ΔT-ΔR	5	0.885	0.810	1.028	1.252	0.971
	10	0.631	0.609	0.822	0.809	0.640
	15	0.546	0.542	0.755	0.655	0.525
	20	0.502	0.508	0.722	0.570	0.463
	25	0.475	0.487	0.702	0.516	0.423
	50	0.423	0.446	0.664	0.391	0.333

Step 3: Quantitative Method for Ranking Selection Criteria

Not surprisingly, different selection criteria produced different results (Table 10). Determining whether a given population is or is not a suitable reference population based on selection criteria such as graphic analysis can be subjective. In addition, treating each selection criterion as equally important may not be appropriate. For example, using the information in Table 10, is it appropriate to select a reference population that has two or three "Yes" entries, or should only populations with four "Yes" entries be selected as suitable reference populations? This approach does not allow certain selection criteria to carry more weight in the overall selection process. That is, correlation may be more important than graphic analysis in the overall selection process. In order to reduce

subjectivity, we developed a method of scoring and weighting each selection criterion. This method allows a more quantitative process for selecting suitable reference populations.

Table 10. Summary of results from graphic analysis, correlations, trend analysis, and power analysis (minimal detectable differences). “Yes” indicates that the population is a suitable reference population for the Chiwawa population; “No” indicates that it may not be a suitable reference population.

Potential reference populations	Graphic analysis	Correlation	Trends	Minimal detectable differences
Spawner Abundance				
Naches	Yes	Yes	Yes	Yes
Entiat	Yes	Yes	Yes	Yes
Marsh	No	No	Yes	No
Sesech	No	No	Yes	Yes
Little Wenatchee	Yes	Yes	Yes	Yes
Natural-Origin Recruits				
Naches	Yes	Yes	Yes	No
Entiat	No	Yes	No	Yes
Marsh	Yes	Yes	Yes	Yes
Sesech	No	Yes	No	No
Little Wenatchee	Yes	Yes	Yes	Yes
Productivity				
Naches	Yes	Yes	Yes	Yes
Entiat	No	No	No	Yes
Marsh	No	Yes	Yes	No
Sesech	Yes	Yes	Yes	Yes
Little Wenatchee	Yes	Yes	Yes	Yes

We developed scoring methods for each of the following five selection criteria:

(1) The proportion of natural-origin spawners (pNOS) in the reference population for the period before supplementation (pre-pNOS);

(2) pNOS in the reference population for the period following supplementation (post-pNOS);

(3) The correlation between the reference and supplemented populations before supplementation;

(4) The relative difference in slopes between the reference and supplemented populations before supplementation; and

(5) The coefficient of variation (CV) of the ratio of supplemented to reference populations before the period of supplementation.

Each selection criteria was scored from 0 to 1, with 0 being the worst possible score and 1 being the best.

The pre- and post-pNOS values were calculated as the average pNOS values before and after supplementation, respectively. Because pNOS values range from 0-1, we did not need to rescale

these values. When using reference populations to evaluate the effects of supplementation programs, it is important that the reference populations maintain high values of pNOS throughout the life of the monitoring program. Therefore, we heavily weighted the mean pNOS scores. We assigned weights of 30 and 40 to the mean pre- and post-pNOS scores, respectively. The relatively larger weight for the post-supplementation period is to reduce the likelihood of retaining a reference population that becomes influenced by hatchery fish during the supplementation period.

We assessed the association between the reference and supplemented populations during the pre-supplementation period by calculating the Pearson correlation coefficient, which ranges from -1 to 1. To scale the coefficient between 0 and 1, we took the absolute value of the coefficient. Thus, a coefficient of -0.92 would be reported as 0.92. For our analyses, we were not concerned with the direction of the relationship, only the strength of the relationship. The correlation coefficient was given a weight of 12.5.

As noted earlier, we used least squares to fit a linear trend to each of the reference populations and the supplemented population during the pre-supplementation period. Using the slope estimates for each trend line, we calculated the relative difference in slopes as the slope of the supplemented population minus the slope of the reference population, divided by the slope of the reference population. To scale this value between 0 and 1, we used absolute values, and depending on the direction of the slopes, we subtracted the relative difference from 1. The latter was needed to make sure a larger relative difference value indicated a small difference in slopes between the supplemented and reference populations. The relative difference score was given a weight of 7.5.

Finally, as a means to score effect size, we calculated the CV of the ratio of supplemented to reference population parameters (i.e., T/R). The CV was calculated as the standard deviation of the ratios divided by the absolute value of the mean ratios. The CV was subtracted from 1. This scaled the value from 0 to 1 with larger values representing the best condition. The CV was given a weight of 10, which is greater than the weight for trend, but less than the weight for correlation.

The total score for a reference population was calculated by multiplying the estimated value, which ranged from 0 to 1, by its weight. The sum of the five weighted values provided a total score, which ranged from 0 to 100. Based on several simulations, we set the cut-off score at 81. That is, if the total score for a given reference population equaled or exceeded 81, the population was included as a suitable reference population. If the total score fell below 81, the population was not considered a suitable reference. Based on the distribution of all scores possible, a score of 81 or greater represented only 3% of the total distribution. Thus, a cut-off of 81 is quite conservative.

Under Step 3, we used this method to select the final suite of suitable reference populations. Table 11 shows results from scoring each of the reference populations using the quantitative method. Using the cut-off criterion of 81, only the Naches, Marsh, and Sesech populations would be considered suitable reference populations for the Chiwawa supplementation program. Both the Entiat and Little Wenatchee populations failed to meet the minimum score, largely because of the influence of hatchery fish within those populations (i.e., relatively low pNOS values).

Table 11. Results from scoring potential reference populations using the selection criteria (pNOS, correlation, trend, and effect size). Populations with scores less than 81 were considered unsuitable as reference populations. Populations with scores equal to or greater than 81 were considered suitable references. These results were based on natural-log transformed data.

Potential reference populations	Population metric		
	Abundance	NORs	Productivity
Naches	85	88	91
Entiat	23	21	16
Marsh	79	91	87
Sesech	84	85	88
Little Wenatchee	51	53	49

An important benefit from scoring the different selection criteria is that the total scores can be used to weight the outcome of differing statistical results. For example, analyses may show that when three suitable reference populations are compared to the supplemented population, two of the reference populations may indicate a significant treatment effect, while the third indicates no effect. Under this scenario it is not clear if the supplementation program has or has not affected the abundance or productivity of the supplemented population. If, however, the two reference populations that produced a significant result had higher total scores than the reference population that did not indicate a significant result, one can place more weight on the results from populations with higher total scores.

Conclusions

The purpose of this exercise was to develop a method for selecting suitable reference populations that could be used to assess the effects of supplementation programs on spawner abundance, NORs, and productivity. The selection process included a three-step process (Figure 8). Step 1 identified populations with similar life-history characteristics, few or no hatchery spawners, a long time series of accurate abundance and productivity estimates, and similar freshwater habitat impairments and out-of-basin effects. Populations that met these criteria were then examined for their graphical and statistical relationship with the supplemented population (Step 2). The statistical analysis under Step 2 were converted to a quantitative model (Step 3) that was used to generate a weighted score for pNOS, correlation, trends, and effect sizes for each potential reference population. Reference populations with total scores of 81 or greater were selected as suitable reference populations.

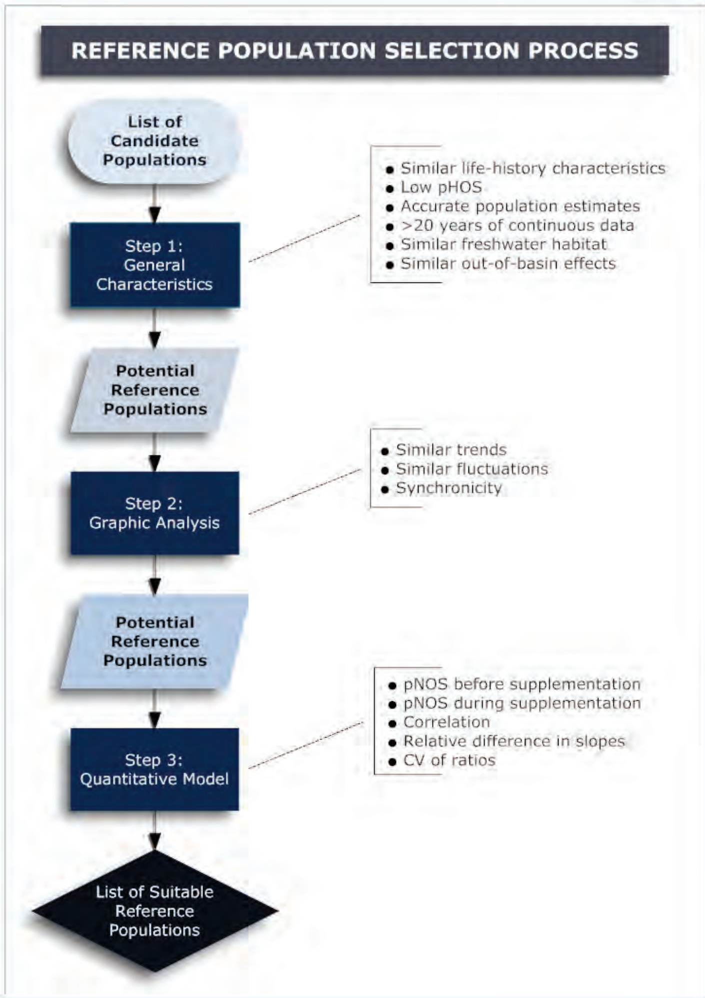

Figure 8. Three-step process for selecting suitable reference populations for supplemented populations.

We used this approach to select suitable reference populations for analyzing the effects of the Chiwawa spring Chinook supplementation program on fish abundance and productivity. The method indicated that the Naches, Marsh, and Sesech populations would serve as suitable reference populations for the Chiwawa spring Chinook supplementation program. Both the Entiat and Little Wenatchee populations failed to meet the minimum score, largely because of the influence of hatchery fish within those populations (i.e., relatively low pNOS values). However, because the presence of hatchery spring Chinook within those populations should decrease, they may serve as unique reference populations in which the comparisons change from all populations receiving

hatchery fish to only the Chiwawa population receiving hatchery fish. Therefore, we will continue to include both the Little Wenatchee and Entiat populations in future analyses.

An important assumption in the use of reference populations is that the supplemented and reference populations that tracked each other before supplementation would continue to track each other in the absence of supplementation. Given that the reference populations did not match the Chiwawa population on all criteria examined (Table 1) and some reference populations tracked the Chiwawa population more poorly than others (Figures 2-7; Tables 2-4), there may be some uncertainty as to whether differences observed between the Chiwawa and reference populations during the supplementation period are associated with the hatchery program, "nuisance" factors[17], or a combination of both. In addition, we have no ability to regulate or control activities in reference areas. Any large-scale change (man-made or natural) in reference areas could affect our ability to assess the effectiveness of the supplementation program.

Because we have no ability to maintain reference areas for long periods of time and may not be able to control all activities even within the supplemented populations, we propose the use of a "causal-comparative" approach to strengthen the certainty of our inferences (Pearsons and Temple 2010). The causal-comparative approach relies on correlative data to try and make a case for causal inference.[18] Correlation is used to rule out alternative hypotheses (note that we make our case as much if not more by disproving plausible alternatives as we do by showing that the data are consistent with a hypothesis). For example, large scale land-use activities or natural events can affect stream flows, fine sediment recruitment, and water temperatures. Changes in these factors can affect the freshwater survival and productivity of fish independently of supplementation programs. If changes in habitat, migratory, and ocean conditions do not affect reference and treatment populations similarly, inferences associated with supplementation programs may be confounded. By measuring and tracking these extraneous factors within reference and treatment areas, we can assess the effects of these state variables on population conditions independent of the supplementation programs. This allows us to more effectively assess the influence of supplementation programs on populations.

To that end, we recommend that the following state variables be measured and tracked within the Chiwawa Basin and each of the reference areas: mean annual precipitation, total and riparian forest cover, road density, impervious surface, and alluvium. These variables can be used to describe differences in water temperatures at different life stages (pre-spawning, egg incubation, and summer rearing) and substrate characteristics, including fine sediments and embeddedness (Jorgensen et al. 2009). They can be used to assess possible changes in spawner abundance, NORs, and productivity that are independent of supplementation.

17 A "nuisance" factor is any factor that is outside the control of the experimenter and can affect the response variable (spawner abundance or productivity). In this case, nuisance factors may include differences in freshwater habitat trends and conditions, out-of-basin effects (e.g., migration and ocean survival), and hatchery strays that affect the Chiwawa and reference populations differently.

18 It is important to point out that correlation does not demonstrate cause-and-effect. It only suggests a relationship between variables. Thus, inferences based on correlation lack the certainty that is associated with a design-based approach.

Analyses with Reference Populations

Once suitable reference populations are selected, methods for analyzing the supplemented and reference populations need to be identified. What follows is a description of different analyses that can be used to assess the effects of supplementation programs on spawner abundance, NORs, and productivity using reference populations. Later in this report we describe methods for assessing supplementation effects when reference populations are not available.

We used some of the reference populations selected for the Chiwawa program to illustrate the different methods for evaluating the effects of the supplementation program on spawner abundance, NORs, and productivity. For abundance, we selected the Naches, Entiat, Little Wenatchee, and Sesech populations as suitable references for the Chiwawa population. For NORs, we selected the Naches, Entiat, Marsh, and Little Wenatchee populations as suitable references. For productivity, we selected the Naches, Sesech, Little Wenatchee, and Marsh Creek as suitable references for the Chiwawa. As noted earlier, we included the Little Wenatchee and Entiat populations, even though they did not meet all the criteria for suitable reference populations.

Analysis of Trends

As a first step, we used trend analyses to assess the effects of the Chiwawa supplementation program on spring Chinook spawner abundance, NORs, and productivity. Here, we compared the slopes of the trends between each treatment/reference pair before and during supplementation using t-tests. If the hatchery program is successfully supplementing the natural spring Chinook population, trends in spawner abundance and NORs should deviate significantly (i.e., the slope of the supplemented population should be greater than the slopes of the reference populations during the supplementation period). For productivity, the slope of the supplemented population, relative to the reference population, should increase or remain the same.

Trend analysis indicated that the relationship of slopes of spawner abundance between the Chiwawa and reference populations did not change significantly after the initiation of supplementation (Figure 9; Table 12). This was true for both transformed and untransformed abundance data. Before supplementation, spawner abundances trended down in both the Chiwawa and reference populations (Figure 9). During the period of supplementation, abundances in both the Chiwawa and reference populations trended upward. Interestingly, in nearly all treatment/reference comparisons, the Pearson correlation coefficient was greater in the supplementation period than in the pre-supplementation period (Table 12). This was most evident in the transformed abundance data (Figure 9).

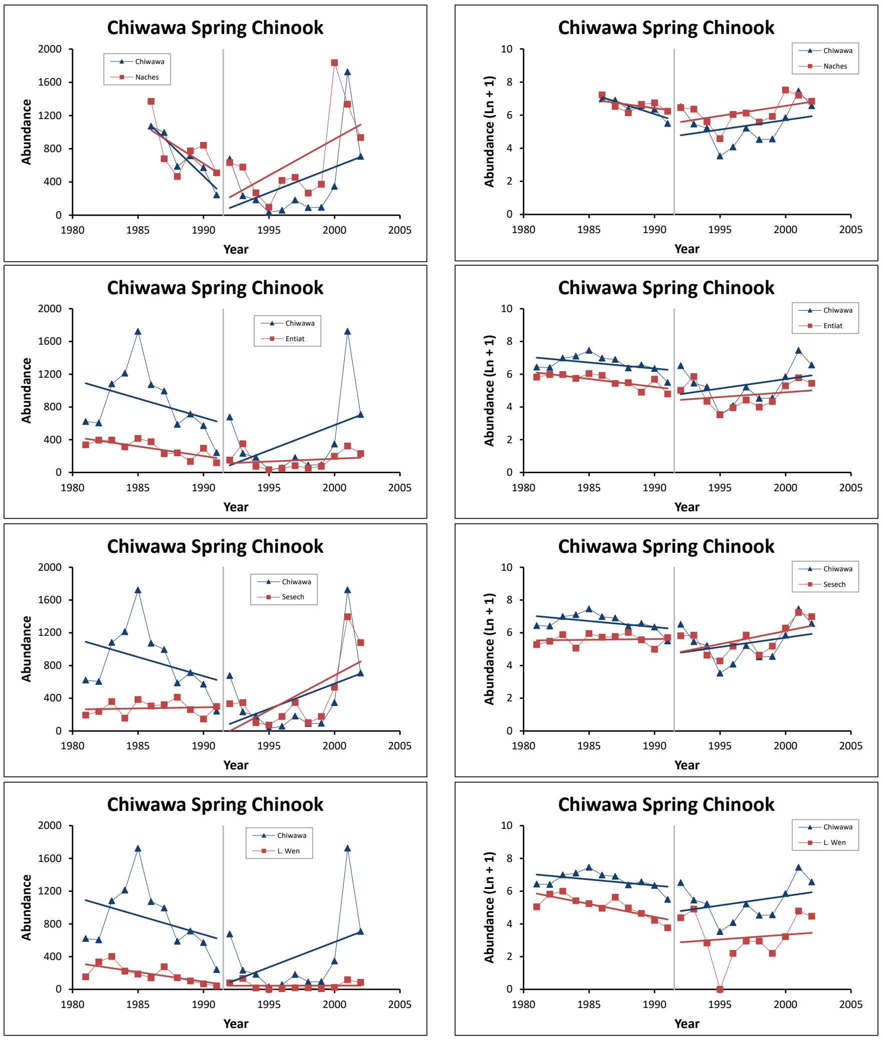

Figure 9. Trends in spring Chinook spawner abundance in the Chiwawa and reference populations. The vertical lines in the figures separate the pre- and post-supplementation periods. Figures on the left include untransformed spawner abundance data; those on the right include natural-log transformed data.

Table 12. Pearson correlation coefficients and t-test results comparing slopes of spawner abundance trends between reference populations and the Chiwawa spring Chinook population before and during the supplementation periods; for correlation coefficients, an asterisk (*) indicates significance at P < 0.05. Analyses include both untransformed and natural-log transformed spawner abundance data.

Reference population	Pearson correlation coefficient		Test on slopes			
			t-value		P-value	
	Before	During	Before	During	Before	During
Spawner Abundance						
Naches	0.684*	0.595	-0.659	-0.414	0.528	0.684
Entiat	0.598*	0.672*	-0.596	1.162	0.559	0.260
Sesech	0.274	0.904*	-1.265	-0.418	0.222	0.681
Little Wenatchee	0.399	0.685*	-0.591	1.330	0.562	0.200
LN Spawner Abundance						
Naches	0.642*	0.813*	-1.323	-0.047	0.222	0.963
Entiat	0.652*	0.860*	0.412	0.422	0.685	0.678
Sesech	0.149	0.878*	-1.431	-0.333	0.170	0.743
Little Wenatchee	0.670*	0.861*	1.325	0.316	0.202	0.756

Trend analysis indicated that the relationship of slopes of NORs between the Chiwawa and reference populations did not change significantly after the initiation of supplementation (Figure 10; Table 13). Before supplementation, Chiwawa NORs trended downward more strongly than the reference populations (Figure 10). However, during the supplementation period, both the Chiwawa and reference population NORs trended upward in parallel. In nearly all treatment/reference comparisons, the Pearson correlation coefficient was greater in the pre-supplementation period than in the supplementation period (Table 13).

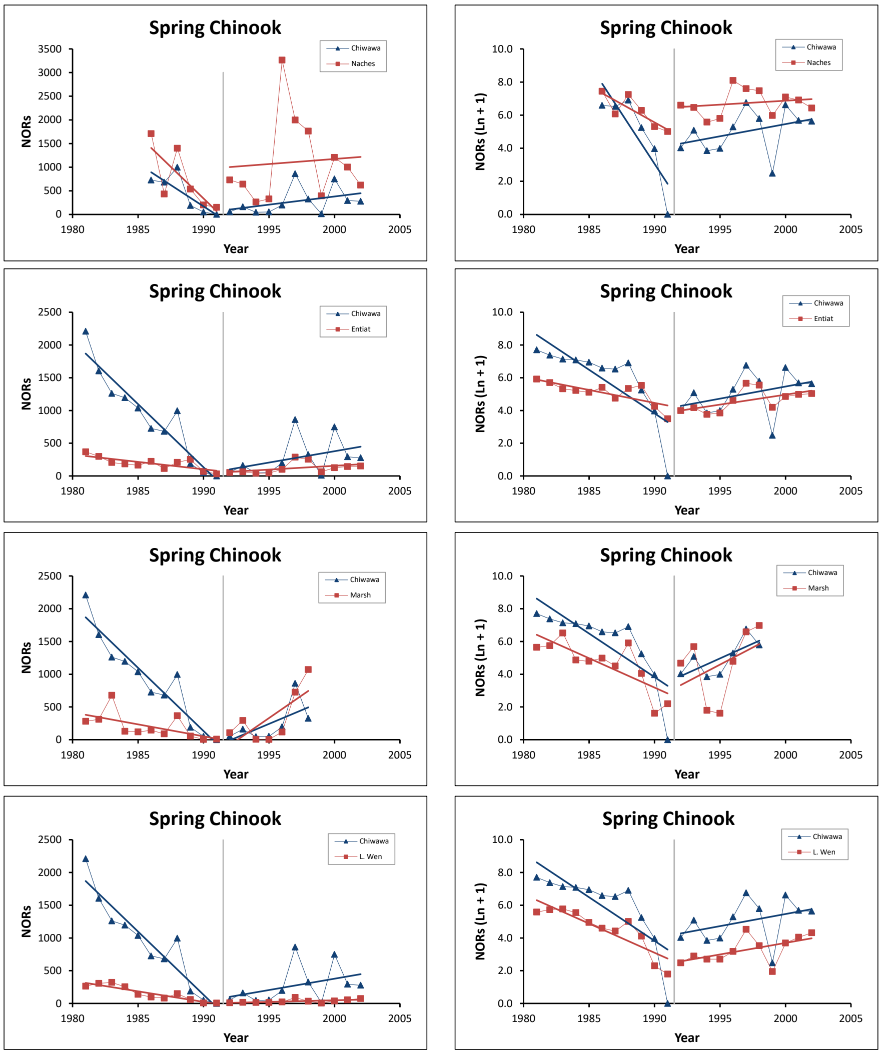

Figure 10. Trends in spring Chinook natural-origin recruits (NORs) in the Chiwawa and reference populations. The vertical lines in the figures separate the pre- and post-supplementation periods. Figures on the left include untransformed NORs; those on the right include natural-log transformed data.

Table 13. Pearson correlation coefficients and t-test results comparing slopes of natural-origin recruits trends between reference populations and the Chiwawa spring Chinook population before and during the supplementation periods; for correlation coefficients, an asterisk (*) indicates significance at $P < 0.05$. Analyses include both untransformed and natural-log transformed natural-origin recruits.

Reference population	Pearson correlation coefficient		Test on slopes			
			t-value		P-value	
	Before	During	Before	During	Before	During
Natural-Origin Recruits						
Naches	0.803*	0.432	0.666	0.140	0.524	0.890
Entiat	0.795*	0.754*	-7.495	0.847	0.000	0.408
Marsh	0.605*	0.677*	-5.786	-0.718	0.000	0.489
Little Wenatchee	0.880*	0.758*	-7.206	1.128	0.000	0.274
LN Natural-Origin Recruits						
Naches	0.824*	0.710*	-1.985	0.693	0.082	0.497
Entiat	0.886*	0.796*	-2.563	0.202	0.019	0.842
Marsh	0.830*	0.835*	-1.038	-0.134	0.313	0.896
Little Wenatchee	0.927*	0.898*	-1.150	0.046	0.265	0.964

As with NORs and spawner abundance data, trend analysis indicated that the relationship of slopes of productivity (recruits/spawner) between the Chiwawa and reference populations did not change significantly after the initiation of supplementation (Figure 11; Table 14). This was true for both transformed and untransformed productivity data. Before supplementation, productivities trended down in both the Chiwawa and reference populations (Figure 11). During the period of supplementation, productivities fluctuated widely in both the Chiwawa and reference populations. Nevertheless, during the supplementation period, productivities generally increased in both the reference and Chiwawa populations. Unlike with spawner abundance, the Pearson correlation coefficients resulting from analysis of productivity data were generally higher in the pre-supplementation period than during the supplementation period (Table 14).

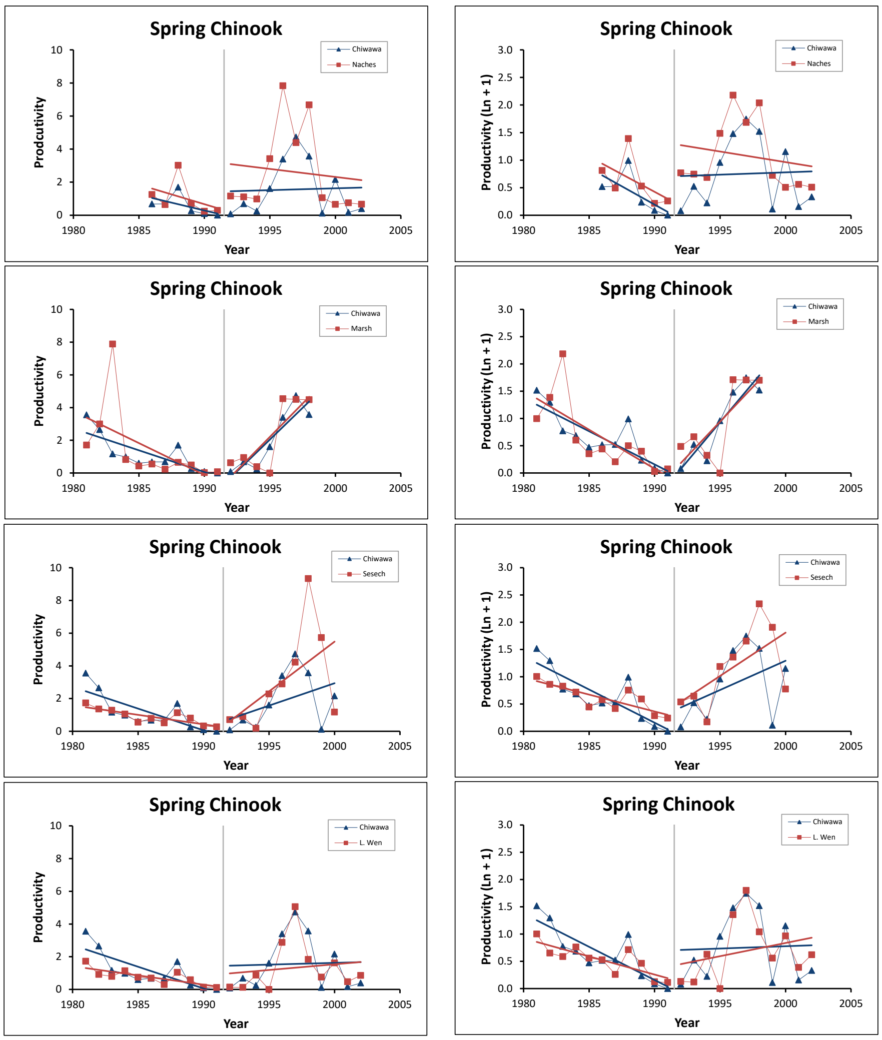

Figure 11. Trends in spring Chinook productivity (recruits/spawner) in the Chiwawa (supplemented) and reference populations. The vertical lines in the figures separate the pre- and post-supplementation periods. Figures on the left include untransformed productivity data; those on the right include natural-log transformed data.

Table 14. Pearson correlation coefficients and t-test results comparing slopes of productivity (recruits/spawner) trends between reference populations and the Chiwawa spring Chinook population before and during the supplementation periods; for correlation coefficients, an asterisk (*) indicates significance at $P < 0.05$. Analyses include both untransformed and natural-log transformed productivity data.

Reference population	Pearson correlation coefficient		Test on slopes			
			t-value		P-value	
	Before	During	Before	During	Before	During
Productivity						
Naches	0.960*	0.802*	0.169	0.387	0.870	0.703
Marsh	0.320	0.910*	0.605	-0.132	0.553	0.898
Sesech	0.903*	0.491	-2.059	-0.837	0.054	0.417
Little Wenatchee	0.848*	0.864*	-2.065	-0.213	0.054	0.834
LN Productivity						
Naches	0.944*	0.805*	-0.042	0.526	0.968	0.605
Marsh	0.610*	0.804*	0.428	0.281	0.674	0.784
Sesech	0.913*	0.531	-2.050	-0.463	0.055	0.651
Little Wenatchee	0.862*	0.751*	-1.811	-0.480	0.087	0.637

Using trend analysis, we found no evidence that the supplementation program has significantly increased the spawner abundance and NORs of spring Chinook in the Chiwawa Basin. Even though we documented an increasing trend in spawner abundance and NORs during the supplementation period, a similar increase in spawner abundance and NORs was observed in the reference populations. In addition, we found no evidence that the supplementation program has increased the productivity of spring Chinook in the Chiwawa Basin. Importantly, the productivity of spring Chinook in the Chiwawa Basin did not trend downward during the supplementation period. Thus, based on trend analysis, it appears that the supplementation program has not increased or decreased the abundance and productivity of spring Chinook in the Chiwawa Basin.

We note that this exercise only tests the slopes of the trend lines. It does not test for differences in elevations of the trend lines. A supplementation program could increase spawner abundance, NORs, and productivity of the target population without changing the slopes of the trend lines. That is, supplementation could cause the elevation of the trend line to be greater during the supplementation period than during the pre-supplementation period. In the next section we evaluate elevation differences by testing mean differences before and after supplementation.

Analysis of Mean Differences, Ratios, and Rates

For assessing mean differences between supplemented and reference populations, we derived three different response variables using transformed and untransformed spawner abundance, NORs, and productivity data. The first included difference scores, which were calculated as the difference between paired treatment and reference data (T-R). The second included ratios, which were calculated as the ratio of paired treatment and reference data (T/R). Finally, we calculated the differences in annual changes in paired treatment and reference population data (ΔT-ΔR; see footnote #2).

If the hatchery program is successfully supplementing the natural spring Chinook population, the mean difference or ratio score of paired spawner abundance data and NORs during the supplementation period should be greater than the pre-supplementation period. For productivity, the mean difference or ratio score during the supplementation period should be equal to or higher than the pre-supplementation period. We tested the following statistical hypotheses.

Spawner Abundance and NORs:

> Ho: Mean Difference (or Ratio) before supplementation ≥ Mean Difference (or Ratio) during supplementation.
>
> Ha: Mean Difference (or Ratio) before supplementation < Mean Difference (or Ratio) during supplementation (i.e., $\mu_{pre} - \mu_{post} < 0$).

Productivity (Recruits/Spawner):

> Ho: Mean Difference (or Ratio) before supplementation ≤ Mean Difference (or Ratio) during supplementation.
>
> Ha: Mean Difference (or Ratio) before supplementation > Mean Difference (or Ratio) during supplementation (i.e., $\mu_{pre} - \mu_{post} > 0$).[19]

For each set of response variables, we tested before/after supplementation effects using a one-tailed Aspin-Welch unequal-variance test. We used the Aspin-Welch unequal-variance test instead of Student's t-test, because in nearly every case, the variances of response variables in the pre-treatment and supplementation periods were unequal.[20] This was true even for natural-log transformed variables. We used the modified Levene equal-variance test to assess the equality of variance. In some cases, the distributions of response variables were not normal (based on the Omnibus Normality test and examination of histograms, normal probability plots, and box plots). Therefore, we also used a randomization test, based on 10,000 Monte Carlo simulations, to assess differences in response variables before and during supplementation. The randomization procedure only allowed the testing of two-tailed hypotheses. Therefore, we generated 95% confidence intervals on the mean difference ($\mu_{pre} - \mu_{post}$) using bootstrapping methods to determine the direction of the difference. We generated 5,000 bootstrap samples to calculate confidence intervals.

All these statistical methods assume that the samples of derived difference or ratio scores from the pre-supplementation and supplementation periods were independent. However, BACI designs, like time-series trend analysis, are repeated-measures designs and therefore are susceptible to temporal correlations in the data. This means that the two samples of difference or ratio scores may not be independent. Under this scenario, ARIMA models can be used to describe the correlation structure in temporal data (Gotelli and Ellison 2004). ARIMA models can be fit individually to the reference and supplemented time series data, or to a derived data series created by taking the ratio or difference of the supplemented/reference data at each time step. ARIMA models, however, require a long time series (N > 40) and therefore we could not use them to model

19 Because of the logic of null hypothesis testing, the rejection of the null hypothesis of no difference in productivity would mean that the supplementation program has reduced the productivity of the target population (here rejection of the null indicates "harm"). Notice that the rejection of the null hypothesis of no difference in spawner abundance means that the supplementation program has improved the spawner abundance in the target population (here rejection of the null indicates "benefit").

20 In cases in which the variances were equal, both the Aspin-Welch test and Student's t-test gave the same result.

the spring Chinook data. Thus, we acknowledge that our analyses may be confounded if the samples are not independent.

Difference Scores (T-R)

Analysis of supplementation effects on spawner abundance using difference scores indicated that supplementation did not significantly increase spawning abundance in the Chiwawa Basin (Table 15; Figure 12). Only the Little Wenatchee-Chiwawa pairing using transformed abundance data indicated a significant increase in spawning abundance following supplementation. The randomization test indicated significant differences in several of the treatment-reference pairs; however, the bootstrap CIs indicated that those differences were in the wrong direction (i.e., CIs > 0). That is, compared to the reference populations, spawner abundance decreased in the Chiwawa Basin during the supplementation period (Figure 12).

Table 15. Results of the Aspin-Welch unequal-variance test, randomization test (based on 10,000 Monte Carlo samples), and 95% CI (based on 5,000 bootstrap samples) on transformed and untransformed spawner abundance data. Tests determined if the mean difference scores during the supplementation period were greater than mean difference scores during the pre-supplementation period.

Reference population	Aspin-Welch unequal-variance test			Randomization test P-value	Bootstrap 95% CI
	t-value	P-value	Effect size		
Spawner Abundance					
Naches	1.066	0.848	184	0.322	-162 – 472
Entiat	1.872	0.962	316	0.078	17 – 633
Sesech	4.502	0.999	607	0.000	349 – 851
Little Wenatchee	1.773	0.954	321	0.093	0 – 690
LN Spawner Abundance					
Naches	2.603	0.990	0.701	0.026	0.210 – 1.214
Entiat	1.701	0.946	0.388	0.108	-0.033 – 0.811
Sesech	5.394	0.999	1.327	0.000	0.891 – 1.805
Little Wenatchee	-2.259	0.018	0.609	0.034	-1.125 – -0.097

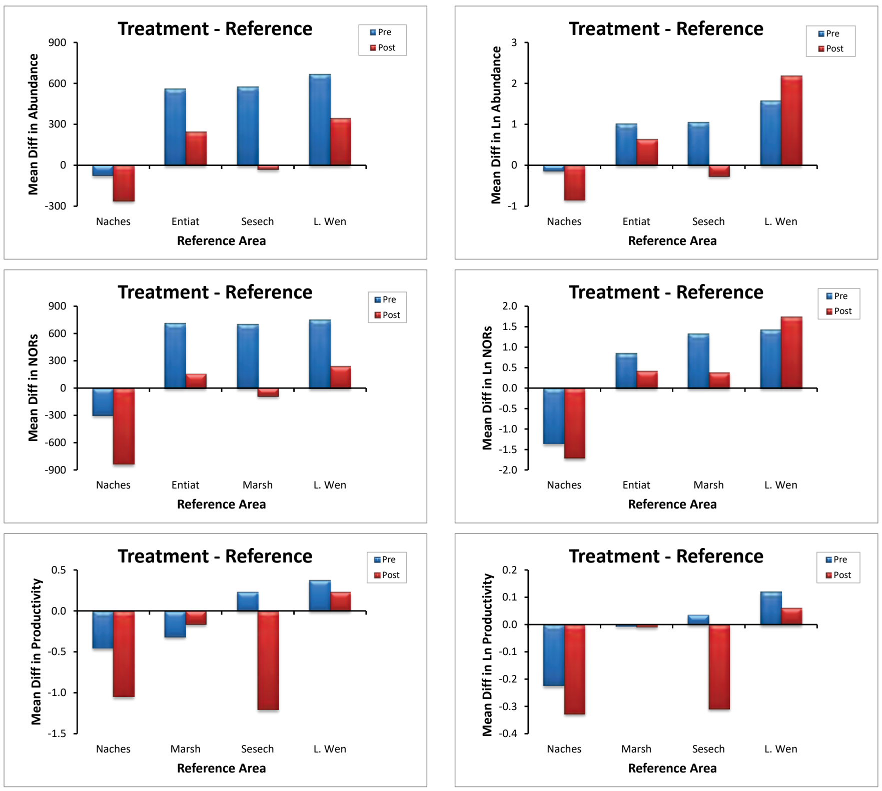

Figure 12. Mean difference (Treatment – Reference) scores of untransformed (figures on the left) and transformed (figures on the right) spawner abundance, natural-origin recruits (NORs), and productivity data before (pre) and after (post) spring Chinook supplementation in the Chiwawa Basin. Positive effects of supplementation on spawner abundance and NORs are indicated when the post-supplementation (red) bars are greater than their corresponding pre-supplementation (blue) bars. Negative effects of supplementation on productivity are indicated when the pre-supplementation (blue) bars are greater than their corresponding post-supplementation (red) bars.

Analysis of supplementation effects on NORs using difference scores indicated that supplementation did not significantly increase NORs in the Chiwawa Basin (Table 16; Figure 12). The randomization test indicated significant differences in several of the treatment-reference pairs; however, the bootstrap CIs indicated that those differences were in the wrong direction. That is, compared to the reference populations, NORs decreased in the Chiwawa Basin during the supplementation period (Figure 12).

Table 16. Results of the Aspin-Welch unequal-variance test, randomization test (based on 10,000 Monte Carlo samples), and 95% CI (based on 5,000 bootstrap samples) on transformed and untransformed natural-origin recruits. Tests determined if the mean difference scores during the supplementation period were greater than mean difference scores during the pre-supplementation period.

Reference population	Aspin-Welch unequal-variance test			Randomization test P-value	Bootstrap 95% CI
	t-value	P-value	Effect size		
Natural-Origin Recruits					
Naches	1.787	0.953	537	0.081	-60 – 1039
Entiat	2.879	0.993	558	0.007	201 – 916
Marsh	3.817	0.999	795	0.001	381 – 1153
Little Wenatchee	2.668	0.991	510	0.013	145 – 863
LN Natural-Origin Recruits					
Naches	0.430	0.659	0.354	0.686	-0.948 – 1.975
Entiat	0.788	0.779	0.445	0.465	-0.504 – 1.583
Marsh	1.45	0.916	0.953	0.168	-0.169 – 2.243
Little Wenatchee	-0.813	0.214	-0.319	0.506	-0.948 – 0.484

Analysis of supplementation effects on productivity (adult recruits/spawner) using difference scores indicated that supplementation did not significantly decrease productivity in the Chiwawa Basin (Table 17; Figure 12). All tests, regardless of treatment-reference pairs, indicated that productivity did not change significantly during the supplementation period. These tests indicate that supplementation has not negatively affected the productivity of spring Chinook salmon in the Chiwawa Basin.

Table 17. Results of the Aspin-Welch unequal-variance test, randomization test (based on 10,000 Monte Carlo samples), and 95% CI (based on 5,000 bootstrap samples) on transformed and untransformed productivity data. Tests determined if the mean difference scores during the supplementation period were less than mean difference scores during the pre-supplementation period.

Reference population	Aspin-Welch unequal-variance test			Randomization test P-value	Bootstrap 95% CI
	t-value	P-value	Effect size		
Productivity					
Naches	1.134	0.139	0.594	0.296	-0.427 – 1.540
Marsh	-0.203	0.579	0.152	0.932	-0.304 – 1.381
Sesech	1.607	0.071	1.435	0.151	-0.403 – 2.917
Little Wenatchee	0.431	0.335	0.147	0.665	-0.498 – 0.762
LN Productivity					
Naches	0.770	0.227	0.104	0.480	-0.125 – 0.378
Marsh	0.012	0.495	0.003	0.992	-0.375 – 0.493
Sesech	1.463	0.087	0.343	0.161	-0.135 – 0.732
Little Wenatchee	0.390	0.351	0.060	0.701	-0.229 – 0.347

Ratio Scores (T/R)

As with difference scores, analysis of supplementation effects on spawner abundance using ratios indicated that supplementation did not significantly increase spawning abundance in the Chiwawa Basin (Table 18; Figure 13). Only the Little Wenatchee-Chiwawa pairing indicated a significant increase in spawning abundance following supplementation. Analysis with both transformed and untransformed Little Wenatchee-Chiwawa data indicated a significant effect. In contrast, only difference scores derived from transformed data indicated a significant effect. The randomization test indicated significant differences in several of the treatment-reference pairs; however, the bootstrap CIs indicated that those differences were in the wrong direction. That is, compared to the reference populations, spawner abundance decreased in the Chiwawa Basin during the supplementation period (Figure 13).

Table 18. Results of the Aspin-Welch unequal-variance test, randomization test (based on 10,000 Monte Carlo samples), and 95% CI (based on 5,000 bootstrap samples) on transformed and untransformed spawner abundance data. Tests determined if the mean ratios during the supplementation period were greater than mean ratios during the pre-supplementation period.

Reference population	Aspin-Welch unequal-variance test			Randomization test P-value	Bootstrap 95% CI
	t-value	P-value	Effect size		
Spawner Abundance					
Naches	2.110	0.970	0.398	0.065	0.056 – 0.737
Entiat	1.254	0.888	0.731	0.223	-0.365 – 1.834
Sesech	4.251	0.999	2.428	0.000	1.278 – 3.435
Little Wenatchee	-2.649	0.009	3.897	0.018	-6.579 – -1.202
LN Spawner Abundance					
Naches	2.783	0.993	0.120	0.021	0.045 – 0.199
Entiat	1.273	0.890	0.055	0.220	-0.026 – 0.135
Sesech	5.143	0.999	0.244	0.000	0.160 – 0.335
Little Wenatchee	-3.462	0.002	0.327	0.003	-0.516 – -0.154

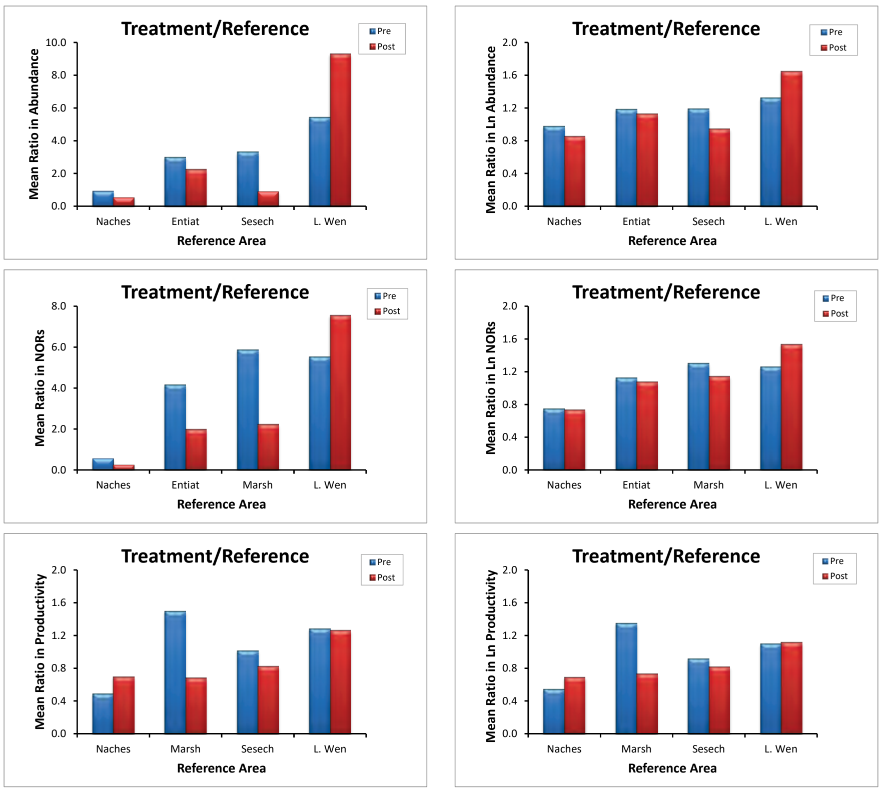

Figure 13. Mean ratios (Treatment/Reference) scores of untransformed (figures on the left) and transformed (figures on the right) spawner abundance, natural-origin recruits (NORs), and productivity data before (pre) and after (post) spring Chinook supplementation in the Chiwawa Basin. Positive effects of supplementation on spawner abundance and NORs are indicated when the post-supplementation (red) bars are greater than their corresponding pre-supplementation (blue) bars. Negative effects of supplementation on productivity are indicated when the pre-supplementation (blue) bars are greater than their corresponding post-supplementation (red) bars.

Analysis of supplementation effects on NORs using ratios indicated that supplementation did not significantly increase NORs in the Chiwawa Basin (Table 19; Figure 13). Only the Little Wenatchee-Chiwawa pairing indicated a significant increase in transformed NORs following supplementation. The randomization test indicated significant differences in several of the treatment-reference pairs; however, the bootstrap CIs indicated that those differences were in the wrong direction. That is, compared to the reference populations, NORs decreased in the Chiwawa Basin during the supplementation period (Figure 13).

Table 19. Results of the Aspin-Welch unequal-variance test, randomization test (based on 10,000 Monte Carlo samples), and 95% CI (based on 5,000 bootstrap samples) on transformed and untransformed natural-origin recruits. Tests determined if the mean ratios during the supplementation period were greater than mean ratios during the pre-supplementation period.

Reference population	Aspin-Welch unequal-variance test			Randomization test P-value	Bootstrap 95% CI
	t-value	P-value	Effect size		
Natural-Origin Recruits					
Naches	1.318	0.881	0.306	0.219	-0.157 – 0.670
Entiat	2.447	0.987	2.172	0.028	0.593 – 3.871
Marsh	2.001	0.965	3.638	0.075	0.532 – 7.201
Little Wenatchee	-1.148	0.136	2.020	0.284	-5.055 – 1.516
LN Natural-Origin Recruits					
Naches	0.057	0.522	0.009	0.967	-0.230 – 0.351
Entiat	0.359	0.638	0.049	0.759	-0.173 – 0.336
Marsh	0.603	0.721	0.161	0.579	-0.272 – 0.681
Little Wenatchee	-1.914	0.038	0.277	0.027	-0.504 – 0.031

Analysis of supplementation effects on productivity (adult recruits/spawner) using ratios indicated that supplementation did not significantly decrease productivity in the Chiwawa Basin (Table 20; Figure 13). Although the Aspin-Welch test indicated a significant effect when comparing the Chiwawa to the Marsh Creek population, both the randomization test and the bootstrap CI did not indicate a significant effect. These tests indicate that supplementation has probably not negatively affected the productivity of spring Chinook salmon in the Chiwawa Basin.

Table 20. Results of the Aspin-Welch unequal-variance test, randomization test (based on 10,000 Monte Carlo samples), and 95% CI (based on 5,000 bootstrap samples) on transformed and untransformed productivity data. Tests determined if the mean ratios during the supplementation period were less than mean ratios during the pre-supplementation period.

Reference population	Aspin-Welch unequal-variance test			Randomization test P-value	Bootstrap 95% CI
	t-value	P-value	Effect size		
Productivity					
Naches	-0.677	0.745	0.209	0.688	-0.700 – 0.425
Marsh	2.236	0.022	0.814	0.054	0.112 – 1.459
Sesech	0.677	0.253	0.191	0.515	-0.356 – 0.718
Little Wenatchee	0.033	0.487	0.018	0.979	-0.879 – 1.162
LN Productivity					
Naches	-0.639	0.734	0.148	0.616	-0.548 – 0.316
Marsh	1.952	0.036	0.613	0.081	-0.003 – 1.170
Sesech	0.447	0.330	0.098	0.663	-0.301 – 0.515
Little Wenatchee	-0.034	0.513	0.015	0.982	-0.692 – 0.861

Difference of Annual Difference Scores (ΔT-ΔR)

Analysis of supplementation effects on spawner abundance using difference scores of annual changes indicated that supplementation did not significantly increase spawning abundance in the Chiwawa Basin (Table 21; Figure 14). None of the statistical analyses detected a significant increase in annual change in the Chiwawa Basin relative to the reference populations.

Table 21. Results of the Aspin-Welch unequal-variance test, randomization test (based on 10,000 Monte Carlo samples), and 95% CI (based on 5,000 bootstrap samples) on transformed and untransformed spawner abundance data. Tests determined if mean difference scores of annual change during the supplementation period were greater than mean difference scores of annual change during the pre-supplementation period.

Reference population	Aspin-Welch unequal-variance test			Randomization test P-value	Bootstrap 95% CI
	t-value	P-value	Effect size		
Spawner Abundance					
Naches	0.009	0.503	2	0.995	-502 – 539
Entiat	-0.239	0.407	48	0.826	-414 – 327
Sesech	-0.126	0.451	20	0.902	-311 – 266
Little Wenatchee	-0.318	0.377	65	0.761	-452 – 311
LN Spawner Abundance					
Naches	-0.425	0.339	0.142	0.698	-0.744 – 0.466
Entiat	-0.084	0.467	0.028	0.933	-0.681 – 0.593
Sesech	-0.349	0.366	0.117	0.740	-0.741 – 0.515
Little Wenatchee	0.001	0.500	0.000	0.999	-0.663 – 0.687

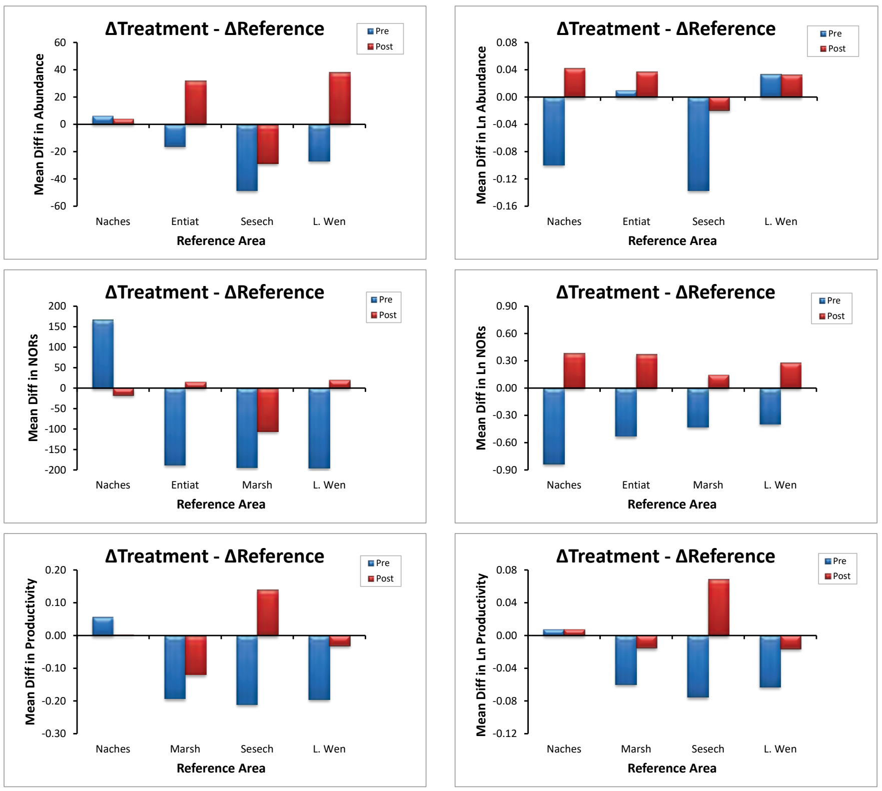

Figure 14. Mean difference scores of annual changes (ΔTreatment – ΔReference) of untransformed (figures on the left) and transformed (figures on the right) spawner abundance and productivity data before (pre) and after (post) spring Chinook supplementation in the Chiwawa Basin.

Analysis of supplementation effects on NORs using difference scores of annual changes indicated that supplementation did not significantly increase NORs in the Chiwawa Basin (Table 22; Figure 14). None of the statistical analyses detected a significant increase in annual change in the Chiwawa Basin relative to the reference populations.

Table 22. Results of the Aspin-Welch unequal-variance test, randomization test (based on 10,000 Monte Carlo samples), and 95% CI (based on 5,000 bootstrap samples) on transformed and untransformed natural-origin recruits. Tests determined if mean difference scores of annual change during the supplementation period were greater than mean difference scores of annual change during the pre-supplementation period.

Reference population	Aspin-Welch unequal-variance test			Randomization test P-value	Bootstrap 95% CI
	t-value	P-value	Effect size		
Natural-Origin Recruits					
Naches	0.399	0.652	184	0.741	-699 – 989
Entiat	-1.381	0.092	202	0.194	-471 – 86
Marsh	-0.505	0.311	88	0.624	-425 – 206
Little Wenatchee	-1.437	0.084	214	0.179	-481 – 64
LN Natural-Origin Recruits					
Naches	-1.301	0.118	1.214	0.224	-2.783 – 0.531
Entiat	-1.408	0.088	0.901	0.188	-1.977 – 0.387
Marsh	-0.712	0.244	0.570	0.517	-1.952 – 0.975
Little Wenatchee	-1.154	0.132	0.674	0.274	-1.706 – 0.497

Analysis of supplementation effects on productivity (adult recruits/spawner) using difference scores of annual changes indicated that supplementation did not significantly decrease productivity in the Chiwawa Basin (Table 23; Figure 14). All tests, regardless of treatment-reference pairs, indicated that productivity did not change significantly during the supplementation period.

Table 23. Results of the Aspin-Welch unequal-variance test, randomization test (based on 10,000 Monte Carlo samples), and 95% CI (based on 5,000 bootstrap samples) on transformed and untransformed productivity data. Tests determined if the mean difference scores of annual change during the supplementation period were less than mean difference scores of annual change during the pre-supplementation period.

Reference population	Aspin-Welch unequal-variance test			Randomization test P-value	Bootstrap 95% CI
	t-value	P-value	Effect size		
Productivity					
Naches	0.002	0.475	0.054	0.952	-1.464 – 1.583
Marsh	-0.063	0.525	0.074	0.948	-2.395 – 2.031
Sesech	-0.317	0.621	0.350	0.628	-2.387 – 1.695
Little Wenatchee	-0.347	0.633	0.163	0.728	-1.023 – 0.725
LN Productivity					
Naches	0.000	0.500	0.000	0.999	-0.408 – 0.445
Marsh	-0.126	0.549	0.044	0.904	-0.715 – 0.595
Sesech	-0.449	0.668	0.144	0.727	-0.685 – 0.509
Little Wenatchee	-0.200	0.578	0.047	0.842	-0.466 – 0.391

We believe results from analysis of mean differences of annual change (ΔT-ΔR) in spawning abundance, NORs, and productivity are difficult to interpret and may be insensitive to treatment effects. A simpler analysis, which is also easier to interpret, is the use of trend analysis. Therefore, we recommend that analyses using differences of annual change be replaced with trend analysis.

Corrections for Density Dependence and Carrying Capacity

The analyses described above assume that the density of spawners or recruits does not affect the survival and productivity of fish. However, it is well known that the density of fish can affect the number of recruits as well as the productivity of the population. This occurs through the relationship between density and mortality. Mortality of fish can be generally classified as density independent and density dependent. In general, when densities are low, the mortality is density independent, but as densities increase, the amount of density-dependent mortality increases. Monitoring programs can make use of this information to derive density-corrected estimates of productivity. In this section, we describe two different methods for deriving density-corrected estimates of productivity.

The first method controlled the effects of density on productivity (adult recruits/spawner; R/S) by partitioning observed productivities into density-independent and density-dependent productivity. When abundance is below the minimum number of spawners (S) needed to produce the maximum number of recruits (K_{sp}), the observed productivity is used in statistical tests. However, when the abundance is equal to or above K_{sp}, the modeled value of productivity (R/K_{sp}) is used in statistical tests.

$$\boldsymbol{Adj\ R/S} = \begin{cases} \boldsymbol{R/S,} & \boldsymbol{if\ S < K_{sp}} \\ \boldsymbol{R/K_{sp},} & \boldsymbol{if\ S \geq K_{sp}} \end{cases}$$

The density-independent and density-dependent productivities were then combined in a single test.

The second method was based on one of the goals of supplementation, which is to fill the capacity of the environment with fish. This method corrects for differences in carrying capacities between the supplemented and reference populations. We did this by calculating the percent saturation of NORs. That is, we calculated the fraction of the habitat (τ) that was filled with NORs by dividing the observed NOR by the modeled maximum number of NORs (K_R) that the habitat could support.

$$\boldsymbol{\tau = \frac{NOR_{obs}}{K_R}}$$

Note that 1-τ represents the unused portion of the carrying capacity and is the term that is multiplied by the exponential growth equation to derive the logistic growth equation. We included τ in the statistical analyses.

These two methods require the estimation of carrying capacity (K_R) and the spawning abundance that produces the maximum number of recruits (K_{sp}). We estimated these parameters for both reference populations and the supplemented population using Ricker, Beverton-Holt, and smooth hockey stick stock-recruitment models. We used only spawner abundance as a predictor of subsequent brood recruitment. We made the following assumptions in proceeding with the analysis:

- *Density-dependent mortality*—For some time period before recruitment, the brood instantaneous mortality rate is proportional to the number of parent spawners (Ricker 1954).
- *Lognormal variation*—At any particular spawning stock size, the variation in recruitment is log-normally distributed about its average, and acts multiplicatively (Quinn and Deriso 1999).
- *Measurement error*—Error in spawning stock size estimates (measurement error) is small relative to the range of spawning stock sizes observed (Hilborn and Walters 1992). Variation in realized recruitment at any particular spawning stock size (process error) dominates recruitment measurement error.
- *Stationarity*—The average stock-recruitment relationship is constant over time (Hilborn and Walters 1992). That is, environmental conditions randomly affect survival independent of stock size or time.

In general, the methods we used to fit the models to the data followed those outlined in Hilborn and Walters (1992) and Froese (2008). The Ricker model, which assumes that the number of recruits increases to a maximum and then declines as the number of spawners increases, takes the form:

$$E(R) = \alpha S e^{-\beta S}$$

where E(R) is the expected recruitment, S is spawner abundance, α is the number of recruits per spawner at low spawning levels, and β describes how quickly the recruits per spawner drop as the number of spawners increases. We estimated K_R as:

$$K_R = \left(\frac{\alpha}{\beta}\right) e^{-1}$$

and K_{sp} as:

$$K_{sp} = \frac{1}{\beta}$$

The Beverton-Holt model assumes that the number of recruits increases constantly toward an asymptote as the number of spawners increases. After the asymptote is reached, the number of recruits neither increases nor decreases. The asymptote represents the maximum number of recruits the system can support (i.e., carrying capacity for the system; K_R). The Beverton-Holt curve takes the form:

$$E(R) = \frac{(\alpha S)}{(\beta + S)}$$

where E(R) and S are as above, α is the maximum number of recruits produced (K_R), and β is the number of spawners needed to produce (on average) recruits equal to one-half the maximum number of recruits. Because $K_{sp} = \infty$ in the Beverton-Holt model, we estimated K_{sp} as the number of spawners needed to produce 0.99(K_R).

Like the Beverton-Holt model, the smooth hockey stick model assumes that the number of recruits increases toward an asymptote (carrying capacity; K_R) as the number of spawners increases. After the carrying capacity is reached, the number of recruits neither increases nor decreases. The carrying capacity represents the maximum number of recruits the system can support. This curve

takes the form (Froese 2008):

$$E(R) = R_\infty\left(1 - e^{-\left(\frac{\alpha}{R\infty}\right)S}\right)$$

where E(R) and S are as above, α is the slope at the origin of the spawner-recruitment curve, and R_∞ is the carrying capacity of recruits (note that $R_\infty = K_R$). As with the Beverton-Holt model, we estimated K_{sp} as the number of spawners needed to produce 0.99(K_R).

We used non-linear regression to fit the three models to spawner-recruitment data. Before fitting the models, we transformed recruitment data using natural logs. We estimated bias and uncertainty measures (95% CI) for the model parameters using bootstrap procedures, which assumed that the {R, S} sample represented or approximated the population. The number of bootstrap samples was 3,000. We computed and stored the non-linear regression results for each bootstrap sample. We then calculated the bootstrap 95% CI by arranging the 3,000 bootstrap parameter values in sorted order and selected the 2.5 and 97.5 percentiles from the list.

We used Akaike's Information Criterion for small sample size (AIC_c) to determine which model(s) best explained the relationship between spawners and recruitment in the supplemented and reference populations. AIC_c was estimated as:

$$AIC_c = -2log\left(£(\theta|data)\right) + 2K + \left(\frac{2K(K+1)}{n-K-1}\right)$$

where $log(£(\theta|data))$ is the maximum likelihood estimate, K is the number of estimable parameters (structural parameters plus the residual variance parameter), and n is the sample size (Burnham and Anderson 2002). We used least-squares methods to estimate $log(£(\theta|data))$, which was calculated as $log(\sigma^2)$, where σ^2 = residual sum of squares divided by the sample size ($\sigma^2 = RSS/n$). AIC_c assessed model fit in relation to model complexity (number of parameters). The model with the smallest AIC_c value represented the "best approximating" model within the model set. Remaining models were ranked relative to the best model using AIC_c difference scores (ΔAIC_c), Akaike weights (w_i), and evidence ratios. Models with ΔAIC_c values less than 2 indicated that there is substantial support for these models as being the best-fitting models within the set (Burnham and Anderson 2002). Models with values greater than 2 had less support. Akaike weights are probabilities estimating the strength of the evidence supporting a particular model as being the best model within the model set. Models with small w_i values are less plausible as competing models (Burnham and Anderson 2002). If no single model could be specified as the best model, a "best subset" of competing models was identified using (1) AIC_c differences to indicate the level of empirical support each model had as being the best model, (2) evidence ratios based on Akaike weights to indicate the relative probability that any model is the best model, and (3) coefficients of determination (R^2) assessing the explanatory power of each model.

Stock-Recruitment Analysis

We successfully fit stock-recruitment models to the Chiwawa and reference population data. The span of spawner data for the Chiwawa and reference populations was greater than 14 times the minimum observed spawners, which should provide sufficient contrast for estimation of model parameters. In addition, the span of recruitment data was greater than 12 times the minimum observed recruitment, again providing sufficient contrast for estimation of parameters. The relationship between natural log R/S and spawners indicated that some of the highest productivities occurred at the lower spawner levels and the lowest productivities generally occurred at the highest spawner levels (Figure 15). This is consistent with the assumption of density-dependent mortality.

Although model fits were generally poor, explaining less than 40% of the residual variation in natural-log recruitment data, we were able to estimate average maximum recruitment levels (K_R) and the spawning levels needed to produce maximum recruitment (K_{sp}) (Table 24; Figure 15). For all populations examined, Akaike information criterion was unable to identify a best approximating model (i.e., ΔAIC_c values were less than 2, indicating support for all three models). However, evaluation of 95% CIs and the asymptotic correlation coefficients indicated that the smooth hockey stick model may be the best approximating model for each population. Therefore, we used estimates of K_R and K_{sp} derived from the smooth hockey stick model to correct for density dependence and different carrying capacities in treatment-reference comparisons.

As part of the regression diagnostics, we examined the dependence of the model residuals on time and found a significant ($P < 0.05$), positive, one-year-lag autocorrelation for the Entiat (0.562), Marsh (0.551), Sesech (0.564), and Little Wenatchee (0.629) populations. For the purposes of our work here, we did not attempt to correct for this one-year-lag correlation in the residuals. Future analyses will explore the use of autoregressive models (e.g., AR1; Noakes et al. 1987) to correct for autocorrelation.

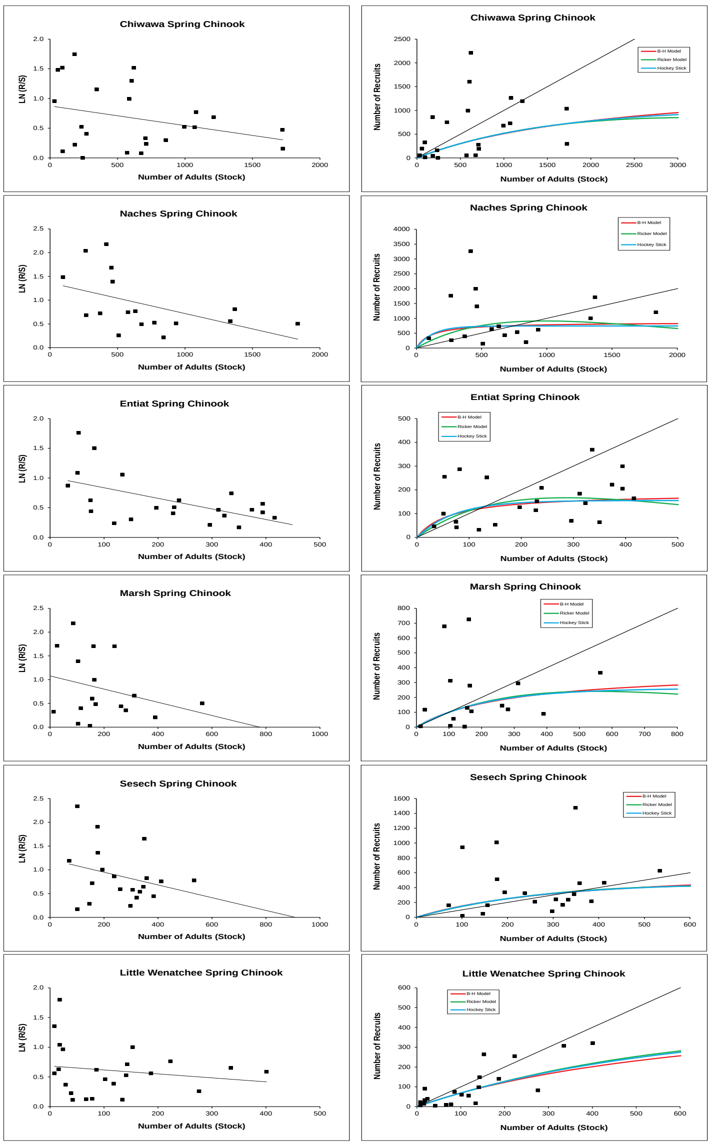

Figure 15. Relationships between natural log recruits/spawner (LN R/S) and spawners (Stock) in the Chiwawa and reference populations (figures on the left) and relationships between numbers of untransformed recruits and spawners in the Chiwawa and reference populations (figures on the right). Figures on the right also show the fit of the Ricker, Beverton-Holt, and the smooth hockey stick models to the data (black straight line represents R=S).

Table 24. Results from fitting Ricker, Beverton-Holt, and smooth hockey stick models to stock-recruitment data from the Chiwawa and reference populations. 95% CI on parameter estimates are based on 3,000 bootstrap trials; Corr coef = asymptotic correlation of the parameter estimates; K_R = maximum natural origin recruits (recruits at carrying capacity); K_{sp} = number of spawners needed to produce K_R; AICc = Akaike's Information Criterion for small sample size; Adj R^2 = coefficient of determination that is adjusted for the number of parameters in the model.

Model	Parameter	Parameter value	Bootstrap 95% CI	Corr coef	K_R	K_{sp}	AICc	Adj R^2
			Chiwawa Population					
Ricker	α	0.7048	-0.6197 1.1055	0.791	852	3,285	-47.949	0.125
	β	0.000304	-0.000668 0.000609					
Beverton-Holt	α	1687.4	-65654539 3062.1	0.989	1,687	43,760	-47.962	0.125
	β	2308.5	-99999538 4526.1					
Smooth hockey stick	α	6.956	-41.313 8.2270	-0.708	1,049	6,847	-47.949	0.125
	β	0.7118	-2.397 1.122					
			Naches Population					
Ricker	α	2.5223	-2.0003 3.9672	0.844	912	983	-45.063	-0.143
	β	0.001018	-0.000752 0.001717					
Beverton-Holt	α	869.4	97.4 1641.4	0.858	869	11,455	-46.801	-0.097
	β	111.8	-346.2 569.8					
Smooth hockey stick	α	6.612	5.9223 7.006	-0.399	744	565	-46.831	-0.095
	β	6.013	-89.071 12.026					
			Entiat Population					
Ricker	α	1.5843	0.1609 2.4178	0.867	167	286	-68.365	-0.049
	β	0.003496	0.001141 0.005906					
Beverton-Holt	α	186.1	67.9 304.3	0.880	186	1,277	-69.895	0.029
	β	65.0	-59.1 189.2					
Smooth hockey stick	α	5.045	4.381 5.378	-0.450	155	344	-69.379	0.003
	β	2.180	-89.369 3.704					
			Marsh Creek Population					
Ricker	α	1.1852	-1.8268 1.9269	0.823	241	552	-32.237	0.218

Model	Parameter	Parameter value	Bootstrap 95% CI	Corr coef	K_R	K_{sp}	AICc	Adj R^2
	β	0.001810	-0.003063 0.003625					
Beverton-Holt	α	383.3	-85109314 665.4	0.970	383	5,310	-32.291	0.234
	β	282.4	-99999944 564.9					
Smooth hockey stick	α	5.565	-22.631 6.584	-0.694	261	984	-32.264	0.227
	β	1.265	-108.574 2.531					
Sesech Population								
Ricker	α	1.6835	-2.9253 2.5951	0.912	421	680	-54.589	-0.005
	β	0.001470	-0.002951 0.002941					
Beverton-Holt	α	689.9	-986.8 2366.7	0.981	690	6,591	-54.678	0.000
	β	351.7	-1059.0 1762.5					
Smooth hockey stick	α	6.1528	-22.851 6.815	-0.821	470	1,185	-54.633	-0.002
	β	0.8000	-119.370 2.909					
Little Wenatchee Population								
Ricker	α	0.7447	0.0828 1.0280	0.735	356	1,298	-66.978	0.357
	β	0.000770	-0.003052 0.001541					
Beverton-Holt	α	564.7	-74423355 1067.6	0.994	565	13,400	-67.055	0.358
	β	719.7	-99999856 1413.4					
Smooth hockey stick	α	6.0181	-49.5620 8.1122	-0.683	411	2,544	-67.000	0.357
	β	0.7550	-0.9539 1.0452					

Method 1: Productivity Data Adjusted for Density Dependence

Analysis of supplementation effects on productivity (adult recruits/spawner adjusted for density-dependent effects based on the smooth hockey stick model) using difference scores indicated that supplementation did not significantly decrease productivity in the Chiwawa Basin (Table 25; Figure 16). All tests, regardless of treatment-reference pairs, indicated that productivity did not change significantly during the supplementation period, even though productivity did decrease during the supplementation period (Figure 16). These results are consistent with those based on unadjusted productivity data (Table 17). This is because most abundance estimates were below the level of assumed density dependence.

Table 25. Results of the Aspin-Welch unequal-variance test, randomization test (based on 10,000 Monte Carlo samples), and 95% CI (based on 5,000 bootstrap samples) on transformed and untransformed productivity data corrected for density dependence. Tests determined if the mean difference scores during the supplementation period were greater than mean difference scores during the pre-supplementation period.

Reference population	Aspin-Welch unequal-variance test			Randomization test P-value	Bootstrap 95% CI
	t-value	P-value	Effect size		
Productivity					
Naches	0.904	0.190	0.496	0.412	-0.511 – 1.497
Marsh	-0.203	0.579	0.152	0.927	-1.298 – 1.372
Sesech	1.607	0.071	1.435	0.146	-0.359 – 2.911
Little Wenatchee	0.431	0.335	0.147	0.668	-0.487 – 0.781
LN Productivity					
Naches	0.570	0.290	0.083	0.568	-0.168 – 0.362
Marsh	0.012	0.495	0.003	0.991	-0.373 – 0.480
Sesech	1.463	0.087	0.343	0.171	-0.125 – 0.732
Little Wenatchee	0.390	0.351	0.060	0.709	-0.218 – 0.365

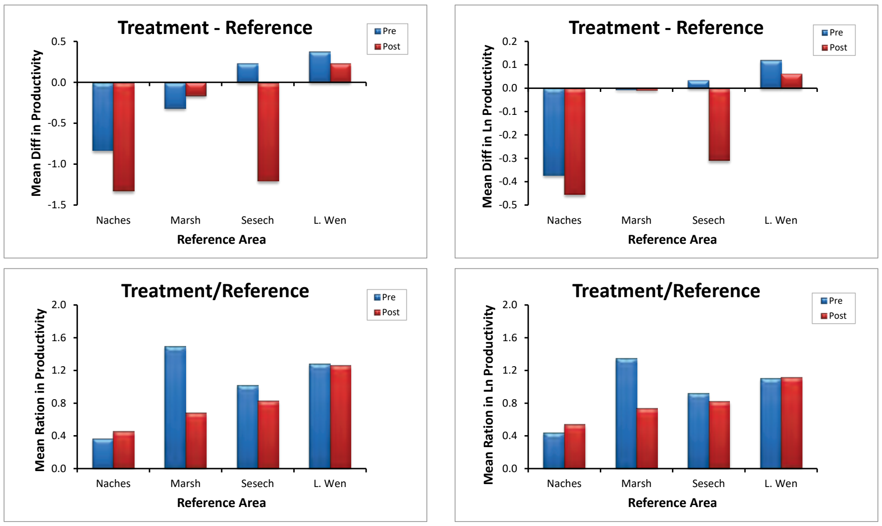

Figure 16. Mean differences (Treatment – Reference; figures on the top) and mean ratios (Treatment/Reference; figures on the bottom) of transformed and untransformed productivity data (adjusted for density dependence) before (pre) and after (post) spring Chinook supplementation in the Chiwawa Basin. Negative effects of supplementation on productivity are indicated when the pre-supplementation (blue) bars are greater than their corresponding post-supplementation (red) bars.

Analysis of supplementation effects on productivity (adult recruits/spawner adjusted for density-dependent effects) using ratios indicated that supplementation did not significantly decrease productivity in the Chiwawa Basin (Table 26; Figure 16). The Aspin-Welch test and the 95% CIs did indicate a significant effect when comparing the Chiwawa to the Marsh Creek population. These results are consistent with those using unadjusted productivity data (Table 20). Again, this is because most abundance estimates were below the level of assumed density dependence.

Table 26. Results of the Aspin-Welch unequal-variance test, randomization test (based on 10,000 Monte Carlo samples), and 95% CI (based on 5,000 bootstrap samples) on transformed and untransformed productivity data corrected for density dependence. Tests determined if the mean ratios during the supplementation period were less than mean ratios during the pre-supplementation period.

Reference population	Aspin-Welch unequal-variance test			Randomization test	Bootstrap 95% CI
	t-value	P-value	Effect size	P-value	
Productivity					
Naches	-0.529	0.696	0.087	0.597	-0.394 – 0.214
Marsh	2.236	0.022	0.814	0.056	0.140 – 1.470
Sesech	0.677	0.253	0.191	0.496	-0.343 – 0.727
Little Wenatchee	0.033	0.487	0.018	0.978	-0.902 – 1.181
LN Productivity					
Naches	-0.621	0.726	0.104	0.536	-0.406 – 0.191

Reference population	Aspin-Welch unequal-variance test			Randomization test P-value	Bootstrap 95% CI
	t-value	P-value	Effect size		
Marsh	1.952	0.036	0.613	0.076	0.005 – 1.163
Sesech	0.447	0.330	0.098	0.649	-0.312 – 0.498
Little Wenatchee	-0.034	0.513	0.015	0.980	-0.697 – 0.852

Our analyses assume that there is a spawner abundance (K_{sp}) at which density-independent effects end and density-dependent effects begin. In reality, density-dependent effects occur at low spawning abundance and intensify as spawning abundance increases (evident in the changing slope of the three stock-recruitment curves used in our analyses). We did not account for these increasing density-dependent effects at spawner abundances less than K_{sp}. If we accounted for the increasing effects of density dependence at spawning abundances less than K_{sp}, the analysis with and without productivity adjustments may give different results.

Method 2: Fraction of Carrying Capacity Filled with NORs

We analyzed the effects of supplementation on filling the capacity of the habitat with natural-origin recruits. The smooth hockey stick model derived the carrying capacity (K_R) estimates for the Chiwawa and reference populations. The fraction of the carrying capacity filled with Chinook recruits before and during supplementation for the Chiwawa and reference populations is provided in Table 27. These data indicate that for the Chiwawa population, the mean fraction of the K_R filled with fish decreased significantly from the pre-supplementation period through the supplementation period (Table 27). Likewise, the Entiat and Little Wenatchee populations showed a significant decline in the mean fraction of K_R filled with adult recruits. In contrast, the mean fraction of K_R in the Naches and Marsh Creek populations increased during the same period (Table 27).[21] Interestingly, the fraction of K_R filled with adult recruits for all populations trended downward during the pre-supplementation period (Figure 17). During the supplementation period, however, the fraction of K_R filled with adult recruits trended upward for all populations. These results suggest that agents of mortality outside the Chiwawa and reference populations were reducing recruitment to the populations.

[21] Although we do not show the results here, statistical analysis of the mean fraction of carrying capacity filled by adult recruits using natural-log transformed data produced the same result as using untransformed data. This was true for all populations.

Table 27. Fraction of the carrying capacity that was filled with Chinook salmon adult recruits in the Chiwawa and reference populations before (pre) and during (post) supplementation in Chiwawa Basin. The smooth hockey stick model estimated carrying capacity for each population. Statistical results from comparing the pre and post mean scores using the Aspin-Welch unequal-variance test are provided at the bottom of the table.

Supplementation period	Chiwawa	Reference populations			
		Naches	Entiat	Marsh	L. Wenatchee
Pre-supplementation period (1981-1992)	2.11		2.38	1.07	0.64
	1.53		1.93	1.20	0.75
	1.20		1.32	2.60	0.78
	1.14		1.19	0.49	0.62
	0.99		1.06	0.46	0.34
	0.70	2.30	1.43	0.56	0.24
	0.65	0.58	0.74	0.34	0.20
	0.95	1.88	1.34	1.40	0.36
	0.18	0.72	1.63	0.22	0.15
	0.05	0.27	0.45	0.02	0.02
	0.00	0.20	0.21	0.03	0.01
Pre-Mean:	0.86	0.99	1.24	0.76	0.37
Pre-Range:	0.00 – 2.11	0.20 – 2.30	0.21 – 2.38	0.02 – 2.60	0.01 – 0.78
Post-supplementation period (1992-2002)	0.05	0.98	0.34	0.41	0.03
	0.15	0.86	0.41	1.13	0.04
	0.04	0.35	0.27	0.02	0.03
	0.05	0.44	0.30	0.02	0.03
	0.19	4.39	0.65	0.45	0.06
	0.82	2.68	1.85	2.78	0.22
	0.31	2.37	1.65	4.10	0.08
	0.01	0.53	0.42		0.02
	0.71	1.62	0.82		0.10
	0.28	1.35	0.93		0.14
	0.27	0.83	0.98		0.18
Post-Mean:	0.26	1.49	0.78	1.27	0.08
Post-Range:	0.04 – 0.82	0.35 – 4.39	0.30 – 1.85	0.02 – 4.10	0.02 – 0.22
One-sided Aspin-Welch t-test of pre and post means	t = 2.846; P = 0.007	t = -0.967; P = 0.825	t = 1.833; P = 0.041	t = -0.799; P = 0.776	t = 3.321; P = 0.003

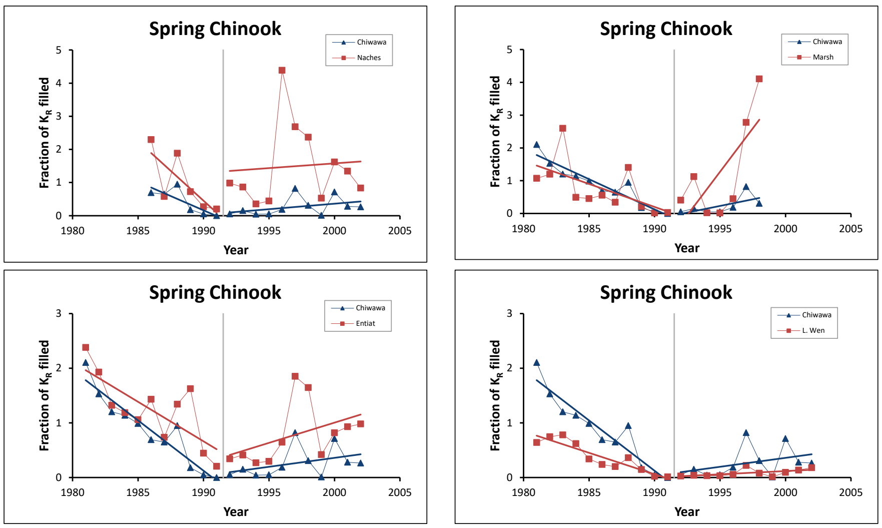

Figure 17. Trends in the fraction of the carrying capacity that was filled with Chinook salmon adult recruits in the Chiwawa and reference populations before (pre) and during (post) supplementation in Chiwawa Basin. The vertical lines in the figures separate the pre- and post-supplementation periods. The smooth hockey stick model estimated carrying capacity for each population.

We then compared the mean difference scores and ratios between the Chiwawa and reference populations before and during supplementation using data representing the fraction of K_R filled with adult recruits. In most of the Chiwawa-reference population comparisons, the absolute value of the mean difference between the fraction of K_R filled with recruits was greater in the supplementation period than during the pre-supplementation period; two of the four pairings were significant (Table 28; Figure 18). Analysis of difference scores using natural-log transformed data indicated that three of the four pairings were significant (Table 28).

Results from analyses using ratios were similar to results using difference scores. Mean ratio scores were generally smaller during the supplementation period than during the pre-supplementation period (Figure 18). This indicated that the mean fraction of K_R filled by adult recruits in most reference populations was greater during the supplementation period than during the pre-supplementation period (i.e., the denominator in the ratio increased between the pre- and post-supplementation periods). In contrast, the fraction of K_R filled by adult recruits in the Chiwawa decreased from the pre- to post-supplementation period (i.e., the numerator in the ratio decreased between the pre- and post-supplementation periods). Thus, unlike the Chiwawa population, the capacity of most reference populations was becoming more saturated during the period when the Chiwawa was being supplemented. Statistical analysis with mean ratios indicated that two of the four pairings were significant (Table 29).

Analyses comparing the Little Wenatchee with the Chiwawa indicate that adult recruits to the Little Wenatchee have been well below its carrying capacity. During the pre-supplementation period, the capacity of the Little Wenatchee was on average 37% saturated with adult recruits. During the supplementation period, the capacity of the Little Wenatchee declined to 8% saturation

with adult recruits (a 22% decline). The Chiwawa, during the pre-supplementation period, was on average 86% saturated. During the supplementation period, percent saturation in the Chiwawa decreased to 26% (a 30% decrease). During the same time periods, the capacity of the Entiat population, which until recently has been supplemented, declined from 124% to 78% saturation (a 63% decline).

Table 28. Results of the Aspin-Welch unequal-variance test, randomization test (based on 10,000 Monte Carlo samples), and 95% CI (based on 5,000 bootstrap samples) on the fraction of the habitat capacity (K_R) that is filled with natural origin recruits. Analyses include both transformed and untransformed data. Tests determined if the mean difference scores during the supplementation period were greater than mean difference scores during the pre-supplementation period.

Reference population	Aspin-Welch unequal-variance test			Randomization test P-value	Bootstrap 95% CI
	t-value	P-value	Effect size		
Fraction of Capacity Filled					
Naches	1.550	0.071	0.657	0.145	-0.173 – 1.378
Entiat	0.835	0.207	0.141	0.422	-0.167 – 0.475
Marsh	2.026	0.040	1.141	0.055	0.064 – 2.054
Little Wenatchee	2.166	0.023	0.310	0.031	0.035 – 0.569
LN Fraction of Capacity Filled					
Naches	2.123	0.026	0.311	0.039	0.031 – 0.575
Entiat	1.405	0.087	0.122	0.176	-0.034 – 0.289
Marsh	2.547	0.017	0.519	0.017	0.125 – 0.864
Little Wenatchee	1.744	0.049	0.130	0.100	-0.004 – 0.273

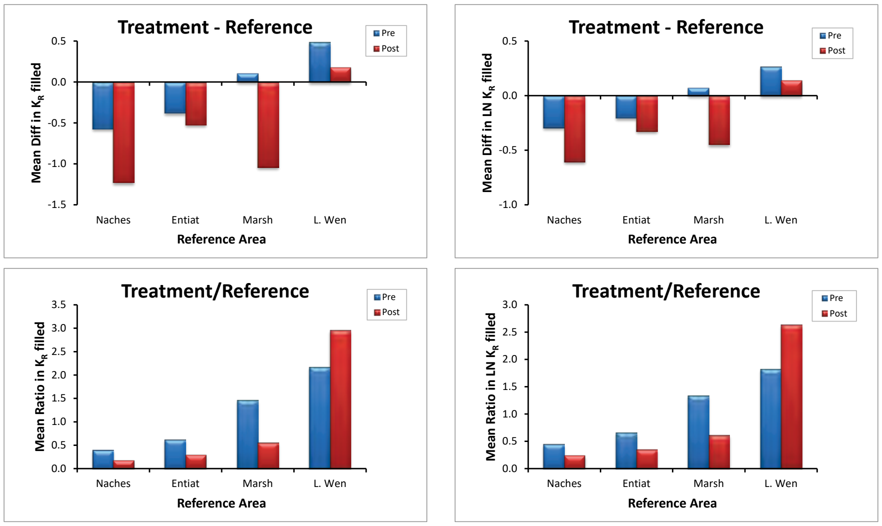

Figure 18. Mean differences (Treatment – Reference; figures on the top) and mean ratios (Treatment/Reference; figures on the bottom) of transformed and untransformed fractions of carrying capacity filled with adult recruits before (pre) and after (post) spring Chinook supplementation in the Chiwawa Basin.

Table 29. Results of the Aspin-Welch unequal-variance test, randomization test (based on 10,000 Monte Carlo samples), and 95% CI (based on 5,000 bootstrap samples) on the fraction of the habitat capacity (K_R) that is filled with natural origin recruits. Analyses include both transformed and untransformed data. Tests determined if the mean ratios during the supplementation period were less than mean ratios during the pre-supplementation period.

Reference population	Aspin-Welch unequal-variance test			Randomization test P-value	Bootstrap 95% CI
	t-value	P-value	Effect size		
Fraction of Capacity Filled					
Naches	1.317	0.119	0.217	0.219	-0.103 – 0.482
Entiat	2.449	0.013	0.321	0.028	0.085 – 0.577
Marsh	2.001	0.035	0.905	0.070	0.138 – 1.788
Little Wenatchee	-1.148	0.864	0.791	0.278	-1.979 – 0.578
LN Fraction of Capacity Filled					
Naches	1.257	0.127	0.207	0.249	-0.099 – 0.484
Entiat	2.346	0.016	0.313	0.031	0.072 – 0.583
Marsh	1.737	0.056	0.729	0.111	0.028 – 1.531
Little Wenatchee	-1.525	0.924	0.815	0.142	-1.751 – 0.195

Comparing Stock-Recruitment Curves

As a final set of treatment and reference population comparisons, we compared the stock-recruitment curves of the Chiwawa population (using {R, S} data only from the supplementation period) to the reference populations (using all available {R, S} data). Specifically, we tested whether the regression parameters were equal between the Chiwawa population and the reference populations, and whether the fitted curves coincided between populations. Earlier in this report we described the data, methods, and results of fitting the Ricker, Beverton-Holt, and smooth hockey stick curves to the data. Because AIC_c was unable to identify a best approximating model, here we included all three models in our analyses. We tested the following hypotheses.

Parameter equivalence:

Ho: Stock-recruitment parameters (α and β) of the Chiwawa population = Stock-recruitment parameters of the reference populations.

Ha: Stock-recruitment parameters (α and β) of the Chiwawa population ≠ Stock-recruitment parameters of the reference populations.

Curve equivalence:

Ho: Modeled stock-recruitment curves of the Chiwawa population = Modeled stock-recruitment curves of the reference populations.

Ha: Modeled stock-recruitment curves of the Chiwawa population ≠ Modeled stock-recruitment curves of the reference populations.

We used two-sided randomization tests to test the null hypotheses of equal model parameters and that fitted curves coincided. Because the total number of permutations was in the millions, we used a Monte Carlo approach to randomly select 10,000 permutations. The test statistic for comparing the model parameters was formed by summing the difference between the population parameter estimates for each pair of populations. The test statistic for comparing the whole curve was formed by summing the difference between the estimated predicted values for each pair of populations at 500 equally spaced points along the curve.

Ricker Relationships

Ricker curves differed significantly between the Chiwawa and reference populations (Figure 19; Table 30). Interestingly, however, the parameters in the Ricker model did not differ significantly among most populations (Table 30). Only the β parameter differed significantly between the Chiwawa and Entiat populations.

In the Ricker model, the α parameter represents intrinsic productivity (i.e., recruits per spawner at low spawner densities). In this analysis, there was not enough evidence in the stock-recruitment data to reject the hypothesis of inequality in intrinsic productivity. Thus, this test was unable to demonstrate that supplementation, based on the Ricker curve, affected productivity in the Chiwawa population.

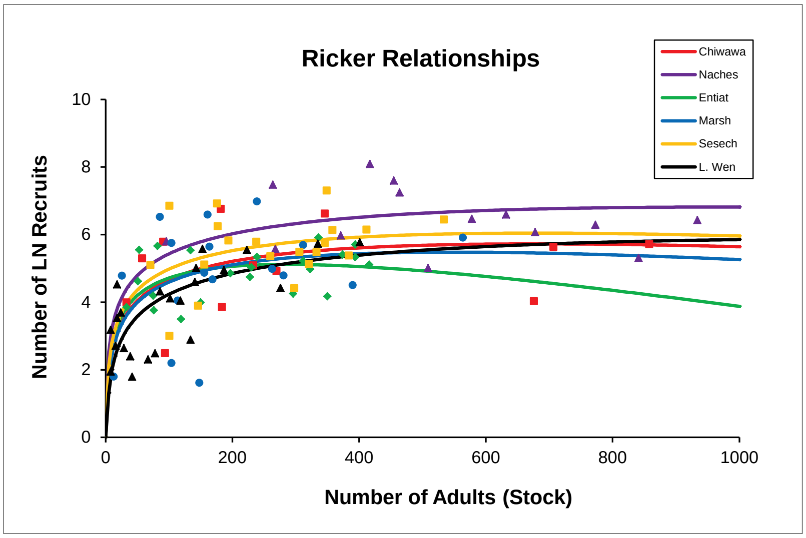

Figure 19. Scatter plot of the number of spawners and natural log adult recruits and fitted Ricker curves to the Chiwawa (supplemented population) and reference (un-supplemented) populations.

Table 30. Randomization test results comparing the equality of Ricker curves and equality of parameter values (α and β). Randomization tests were based on 10,000 Monte Carlo samples. Equality or curves was based on 500 points along the x-axis (spawner abundance axis).

Curves tested	Curve inequality randomization P-value	Parameter inequality		
		Model Parameter		Randomization P-value
		Chiwawa	Reference	
Chiwawa v. Naches	0.008	α = 1.2247	α = 2.5267	0.236
		β = 0.0015	β = 0.0010	0.600
Chiwawa v. Entiat	0.004	α = 1.2247	α = 1.5836	0.978
		β = 0.0015	β = 0.0035	0.025
Chiwawa v. Marsh	0.034	α = 1.2247	α = 1.1855	0.997
		β = 0.0015	β = 0.0018	0.688
Chiwawa v. Sesech	0.036	α = 1.2247	α = 1.6818	0.972
		β = 0.0015	β = 0.0015	0.997
Chiwawa v. L. Wenatchee	0.034	α = 1.2247	α = 0.7439	0.969
		β = 0.0015	β = 0.0008	0.203

Beverton-Holt Relationships

Beverton-Holt curves differed significantly only between the Chiwawa and Naches populations (Figure 20; Table 31). There was no significant difference in curves between the Chiwawa and the other reference populations. The parameters in the Beverton-Holt model did not differ significantly among any of the populations (Table 31). This was true even for the Chiwawa and Naches populations.

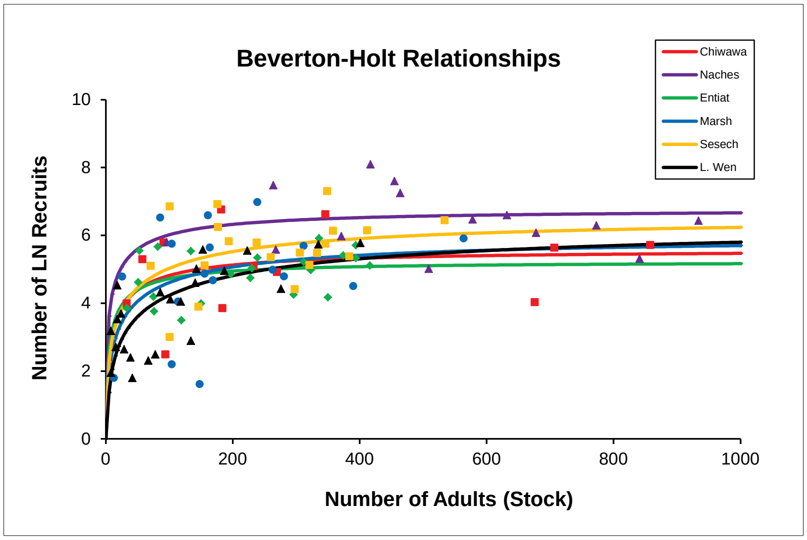

Figure 20. Scatter plot of the number of spawners and natural log adult recruits and fitted Beverton-Holt curves to the Chiwawa (supplemented population) and reference (un-supplemented) populations.

Table 31. Randomization test results comparing the equality of Beverton-Holt curves and equality of parameter values (α and β). Randomization tests were based on 10,000 Monte Carlo samples. Equality or curves was based on 500 points along the x-axis (spawner abundance axis).

Curves tested	Curve inequality randomization P-value	Parameter inequality		
		Model Parameter		Randomization P-value
		Chiwawa	Reference	
Chiwawa v. Naches	0.036	$\alpha = 264.25$	$\alpha = 870.62$	0.777
		$\beta = 113.79$	$\beta = 112.24$	0.963
Chiwawa v. Entiat	0.746	$\alpha = 264.25$	$\alpha = 186.34$	0.960
		$\beta = 113.79$	$\beta = 65.33$	0.954
Chiwawa v. Marsh	0.850	$\alpha = 264.25$	$\alpha = 381.79$	0.944
		$\beta = 113.79$	$\beta = 281.04$	0.891

Curves tested	Curve inequality randomization P-value	Parameter inequality		
		Model Parameter		Randomization P-value
		Chiwawa	Reference	
Chiwawa v. Sesech	0.272	α = 264.25	α = 689.31	0.821
		β = 113.79	β = 351.59	0.869
Chiwawa v. L. Wenatchee	0.654	α = 264.25	α = 568.69	0.864
		β = 113.79	β = 725.87	0.751

Smooth Hockey Stick Relationships

Smooth hockey stick curves differed significantly between the Chiwawa and Naches populations and the Chiwawa and Sesech populations (Figure 21; Table 32). There was no significant difference in curves between the Chiwawa and the other reference populations. Most of the parameters in the smooth hockey stick model did not differ significantly among the populations (Table 32). However, the productivity parameter β did differ significantly between the Chiwawa and the Naches and the Chiwawa and Little Wenatchee populations. The β parameter for the Naches was significantly greater than the Chiwawa, while the β parameter for the Little Wenatchee was significantly less than the Chiwawa.

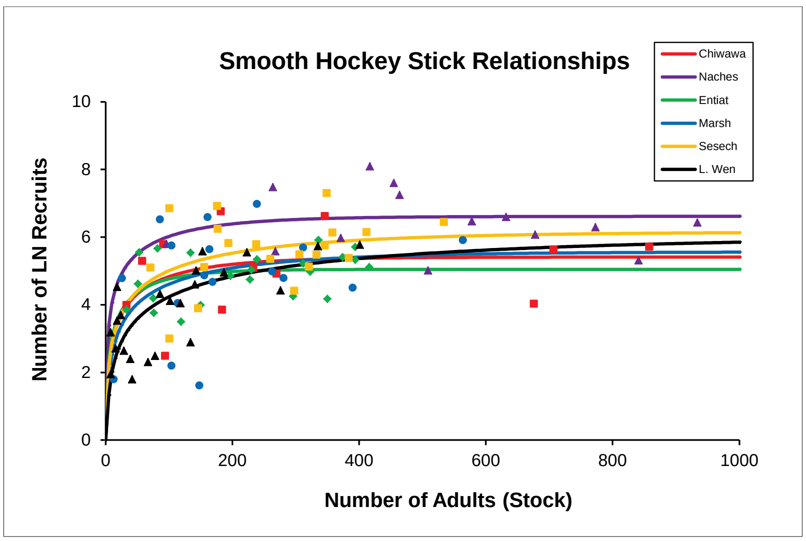

Figure 21. Scatter plot of the number of spawners and natural log adult recruits and fitted smooth hockey stick curves to the Chiwawa (supplemented population) and reference (un-supplemented) populations.

Table 32. Randomization test results comparing the equality of smooth hockey stick curves and equality of parameter values (α and β). Randomization tests were based on 10,000 Monte Carlo samples. Equality or curves was based on 500 points along the x-axis (spawner abundance axis).

Curves tested	Curve inequality randomization P-value	Parameter inequality		
		Model Parameter		Randomization P-value
		Chiwawa	Reference	
Chiwawa v. Naches	0.000	α = 5.41	α = 6.61	0.000
		β = 1.84	β = 5.99	0.000
Chiwawa v. Entiat	0.999	α = 5.41	α = 5.05	0.999
		β = 1.84	β = 2.17	0.999
Chiwawa v. Marsh	0.999	α = 5.41	α = 5.56	0.999
		β = 1.84	β = 1.27	0.999
Chiwawa v. Sesech	0.000	α = 5.41	α = 6.15	0.000
		β = 1.84	β = 1.80	0.999
Chiwawa v. L. Wenatchee	0.990	α = 5.41	α = 6.02	0.999
		β = 1.84	β = 0.75	0.000

Comparing different stock-recruitment curves and their parameters did not provide strong evidence that the supplementation program has negatively affected the productivity of the Chiwawa population.

Analysis without Reference Populations

In some cases, suitable reference populations may not exist to compare with supplemented populations. It is therefore important to have alternative analyses to assess supplementation effects. In this section, we describe methods that can be used to assess supplementation effects when suitable reference populations are not available. We discuss before-after comparisons, correlation analysis, and comparisons to standards as alternatives when reference populations are unavailable.

Before-After Comparisons

Before-after analyses compare population metrics (spawner abundance, NORs, and productivity) before supplementation to those during supplementation. In this case, data collected before supplementation represent the reference condition. The assumption is that population trajectories measured during the pre-supplementation period would continue in the absence of supplementation. We compared trends in abundance and productivity, mean abundance and productivity, and stock-recruitment relationships before and after supplementation.

Trend Analysis

Comparing trends before and after supplementation can be used to assess the effects of supplementation. Here, we compared the slopes of trends of spawner abundance, NORs, and productivity before and during supplementation using t-tests. If the hatchery program is successfully supplementing the natural spring Chinook population, the trend for spawner abundance and NORs during supplementation should be greater than the slope during the pre-supplementation period. For productivity, the slope during the supplementation period should increase or remain the same as that during the pre-supplementation period.

Visual examination of trends of Chiwawa data indicates that spawner abundance, NORs, and productivity decreased during the pre-supplementation period, but increased during the supplementation period (Figure 22). Only the changes in NOR trends were significant (Figure 22). This was true for both transformed and untransformed data.

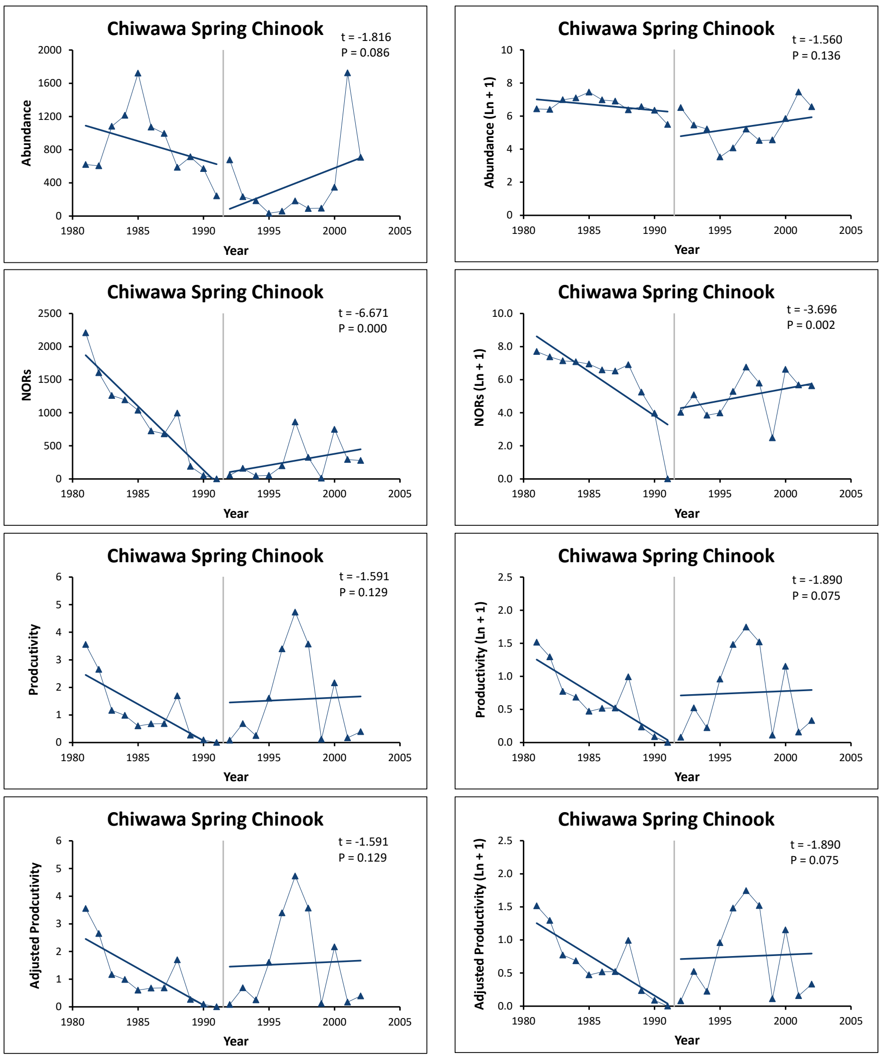

Figure 22. Trends in Chiwawa spring Chinook spawner abundance, natural-origin recruits (NORs), productivity (adults recruits per spawner), and adjusted productivity (adjusted for density dependence) before and during supplementation. The vertical lines in the figures separate the pre- and post-supplementation periods. Figures on the left show untransformed data; figures on the right include natural-log transformed data. Figures include results of t-tests comparing slope of trends before and during supplementation.

Analysis of Mean Scores

We also compared mean spawner abundance, NORs, and productivity data before and after supplementation. If the hatchery program is successfully supplementing the natural spring Chinook population, mean spawner abundance and NORs during the supplementation period should be greater than the pre-supplementation period. For productivity, the mean productivity during the supplementation period should be equal to or higher than the pre-supplementation period. We tested the following statistical hypotheses.

Spawner Abundance and NORs:

Ho: Mean spawner abundance and NORs before supplementation ≥ Mean spawner abundance and NORs during supplementation.

Ha: Mean spawner abundance and NORs before supplementation < Mean spawner abundance and NORs during supplementation.

Productivity (Recruits/Spawner):

Ho: Mean productivity before supplementation ≤ Mean productivity during supplementation.

Ha: Mean productivity before supplementation > Mean productivity during supplementation.

We tested before-after supplementation effects using a one-tailed Aspin-Welch unequal-variance test. We also used a randomization test, based on 10,000 Monte Carlo simulations, to assess differences in spawner abundance and productivity before and during supplementation. The randomization procedure only allowed the testing of two-tailed hypotheses. Therefore, we generated 95% confidence intervals on the mean difference (μ_{pre} - μ_{post}) using bootstrapping methods to determine if the significant result from the randomization test was in the right direction. We generated 5,000 bootstrap samples to calculate confidence intervals.

Mean spawner abundance during the supplementation period was significantly less than the pre-supplementation spawner abundance (Table 33). Mean spawner abundance decreased 46% between the pre- and post-supplementation periods. Likewise, mean NORs decreased significantly between the two periods (Table 33). On the other hand, productivity increased slightly, but not significantly, between the pre- and post-supplementation periods (Table 33). This was true for both adjusted and transformed productivity data.

Table 33. Statistical results comparing mean scores of spawner abundance, natural-origin recruits (NORs), and productivity (using both untransformed and natural-log transformed) before and during supplementation of Chiwawa spring Chinook. Randomization tests were based on 10,000 Monte Carlo samples and 95% CI were based on 5,000 bootstrap samples.

Population metric	Mean scores		Test on means			
			Aspin-Welch test		Random test P-value	Bootstrap 95% CI
	Before	During	t-value	P-value		
Abundance	856	393	2.383	0.986	0.028	112 - 843
LN Abundance	6.6	5.4	3.304	0.997	0.004	0.56 – 1.99
NORs	905	275	2.846	0.993	0.009	214 – 1034
LN NORs	6.0	5.0	1.197	0.876	0.250	-0.40 – 2.54
Productivity	1.13	1.56	-0.721	0.759	0.479	-1.55 – 0.73
LN Productivity	0.64	0.75	-0.450	0.671	0.649	-0.55 – 0.35
Adj Productivity	1.12	1.56	-0.721	0.759	0.477	-1.54 – 0.71
LN Adj Productivity	0.64	0.75	-0.450	0.671	0.652	-0.57 – 0.34

Analysis of Stock-Recruitment Curves

The third method compared stock-recruitment curves of the Chiwawa population during supplementation with those generated before supplementation. Specifically, we tested whether the regression parameters were equal between the pre- and post-supplementation periods, and whether the fitted curves coincided between the two time periods. We used the methods described earlier to fit the Ricker, Beverton-Holt, and smooth hockey stick curves to the two data sets. We tested the following hypotheses.

Parameter equivalence:

Ho: Stock-recruitment parameters (α and β) of the pre-supplementation period = Stock-recruitment parameters of the supplementation period.

Ha: Stock-recruitment parameters (α and β) of the pre-supplementation period ≠ Stock-recruitment parameters of the supplementation period.

Curve equivalence:

Ho: Modeled stock-recruitment curves from the pre-supplementation period = Modeled stock-recruitment curves from the pre-supplementation period.

Ha: Modeled stock-recruitment curves from the pre-supplementation period ≠ Modeled stock-recruitment curves from the pre-supplementation period.

We were only able to fit stock-recruitment curves to the post-supplementation data. Non-linear regression was unable to converge on a solution using only pre-supplementation data. Therefore, we were unable to use this method to test supplementation effects on the Chiwawa spring Chinook population. If we could have fit curves to both the pre- and post-supplementation periods, we would have used two-sided randomization tests to evaluate the null hypotheses of equal model parameters and that fitted curves coincided.

Before describing correlation approaches, it is important to note that comparing before-after data can sometimes be misleading. For example, the spawner abundance, NORs, and productivity data presented in Figure 22 suggest that supplementation is increasing the abundance and productivity of spring Chinook in the Chiwawa Basin. However, when we compared these trends to those from reference populations during the same time periods (Figures 9-11), it becomes clear that supplementation was not responsible for increasing the trends in spawner abundance, NORs, and productivity of the Chiwawa population. Thus, whenever possible, it is wise to compare before-after data with a reference population.

Correlation Analyses

A simple way to see if the supplementation program is increasing or decreasing productivity is to assess the association between the proportion of adult spawners that are made up of hatchery adults (pHOS) and productivity (recruits/spawner). If the supplementation program is working as planned, the increase in hatchery fish spawning naturally should increase the productivity of the population. It should not decrease the productivity of the population.

We tested the association between pHOS and adult productivity[22] using Pearson correlation. During the pre-supplementation period, productivity averaged 1.13 recruits/spawner; during the supplementation period, productivity averaged 1.39 recruits/spawner. This increase in productivity did not appear to be strongly correlated to pHOS (Figure 23). Correlation analysis showed that there was no significant association between pHOS and productivity, even though productivity increased with increasing pHOS.

22 Note that the analysis could also include juvenile productivity (e.g., smolts/spawner).

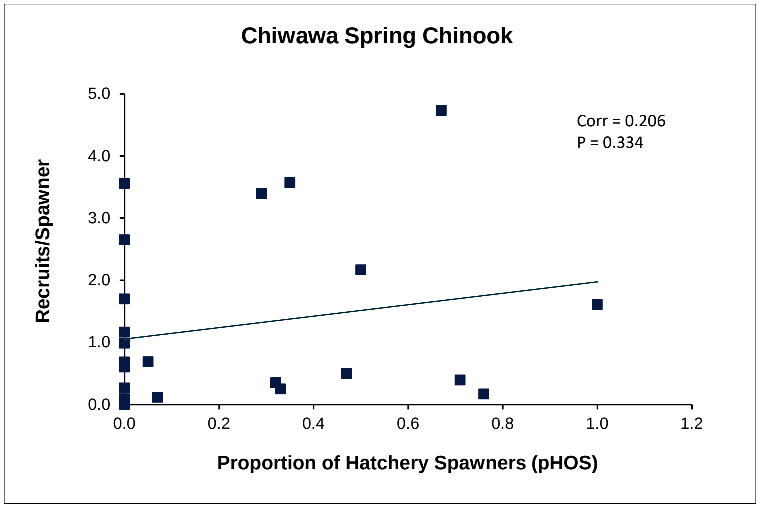

Figure 23. Association between the proportion of spawners that are made up of hatchery adults (pHOS) and the number of natural-origin recruits. The Pearson correlation coefficient (Corr) and its P-value (P) are shown in the figure.

The association between pHOS and productivity can also be assessed by testing the correlation between pHOS and the residuals from stock-recruitment curves fitted to the Chiwawa spawner and natural-origin recruitment data. This approach removes the effects of density dependence on the relationship between pHOS and productivity. A significant negative association provides evidence that hatchery-origin spawners may not be as productive as natural-origin spawners.

The Ricker, Beverton-Holt, and smooth hockey stick models were fit to the Chiwawa stock and recruitment data (including {S, R} data from both the pre- and post-supplementation period, 1981-2004) using methods described earlier. Residuals were calculated by subtracting the predicted recruitment values from the observed (modeled) values. Pearson correlation then tested the association between pHOS and the residuals from each model.

Although there was a negative trend in residuals with increasing pHOS, suggesting that hatchery-origin spawners may not be as productive as natural-origin spawners, the association was not significant (Figure 24). Thus, based on these analyses, there is no strong evidence that the supplementation program has significantly benefited or harmed the natural spring Chinook population.

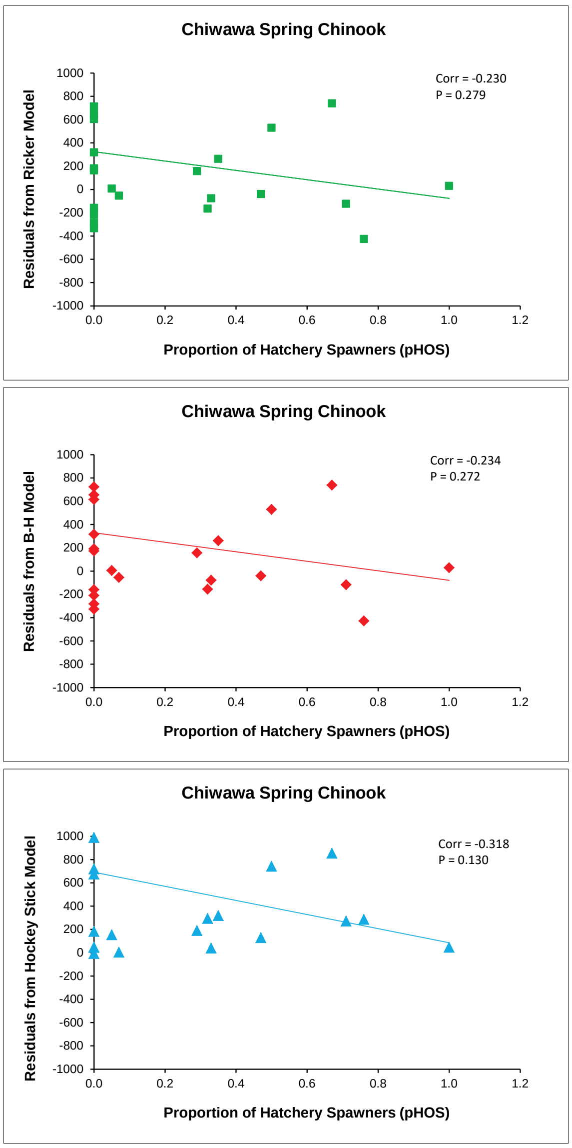

Figure 24. Association between the proportion of spawners that are made up of hatchery adults (pHOS) and the residuals from Ricker, Beverton-Holt (B-H), and smooth hockey stick stock-recruitment models. The Pearson correlation coefficient (Corr) and its P-value (P) are shown in the figures.

Comparison to Standards

In those cases in which suitable reference populations are not available and there are no pre-supplementation data, the investigator is left with comparing population parameters to relevant standards. Standards can include performance of natural-origin fish in similar environments (a type of reference condition), mitigation requirements, quantitative objectives of the program, Biological Assessment and Management Plan (BAMP) values, or other appropriate standards. An example of a statistical hypothesis would be:

Ho: Productivity (Recruits/Spawner) of the supplemented population $\geq$ standard productivity.

Ha: Productivity (Recruits/Spawner) of the supplemented population $<$ standard productivity.

For these analyses to be useful, the standards must be based on biological reality.

Conclusions and Recommendations

Hatcheries are an important component of fish production within the Upper Columbia Basin. The goal of some of these programs is to supplement natural production in declining populations. The supplementation programs generally use both hatchery and natural (spawned and reared in nature from either wild or hatchery parents) adults for hatchery broodstock. These programs are designed to supplement natural populations by increasing natural reproduction while preventing the establishment of a domesticated hatchery stock. Thus, the programs should increase total spawning escapement and NORs, and not reduce the productivity of the natural population. Measuring the success of these programs is challenging and expensive.

In this paper, we described methods that can be used to determine if supplementation programs are achieving some of their goals. This paper focused on the use of reference populations to determine if the supplementation programs increase total spawning escapement, NORs, and maintain or increase productivities. In some cases, suitable reference populations may not be available (e.g., we found no suitable reference populations for Upper Columbia steelhead and sockeye). In these cases, alternative methods are needed to assess supplementation effects. We also described these alternative methods in this paper.

Identification of Reference Populations

Finding suitable reference populations that match well with supplemented populations is a difficult and time-consuming process. Our three-step selection process included identification of populations with similar life-history characteristics, few or no hatchery spawners, a long time series of accurate abundance and productivity estimates, and similar freshwater habitat impairments and out-of-basin effects. Those populations that met these criteria were then examined for their relationship with the supplemented population (in this case, the Chiwawa spring Chinook population). Several criteria were scored, including pNOS, correlation, trend, and effect size. Reference populations with total weighed scores of 81 or greater were selected as suitable reference populations.

This selection process provided a valuable framework for selecting suitable reference populations for supplemented populations. Interestingly, we found that a given reference population may match well with one parameter of the supplemented population (e.g., spawning escapement), but not for all parameters (e.g., not NORs or productivity). The reason for this may be related to errors

in the estimation of population parameters and/or differential factors limiting population parameters of supplemented and reference populations. Therefore, depending on the parameter analyzed, a different suite of reference populations may be needed.

An important assumption in the use of reference populations is that the supplemented and reference populations that tracked each other before supplementation would continue to track each other in the absence of supplementation. Given that the reference populations did not match the Chiwawa population on all criteria examined, and some reference populations tracked the Chiwawa population more poorly than others, there may be some uncertainty as to whether differences observed between the supplemented and reference populations during the supplementation period are associated with the hatchery program, or other unaccounted factors. For example, any large-scale change (man-made or natural) within the reference or supplemented population could affect our ability to assess the effectiveness of the supplementation program.

To account for some of these uncontrollable factors, we recommend the use of a "causal-comparative" approach to strengthen the certainty of our inferences. This approach relies on correlative data to try and make a case for causal inference. We recommend that the following state variables be measured and tracked within the supplemented and reference populations: mean annual precipitation, total and riparian forest cover, road density, impervious surface, and alluvium. These variables can be used to describe differences in water temperatures at different life stages (pre-spawning, egg incubation, and summer rearing) and substrate characteristics, including fine sediments and embeddedness. These state variables can be used to help explain possible changes in spawner abundance, NORs, and productivity that are independent of supplementation. In addition, the use of multiple reference streams reduces the possibility that man-made changes to a single reference stream will influence the interpretation of the results.

Analyses with Reference Populations

Using reference populations, we evaluated the effects of supplementation on natural-log transformed and untransformed total spawning escapement, NORs, and productivity by comparing trends, analyzing mean differences, ratios, and rates, and comparing stock-recruitment curves and their parameters. For trend analysis, we compared the slopes of the trends between each supplemented/reference pair before and during supplementation. If the hatchery program is successfully supplementing the natural population, trends in spawner abundance and NORs should deviate significantly during the supplementation period (i.e., the slope of the supplemented population should be greater than the slopes of the reference populations during the supplementation period), but not during the pre-supplementation period. For productivity, the slope of the supplemented population, relative to the reference population, should increase or remain the same.

Because trend analysis only tests the slopes of the trend lines, it does not test for differences in elevations of the trend lines, additional analyses were needed to determine if supplementation increased spawner abundance, NORs, and productivity of the target population without changing the slopes of the trend lines. To do this, we derived three different response variables using natural-log transformed and untransformed spawner abundance, NORs, and productivity data. The first derived variable included difference scores, which were calculated as the difference between paired treatment and reference data (T-R). The second included ratios, which were calculated as the ratio of paired treatment and reference data (T/R). Finally, we calculated the differences in annual changes in paired treatment and reference population data (ΔT-ΔR). If the hatchery

program is successfully supplementing the natural population, the mean difference or ratio score of paired spawner abundance data and NORs during the supplementation period should be greater than the pre-supplementation period. For productivity, the mean difference or ratio score during the supplementation period should be equal to or higher than the pre-supplementation period.

As a final set of analyses, we compared the stock-recruitment curves of the supplemented population (using stock and recruitment data only from the supplementation period) to the reference populations (using all available stock and recruitment data). Specifically, we tested whether the regression parameters were equal between the supplemented population and the reference populations, and whether the fitted curves coincided between populations. Here, we were most interested in comparing the productivity parameters in the models.

Surprisingly, these different analyses yielded similar results when they were applied to the Chiwawa spring Chinook and reference population data. Trend analysis was unable to detect a significant difference in trends between the supplemented and reference populations during the supplementation period. Even though we measured an increasing trend in spawner abundance, NORs, and productivity in the supplemented population during the supplementation period, these same parameters trended upward in the reference populations. Likewise, we were unable to detect a significant supplementation effect using difference scores, ratios, and differences in annual changes. However, we found the results from analysis of mean differences of annual change difficult to interpret and they may be insensitive to treatment effects. A simpler analysis, which is also easier to interpret, is to use trend analysis. Finally, comparing stock-recruitment curves and their parameters did not provide strong evidence that supplementation has affected the productivity of the natural population.

Based on these results, we do not recommend using difference scores of annual change (ΔT-ΔR), nor do we recommend comparing stock-recruitment curves and their parameters. As noted above, difference scores of annual change are difficult to interpret and may be redundant with trend analysis. Testing stock-recruitment curves and their parameters appears redundant with testing differences in productivity using difference scores or ratios. In addition, the analyses are computer intensive and do not appear to be very sensitive to changes.

There was little difference in results using difference scores and ratios. It appears that ratios may be more sensitive to change than difference scores (e.g., we found significant differences in some comparisons using ratios but not with difference scores), but ratios can be more difficult to interpret than difference scores. Nevertheless, we recommend the use of ratios in future analyses.

Correcting for Density Dependence and Carrying Capacity

The analyses described so far assumed that the density of spawners or recruits did not affect the survival and productivity of fish. However, without controlling for density effects, productivity of the population would continue to decline with increasing abundance. This scenario could occur in supplementation programs that increase the number of spawners, and could result in lower productivities relative to reference populations. In addition, lower productivities may be caused by differential environmental carrying capacities rather than the capacity of the supplemented fish to produce offspring. Therefore, we described two different methods for deriving density-corrected estimates of productivity. The first controlled the effects of density on productivity by partitioning observed productivities into density-independent and density-dependent productivity. These productivities were then combined in a single test. The second method corrected for differences in carrying capacities between the supplemented and reference populations. This was accomplished

by calculating the percent saturation of NORs, which was estimated as the ratio of observed NORs to the maximum number of NORs that the habitat could support.

We fit Ricker, Beverton-Holt, and smooth hockey stick models to stock and recruitment data to estimate the maximum number of NORs (NORs at carrying capacity) and the maximum number of spawners needed to produce maximum NORs. We fit models to the supplemented and reference populations. Using information-theoretic criterion and evaluating the precision of estimated parameters, we found that the smooth hockey stick model provided the best estimates of maximum NORs and spawners. We used these modeled values to estimate density-independent and density-dependent productivities, and saturation of NORs.

Statistical analyses, using difference scores and ratios of adjusted Chiwawa spring Chinook productivity data, found no significant effects of supplementation on the productivity of the supplemented population. Indeed, the results from correcting for density dependence were similar to those without correcting for density dependence. This is in part because the abundance of the supplemented and reference populations has been below their respective carrying capacities in most years. This was clearly demonstrated in the analyses of NORs corrected for carrying capacity. In the supplemented population, the mean fraction of the carrying capacity filled with NORs decreased significantly during the supplementation period. In other words, the carrying capacity was filled with more NORs during the pre-supplementation period than during the supplementation period, which is contrary to the goal of supplementation. By comparison, two of the reference populations showed a similar decrease in saturation, while the other two reference populations actually increased in saturation. Analyzing the saturation scores using BACI-design analyses indicated that two of the four pairings differed significantly. That is, the percent saturation of the supplemented population decreased significantly relative to two reference populations.

Because productivity can be affected by the abundance of spawners and recruits, we recommend that future analyses comparing supplemented and reference populations adjust for density-dependent effects and differential carrying capacities. Although we detected only slight differences between adjusted and unadjusted results, as supplemented stocks recover, it will become more important to adjust productivities to account for density dependence. Importantly, the analyses using percent saturation placed NORs in the context of the carrying capacity of the environment. This will help managers determine if supplementation programs are filling or over-filling the capacity of the habitat with NORs.

As we noted earlier, analyses using productivities adjusted for density dependence assume that there is a spawner abundance at which density-independent effects end and density-dependent effects begin. In reality, density-dependent effects occur at low spawning abundance and intensify as spawning abundance increases. We did not account for these increasing density-dependent effects at lower spawner abundances. This is an area that needs additional attention.

Analyses without Reference Populations

Because of the rigorous criteria we used to select reference populations, it is likely that reference populations may not exist for making comparisons with supplemented populations. For example, we used the criteria described in this paper to identify reference populations for supplemented steelhead and sockeye populations in the Upper Columbia Basin. We were unsuccessful in identifying any suitable reference populations. Therefore, in the absence of suitable reference populations, it is important to have alternative methods for assessing supplementation effects. We described three different types of analyses one can use to assess supplementation effects in the

absence of reference populations. They include before-after comparisons, correlation analysis, and comparisons to standards.

Before-after analyses compare population metrics before supplementation with those during supplementation. In this case, data collected before supplementation represent the reference condition. The assumption is that population trajectories measured during the pre-supplementation period would continue in the absence of supplementation. We compared trends in spawner abundance, NORs, and productivity before and after supplementation. In addition, we compared mean scores in these three parameters before and after supplementation. Finally, we attempted to compare stock-recruitment parameters before and after supplementation. The hypotheses examined were that the spawner abundance and NORs would be greater during the supplementation period, and that productivities would not decline during the supplementation period.

Trend analysis indicated that the all three Chiwawa spring Chinook population parameters trended downward during the pre-supplementation period, but trended upward during supplementation. On the other hand, mean spawner abundance and NORs were lower during the supplementation period than during the pre-supplementation period. Mean productivities increased, but not significantly, during the supplementation period. We were unable to compare pre- and post-supplementation stock-recruitment curves because we were unable to fit stock-recruitment models to the pre-supplementation data.

We used correlation analyses to determine if the proportion of hatchery-origin fish that spawn naturally on the spawning grounds (pHOS) increased productivity. In addition, we used correlation to assess the association between pHOS and the residuals from stock-recruitment relationships. A significant negative association provides evidence that hatchery-origin spawners may not be as productive as natural-origin spawners. The analysis indicated that the productivity of Chiwawa spring Chinook increased with increasing pHOS, but the association was not significant. In contrast, there was a negative association between pHOS and the stock-recruitment residuals, but again the association was not significant. The latter analysis accounts for density-dependent effects.

In concert, the before-after comparisons and correlation analyses do not provide conclusive evidence that the supplementation program has increased spawner abundance and NORs, or that it has significantly reduced the productivity of the supplemented population. Although increasing the number of hatchery fish on the spawning grounds appears to reduce NORs and productivity, mean productivity actually increased during the supplementation period compared to the pre-supplementation period.

It is important to note that relying on only one set of analysis could result in drawing a wrong conclusion. For example, if we had only conducted trend analysis, we may have concluded wrongly that the Chiwawa spring Chinook supplementation program significantly increased spawner abundance, NORs, and productivity in the supplemented population. The analysis of mean scores and correlations indicates that the supplementation program has not increased spawner abundance or NORs in the supplemented population. Therefore, in the absence of suitable reference populations, we recommend that analyses include the evaluation of trends, means scores, and correlations. By conducting more than one set of analyses, one can use weight-of-evidence to assess the effects of supplementation programs.

Under the scenario that there are no reference populations or pre-supplementation data, one is left with comparing population parameters to relevant standards. These standards could come from mitigation requirements, quantitative objectives, or published or unpublished standards. One could also use correlation to evaluate the association between productivity and pHOS, but this requires a wide range in pHOS values to be most effective. A more extreme approach, which probably would not gain much traction with managers, is to shutoff the supplementation program for some time and then evaluate the effects of the program in a before-after design. The Entiat spring Chinook hatchery program provides a unique opportunity to evaluate this type of management decision.

Some Concerns and Limitations

No matter how hard we try to explain different sources of variation in population data, we are limited by the quality of the data. Teasing out the effects of supplementation requires long time series of population data. Because funding levels and methods change over time, the quality (i.e., accuracy and precision) of the data also changes over time. Importantly, the population parameters examined in this paper (spawner abundance, NORs, and productivity) are rarely measured directly in the field. That is, other population metrics, such as numbers of redds, number of fish counted at weirs or dams, scales, tags, etc., are sampled in the field. These metrics are then used to calculate spawner abundance[23], NORs, and productivity, often based on assumptions about fish/redd, pre-spawning loss, marking rates, and sampling rates. This has a tendency to increase the variability in the data independent of supplementation programs. In our studies, we can only control sampling within the supplemented populations, and even that is limited by available funding. We have no control over the sampling within reference populations. Thus, we have to assume that sampling within the reference populations will continue and that sampling effort will remain comparable to that in the supplemented populations.

In our analyses, we included both the Entiat and Little Wenatchee populations as references for the Chiwawa population. In the analyses, we treated them as equivalent to the other reference populations. That is, the statistical procedures used to compare the supplemented population to each reference population were identical. This is appropriate. However, the interpretation of the results must be different when comparing the Entiat and Little Wenatchee to the supplemented population, because they are populations that were influenced by hatchery fish. As noted earlier, the Entiat spring Chinook hatchery program has been discontinued. Therefore, it provides a unique type of reference where the comparison changes from both populations being supplemented to only one population being supplemented. For the Little Wenatchee, nearly all the strays came from the Chiwawa program. Straying should stop or be greatly reduced with the change in water supply to the Chiwawa Rearing Ponds. In sum, one must be careful in how they interpret these test-reference results.

Finally, it is important to point out that for this paper, we conducted 463 statistical tests. Because we set our Type I error rate at 0.05, by random chance alone, we may have incorrectly rejected about 23 null hypotheses. Inasmuch as this work was designed to evaluate different ways to analyze test-reference data, the number of future analyses will be greatly reduced based on the results from this work. However, if the Type I error rate is a concern to managers, researchers can

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23 The smooth hockey stick model, which we used to estimate density-dependent correction factors for productivity and NORs, is sensitive to errors in spawner escapement estimates. Therefore, it is important to use accurate and precise estimates of spawner escapement.

use a lower error rate, such as α = 0.01. Another option is to analyze test-reference data graphically. Although this is subjective, there are no statistical analyses and therefore no concerns with violating assumptions of statistical tests, including temporal correlation. We believe researchers should use the statistical procedures recommended in this report to support graphic analysis.

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FINAL

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ANCHOR QEA

Memorandum

To: Wells, Rocky Reach, and Rock Island HCP Hatchery Committees

Date: October 19, 2017

From: Tracy Hillman, HCP Hatchery Committees Chairman

cc: Sarah Montgomery, Anchor QEA, LLC

Re: Final Minutes of the September 20, 2017 HCP Hatchery Committees Meeting

The Wells, Rocky Reach, and Rock Island Hydroelectric Projects Habitat Conservation Plan (HCP) Hatchery Committees meeting was held at the Grant PUD office in Wenatchee, Washington, on Wednesday, September 20, 2017, from 9:00 a.m. to 12:00 p.m. Attendees are listed in Attachment A to these meeting minutes.

Action Item Summary

- Andrew Murdoch (Washington Department of Fish and Wildlife [WDFW]) will write an overview of proposed expanded sampling at the off-ladder fish trap (OLAFT) at Priest Rapids Dam (Item I-A). *(Note: this item is ongoing.)*
- Mike Tonseth will coordinate with Todd Seamons (WDFW) to produce an outline or recommended approach for genetic monitoring (Item I-A). *(Note: this item is ongoing.)*
- Tracy Hillman will distribute the Upper Columbia Salmon Recovery Board's (UCSRB) discussion draft Hatchery Report to the Hatchery Committees when he receives it (Item I-A). *(Note: Hillman sent the report to Montgomery, who distributed it to the Hatchery Committees on October 13, 2017.)*
- Tracy Hillman will invite Greer Meier (UCSRB) to an upcoming Hatchery Committees meeting to discuss the Hatchery Report (Item I-A). *(Note: Meier plans to attend the November 15, 2017 Hatchery Committees meeting.)*
- Kirk Truscott will discuss internally and coordinate with Keely Murdoch on potential edits to Chelan PUD's *Draft Statement of Agreement Regarding the District's Coho Obligation* (Item II-A).
- Tom Kahler will send Douglas PUD's Transition Plan Outline to Sarah Montgomery for distribution to the Hatchery Committees (Item III-A). *(Note: Montgomery distributed the outline following the meeting on September 20, 2017.)*
- Douglas PUD will provide their Transition Plan to the Hatchery Committees for review (Item III-A). *(Note: Tom Kahler sent the plan to Montgomery, which she forwarded to the Hatchery Committees on October 16, 2017.)*

- Hatchery Committees representatives will review the revised monitoring and evaluation (M&E) Plan for PUD Hatchery Programs and discuss it during the October 18, 2017 Hatchery Committees meeting (Item IV-D). *(Note: Montgomery distributed the latest version of the plan on October 10, 2017.)*
- Tracy Hillman will invite Barry Berejikian (Northwest Fisheries Science Center) to the October 18, 2017 Hatchery Committees meeting to discuss steelhead in the Twisp River (Item V-A). *(Note: Berejikian plans to attend the October 18, 2017 meeting.)*

Decision Summary

- There were no decisions approved during today's meeting.

Agreements

- There were no agreements discussed during today's meeting.

Review Items

- Sarah Montgomery sent an email to the Rocky Reach and Rock Island Hatchery Committees on August 15, 2017, notifying them that the Chelan PUD *Draft Statement of Agreement Regarding the District's Coho Obligation* is available for a 30-day review, with comments due to Catherine Willard by September 14, 2017. Chelan PUD indicated they will request approval of the Statement of Agreement (SOA) at the Hatchery Committees September 20, 2017 meeting. *(Note: this item will be discussed at the November 15, 2017 Hatchery Committees meeting.)*
- Sarah Montgomery sent an email to the Hatchery Committees on September 1, 2017, notifying them that the Draft 2016 Douglas PUD and Grant PUD M&E Annual Report is available for a 60-day review, with edits and comments due to Greg Mackey by October 31, 2017. *(Note: Douglas PUD requested comments in 30 days if possible, which would be October 2, 2017.)*
- Sarah Montgomery sent an email to the Hatchery Committees on October 16, 2017 notifying them that the draft plan, Implementation of Comprehensive Monitoring and Evaluation of Wells Hatchery Complex Programs in 2018, is available for review with edits and comments due to Greg Mackey by December 1, 2017.

Finalized Documents

- Sarah Montgomery sent an email to the Hatchery Committees on September 15, 2017, notifying them the Chelan PUD and Grant PUD 2016 Final M&E Annual Report and Appendices is now available for download from the Hatchery Committees Extranet site.

I. Welcome

A. Review Agenda, Review Last Meeting Action Items, and Approve the August 16, 2017, Meeting Minutes (Tracy Hillman)

Tracy Hillman welcomed the Hatchery Committees and asked for any additions or changes to the agenda. Hillman added agenda items for annual and monthly M&E reports. Keely Murdoch requested that Douglas PUD discuss the transition plan for the Wells Program hatcheries. Greg Mackey agreed and also added an item for Wells Fish Hatchery Modernization.

The Hatchery Committees representatives reviewed the revised draft August 16, 2017 meeting minutes. Sarah Montgomery said there are a few outstanding comments in the notes, and representatives revised the meeting minutes. Hatchery Committees representatives present approved the draft August 16, 2017 meeting minutes, as revised.

Action items from the Hatchery Committees meeting on August 16, 2017, and follow-up discussions were addressed *(note: italicized text below corresponds to agenda items from the meeting on August 16, 2017)*:

- *Andrew Murdoch (Washington Department of Fish and Wildlife [WDFW]) will write an overview of proposed expanded sampling at the off-ladder fish trap (OLAFT) at Priest Rapids Dam (Item I-A).*
  Mike Tonseth said this item is ongoing.
- *Sarah Montgomery will clarify the review period for the Chelan PUD Draft Statement of Agreement (SOA) Regarding the District's Coho Obligation and provide an update to the Hatchery Committees (Item II-A).*
  This item is complete.
- *Mike Tonseth will coordinate with Todd Seamons (WDFW) to produce an outline or recommended approach for genetic monitoring (Item III-E).*
  Tonseth said he began coordinating with Seamons and this item is ongoing.
- *Mike Tonseth will send the revised Table 3 of the Hatchery Monitoring and Evaluation (M&E) Plan to Tracy Hillman for inclusion in the 2017 Update (Item III-G).*
  This item is complete. Tonseth provided the table to Hillman on August 17, 2017.

- *Sarah Montgomery will send SOAs regarding Non-target Taxa of Concern (NTTOC) study results to Tracy Hillman (Item III-G).*
  This item is complete.
- *Tracy Hillman and Todd Pearsons will revise NTTOC and adaptive management language in the Draft 2017 Update to the M&E Plan for PUD Hatchery Programs and provide a revised version for Hatchery Committees review (Item III-G).*
  Hillman revised the plan and Sarah Montgomery distributed a revised version for review on September 2, 2017, which will be discussed today.

II. Chelan PUD

A. Draft Coho Salmon Mitigation SOA (Catherine Willard)

Catherine Willard shared the document titled *Draft Statement of Agreement Regarding the District's Coho Obligation*, which Sarah Montgomery distributed to the Hatchery Committees on September 6, 2017 (Attachment B). Willard said the revised version includes clarifications regarding which calculations apply to which coho reintroduction projects (i.e. Methow sub-basin or Wenatchee sub-basin). She asked if there are any comments or questions.

Kirk Truscott said the Colville Confederated Tribes (CCT) need to discuss this internally before approving it, and asked to coordinate discussions with the Yakama Nation (YN). Keely Murdoch agreed and said YN and CCT will coordinate any proposed revisions to the SOA and provide an update to the Hatchery Committees at the October 18, 2017 Hatchery Committees meeting.

B. Tumwater Feasibility Study for Lamprey Update (Catherine Willard)

Catherine Willard said Chelan PUD has been working on a feasibility study for lamprey passage at Tumwater Dam. She said an updated version of the study will be available for review soon. Bill Gale asked if the study needs to be reviewed by Chelan PUD management again. Alene Underwood said no and it will likely be distributed in October 2017. Gale asked if the draft will be available for the Rocky Reach Fish Forum (RRFF) to review. Underwood said Chelan PUD will ask the RRFF to review the document and provide comments.

Willard said the YN has been introducing lamprey into the Wenatchee River in 2016 and 2017, above and below Tumwater Dam, and lamprey have been counted at the Tumwater Dam observation window. Gale asked how many lamprey have been counted at the window and Willard said during the times trapping was not occurring, 14 lamprey were counted passing by the observation window at night. She said between July 16 to August 31, limited trapping occurs at Tumwater for up to 16 hours per day (versus 24 hours/7 days/week). Additionally, from August 31 to September 6, 2017, trapping was not occurring at Tumwater Dam to evaluate lamprey passage in the fishway after the August 31st lamprey release. She said when the trap is not operating, the denil is not operating, and lamprey are using the fishway to ascend the dam. However, she did note that a lamprey was observed ascending the denil, which was captured on video by WDFW technicians. She said PIT-tag detection data have not been uploaded to PTAGIS yet, but it appears that 24 unique detections in the Tumwater Dam fish ladder are likely the lamprey most recently released by the YN. She said PIT-tag detections have occurred previously in the fish ladder at Tumwater Dam.

III. Douglas PUD

A. Wells Transition Plan (Greg Mackey)

Greg Mackey said Douglas PUD terminated their contract with WDFW to operate the Wells and Methow fish hatcheries. He said this decision was precipitated by complaints, investigations, and firings at Wells Fish Hatchery, covered heavily by media. He said the Douglas PUD General Manager and commissioners have been working to determine a path forward and directed the PUD to terminate the WDFW contract. Mackey said the termination includes a contractually-determined 90-day transition period, which may or may not be extended pending higher-level discussions.

Mackey said Steve Parker (YN) contacted Douglas PUD with concerns, mostly about the transition period, and Shane Bickford (Douglas PUD) discussed the transition period with him. Mackey said no determination has been made yet to extend the transition period, but Douglas PUD is not opposed to a longer period such as 120 days.

Mackey said Douglas PUD is drafting a transition plan and shared hard-copies of the Transition Plan Outline to meeting attendees (Attachment C). Tom Kahler said he would send an electronic copy to Sarah Montgomery to distribute to the Hatchery Committees. Mackey said Douglas PUD intends to distribute the Transition Plan for the Hatchery Committees to review soon, as it is nearly complete. He said it will be important to receive input from representatives about any missing pieces or program details. Mackey said Douglas PUD has posted approximately 10 positions, which they intend to fill very soon. He said the fish health position, if not filled by Douglas PUD, would be contracted to the U.S. Fish and Wildlife Service (USFWS), WDFW, or other qualified sources.

Keely Murdoch thanked Mackey for the update and agreed with his summary of Parker's feedback that YN would prefer a longer transition period. She said 90 days may be too short of a time to discuss and cover all items and tasks. She said jointly held permits, roles and responsibilities, National Pollutant Discharge Elimination System permits, marking, staffing, operation of Carlton Pond, and adult management and surplusing are just a few of the complex management actions that need to be worked out during the transition. She suggested not just a longer transition period, but also a more collaborative transition plan. She said the Wells and Methow fish hatcheries are central to Douglas PUD's hatchery mitigation requirements and communication and involvement with others who make related management decisions is necessary to ensure a smooth transition. Mackey said Douglas PUD intends to keep the M&E contract with WDFW in place, as there are no performance issues with those tasks. He said it also conceptually makes sense to have the M&E contract separate from the hatchery operations so that oversight can be performed separate from operations. He said it would not make sense for Douglas PUD to monitor their own programs, even though this has not been an issue in the past with WDFW having both contracts

Tonseth said a detailed transition plan is the most necessary piece of this transition to make sure nothing gets missed. He said parties will not understand if the transition is working unless a plan is being followed. He said he hopes to see a full transition plan available for review soon, as Bickford indicated. Mackey said Douglas PUD will distribute the draft soon and asked for representatives to provide feedback on the outline so Douglas PUD can adjust the plan as needed.

Brett Farman said the National Marine Fisheries Service (NMFS) has similar concerns regarding the transition period and making sure nothing is missed. He said NMFS is working to understand how to transfer and renew permits with Douglas PUD as the hatchery operator. He said, for example, NMFS needs to ensure the operating party meets qualifications and has a demonstrated track record of hatchery performance in order to transfer permits. He said NMFS is working to interpret this regulatory language and will provide a letter with their concerns soon.

Bill Gale said this is a big change in hatchery operations and the policy aspects of the termination are outside many Hatchery Committees representatives' control. He said as agency representatives, Hatchery Committees representatives are responsible for oversight of hatchery mitigation related to the Rock Island, Rocky Reach, and Wells projects. He said he is pleased that Douglas PUD is hiring staff and working on a transition plan, but urged Douglas PUD to make the transition plan collaborative within the Hatchery Committees because representatives are charged with overseeing mitigation related to these programs. He said representatives have the responsibility and obligation to ensure that mitigation and plans for transition are going to be implemented. He said the USFWS is working to understand some of the regulatory aspects of this transition, and would prefer a more deliberate and collaborative transition process over a longer period. He also voiced frustration with the lack of communication about the transition and asked for Hatchery Committees representatives to be kept better informed of these sorts of changes in the future.

Kahler agreed that the luxury of better communication regarding the contract termination would have been ideal, but was not an option. Tonseth agreed and said better communication on all sides could have reduced stress and surprises associated with the transition.

Kirk Truscott said he also urges Douglas PUD to communicate with the Hatchery Committees regarding the transition and asked that the Hatchery Committees review the transition plan.

Kahler summarized that Douglas PUD will provide a transition plan soon for the Hatchery Committees to review and thanked everyone for their input, expertise, and offers of help during the transition.

B. Wells Fish Hatchery Modernization (Greg Mackey)

Greg Mackey said the Wells Fish Hatchery Modernization project is nearly complete. He said Douglas PUD extended the contract end date past August 31, 2017, to finish minor items such as grating and fixed ladder designs, but the building is operational and essentially complete as scheduled. He invited Hatchery Committees representatives to visit and said he plans to schedule a tour or perhaps an upcoming Hatchery Committees meeting there this fall.

IV. Joint HCP-HC/PRCC HSC

A. USFWS Bull Trout Consultation Update (Bill Gale)

Bill Gale said he does not have an update from Karl Halupka (USFWS) regarding bull trout consultations. Mike Tonseth said WDFW met with National Oceanic and Atmospheric Administration and USFWS staff earlier this week and said they discussed strategies and outstanding items for bull trout consultation. Tonseth said Halupka finished making edits and responding to comments on the Biological Opinion for the batch of Wenatchee subbasin programs and Sierra Franks (USFWS) is currently reviewing the document. He said Franks indicated there are no major red flags in the document and it will go through a more senior review and then back to Halupka for revisions. Tonseth said the Wenatchee steelhead permit will likely be the only remaining permit issued in 2017, because it only needs Section 7 consultation and signatures.

B. NMFS Consultation Update (Brett Farman)

Brett Farman said Emi Kondo (NMFS) intends to finish the proposed action for the upper Columbia River unlisted summer Chinook salmon programs next week and is incorporating edits and comments from reviewers. He said Chuck Peven (Peven Consulting Inc.) is working on the Biological Opinion for the upper Columbia River unlisted programs and may contact people for information.

C. Wenatchee Spring Chinook Salmon Lifecycle Modeling (Jeff Jorgensen)

Tracy Hillman introduced Jeff Jorgensen (Ocean Associates, Inc.), who shared a presentation titled *Lifecycle modeling in the Wenatchee River Basin* (Attachment D). Hillman said he and Andrew Murdoch have also participated in developing this model and Jorgensen leads one of several lifecycle modeling teams. Jorgensen said the different teams share ideas and code and, while models may be driven by different factors, most of the work is directed to inform biological opinions and recovery planning. He said today he will describe the Wenatchee spring Chinook salmon lifecycle model.

Roots and basics of the model (slides 1-4)

Jorgensen said the Wenatchee lifecycle model is a population dynamics model that addresses how the population changes relative to natural factors or demographic rates and has its roots in a matrix-type model. He said the Independent Scientific Advisory Board (ISAB) reviewed the Wenatchee model in 2013 and again in 2017. He said to determine how many fish move to the next step of the model, you multiply the number of fish by difference equations. This allows for applying different demographic parameters to different production areas, such as management areas in the Wenatchee basin (e.g., Chiwawa River or White River).

Running the model and using modules (slides 5-13)

Running the model starting with spawner abundance produces different outcomes, which can be summarized and characterized to determine tendencies and variation. Jorgensen said there are a lot of data in the Wenatchee basin that help inform this model. Estimates of spawner abundance and juvenile production are particularly useful to fit a fish production function within the model based on observations. Numbers of spawners, numbers of smolts, and hatchery relative reproductive success are all used to calibrate and parameterize the model. Additionally, smolt-to-adult survival rates, harvest rates, fish passage rates, and pre-spawn mortality are all factored into the model. In the Wenatchee basin, different production areas account for different production levels.

Jorgensen said the model is separated into different modules and one of those is the hatchery module, which considers broodstock, conservation, and mitigation elements to hatchery programs in the Chiwawa River and Nason Creek. He said hatchery fish are allowed to spawn in the wild based on percent natural influence (PNI) targets and percentage of hatchery origin spawners (pHOS), which set the baseline for natural-origin returns in the model. He said recent PNI estimates for the Chiwawa River, for example, are used in the model because hatchery fish are less productive than natural fish, so their spawning success is discounted. Kirk Truscott asked if the model accounts for hatchery fish spawning in the wild in separate areas. Jorgensen said hatchery fish tend to choose marginal habitat compared to wild fish, and that difference is still being discussed for incorporation in the model. Andrew Murdoch said the lifecycle modeling team will incorporate as much detail as possible to the model, especially in specific basins. Bill Gale asked if the model should consider three- or four-population estimates for PNI. Jorgensen said each area could be considered separately if enough data are available. Hillman asked if the same function is being used for both the Chiwawa River and Nason Creek. Jorgensen said yes. Hillman said for example, in the Chiwawa River, hatchery fish spawn mostly in the lower part of the river, so the Chiwawa River could be written into the model as having two separate spawning aggregates.

Jorgensen emphasized that the lifecycle model evolves as more information becomes available and the hatchery module operates within the lifecycle model. He said at low natural-origin return abundance, hatchery managers have more flexibility for hatchery fish to spawn in the wild. He said the model sets a hatchery-origin return ceiling at very low natural-origin return abundance. In the Chiwawa River, for example, the pHOS line is a function of natural-origin returns.

Evaluating hatchery programs (slides 14-16)

Jorgensen said there are different scenarios for evaluating hatchery management. Broodstock collection levels, smolt releases, and domestication can change, which would all affect the number of hatchery-origin spawners spawning in the wild.

Scenarios and outputs (slides 17-30)

Jorgensen said hatcheries, habitat, hydropower projects, avian predation, ocean conditions, harvest, and pinniped predation are all factors included in the model that can change. In addition, Lake Wenatchee and toxics can be included in the model, but those will not be discussed today. Jorgensen said, for example, some potential changes to the habitat variable include improving juvenile rearing capacity by reconnecting side channels and converting rangeland to floodplain.

The model can be run by changing multiple scenarios at a time, and the output is a graph of natural-origin spawners vs. each scenario. The model also allows for referencing recruits back to brood year, so quasi-extinction risk and viable salmon population scores can be considered.

Jorgensen said sensitivity analyses help identify the big drivers in the lifecycle model. Jorgensen said Lake Wenatchee is one area where it is difficult to understand how to parameterize the lifecycle model. He said there are opportunities and challenges when considering Lake Wenatchee, but the effects of changing habitat or other actions pertaining to the lake are currently unclear. Some of the scenarios for the lake consider changes in habitat for eggs, habitat for parr, and lake survival under different hatchery scenarios, with the output being a change in the number of smolts leaving Lake Wenatchee, a change in natural origin spawners, or other factors.

Next steps and acknowledgments (slides 31-33)

Jorgensen said the lifecycle modeling team is working on incorporating pre-spawn mortality and the early migrant juvenile-life-history strategy into the model. He said they will consider the results of spatially continuous, long-term time-series stream-temperature data, and perhaps incorporate it into fish-habitat relationships. Jorgensen acknowledged his funding sources and collaborators and asked for any questions or comments.

Questions and comments

Greg Mackey asked if Jorgensen ever encountered populations going extinct during model runs and asked if adjustments had to be made for calibration to reasonably represent current conditions. Jorgensen said they did not run into an extinction situation when running the model, likely because in the Wenatchee basin there are two life-history stages to calibrate the model and keep it within reasonable bounds.

Hillman asked how important was the hatchery component to overall abundance? Jorgensen said the hatchery component is very important to abundance especially compared to habitat or harvest. He said the lifecycle modeling team can run more scenarios to further isolate the hatchery component and determine its influence.

Peter Graf asked if the alternative hatchery scenario, which reduced pHOS, included commensurate changes in linked parameters, such as reduced broodstock collected or reduced juvenile releases. Jorgenson said that in this case the parameters were not linked and that only pHOS reduced, but those variables could be linked in the model. Tom Kahler commented that those parameters should be linked for a proper evaluation of hatcheries.

Peter Graf asked why adult survival to Bonneville Dam is described as an unknown quantity in the model and included in the calibration process. Jorgensen said it is used as a test case to see if the model fits, and used to help calibrate the model. Jorgensen noted that since discussing this further with the ISAB, the lifecycle modeling team has taken a more approximate approach to calibrating the model in order to account for natural variability and covariability. Graf asked if Lake Wenatchee survival could be treated similarly to the other less certain variables like year-1 ocean survival and be included in the calibration process. Jorgensen said it could but some prior knowledge or data is needed to create bounds around the vairaible otherwise the variable will not have an effect on the model. Mackey asked about the end product of the model. That is, will the model be available so anyone can run the model? Jorgensen said it would be difficult to train people to run the model themselves, but the modeling team may run all possible combinations and then create something like a Shiny application to display the results. Mike Tonseth asked if the Hatchery Committees identified a suite of questions or scenarios to evaluate, would the modeling team be able to run those. Jorgensen said yes. Andrew Murdoch said the model will change over time and data currently being collected will further inform the model.

Jorgensen summarized that the model is intended to be useful for managers and asked for representatives present to consider improvements to the model.

Tom Kahler asked about including water transport time, plume size, and the timing and duration of the spring freshet in the model. Jorgensen said these were considered when the model was being developed, but ultimately were not included because they correlate with model inputs that are already included. Additionally, the time series for those data is not as lengthy as other parameters like ocean regimes. Jorgensen said the lifecycle modeling team will be developing a revised module for ocean survival (currently under development for modeling for the Snake River), which includes more variables. He said water and travel time do not end up having a large influence on the model, but when included with ocean survival the variables are similar. Jorgensen said the model can be forced to run with bad ocean conditions to simulate a bad ocean sample, and a very visible relationship is seen between ocean conditions and decreased fish numbers.

Hatchery Committees representatives present thanked Jorgensen for presenting the model and expressed interest in future developments in the model and potentially running certain hatchery scenarios.

D. M&E Plan for PUD Hatchery Programs 2017 Update (All)

Tracy Hillman said he revised the M&E Plan for PUD Hatchery Programs to reflect changes discussed during the August 16, 2017 Hatchery Committees meeting. Sarah Montgomery distributed a revised version of the plan for review on September 2, 2017 (Attachment E). Hillman reviewed the edits in the document, and questions and comments were discussed.

Hillman said language in Section 7.2 (Non-target Taxa of Concern) is new and asked if anyone had comments. There were no immediate questions, but representatives indicated they would like more time to review it.

Hillman said he added language to Section 8 (Adaptive Management) regarding analyzing major program changes. He said in order to complete theses analyses, the Hatchery Committees will need to identify major program changes in fish culture or M&E for each program and suggested that the Hatchery Committees start by identifying program changes with spring Chinook salmon during the October 18, 2017 Hatchery Committees meeting.

Hillman said he is still drafting Appendix 1, Carrying Capacity, and it will be available for review soon. He summarized that Hatchery Committees representatives will review the revisions to the plan and discuss it again at the Hatchery Committees October 18, 2017 meeting.

E. 2016 Chelan PUD and Grant PUD M&E Annual Report (Tracy Hillman)

Tracy Hillman reminded the Hatchery Committees that the Chelan PUD and Grant PUD 2016 Final M&E Annual Report and Appendices are now available for download from the Hatchery Committees Extranet site (note: Sarah Montgomery sent this information to the Hatchery Committees on September 15, 2017).

F. Chelan PUD and Grant PUD Hatchery Programs M&E Progress Report – August 2017 (Tracy Hillman)

Hillman shared the document, Chelan PUD and Grant PUD Hatchery Programs M&E Progress Report – August 2017 (Attachment F), which Sarah Montgomery distributed to the Hatchery Committees on September 19, 2017. He said in the section discussing 2016 Brood Nason Spring Chinook Salmon, there was an action that needs to be clarified. He said there was an over-production of both wild-by-wild (WxW) and hatchery-by-hatchery (HxH) spring Chinook salmon. As a result, a surplus of 41,263 HxH spring Chinook were released into Banks Lake. He said the remaining HxH Chinook salmon totals about 76,135 fish, which is below the production goal for this program (goal = 98,760 HxH fish). He said the over-production of WxW fish were marked as part of the safety-net program; thus, the safety-net program will meet its release target.

Keely Murdoch asked why the overage and subsequent release were not discussed with the Hatchery Committees before decisions were made. She said decisions to release fish to Banks Lake and to mark WxW fish as if they are HxH (ad-clip+coded wire tag [CWT]) does not reflect the purpose and spirit of the Hatchery Committees. Catherine Willard asked if there is a Hatchery Committees agreed-to policy for moving and tagging fish outside of what is described in broodstock collection protocols. Murdoch said the precedent is to discuss where and how to release excess fish as a committee. Mike Tonseth said some surplus management decisions and prioritizations are included in the broodstock collection protocols for steelhead, but not juvenile spring Chinook. He said an additional item to consider is that fish could not be transferred to the Chiwawa program because progeny of fish that would have had the highest assignments to the Chiwawa (from the composite brood collected at Tumwater for the Nason program) had already been comimingled with the rest of the Nason program which precluded being able to transfer those progeny to the Chiwawa program because Nason Creek is a composite program and Chiwawa is not. Tonseth said this should be discussed, so that if a surplus occurs again, particularly with WxW progeny, fish can be moved between programs to satisfy conservation targets. Peter Graf said protocols and permits should be reviewed and discussed to determine how to manage overages and balance conservation programs. He said Grant PUD has concerns about WxW fish being marked as ad-clip+CWT, and asked what the venue is for discussing these concerns.

Bill Gale said this should be discussed in both the Hatchery Committees and Priest Rapids Coordinating Committee Hatchery Sub-Committee meetings. Tonseth said presently, utilizing WxW overages in the Nason Creek program for the Chiwawa program would be inconsistent with current permits. He said pending consultation with NOAA and discussion with the Hatchery Committees and Hatchery Sub-Committee, surplus WxW fish in the Nason program may be able to be prioritized for the Chiwawa program if a deficit occurs and the ability to keep progeny of fish with the highest assignments to the Chiwawa can be reared separately until an overage or insufficiency can be identified. Tonseth suggested additional alternatives and stated that further discussion is required with NOAA and other agencies.

Keely Murdoch said she is not certain the outcome of this overage (transfer to Banks Lake) would have been the same if it were discussed with the Hatchery Committees. She said she is not sure whether YN would have supported marking WxW fish with HxH fish, or the transfer to Banks Lake. She said the Hatchery Committees should discuss the protocol and decision-making standards for this type of decision in the future, especially for transferring fish as it may influence contracting and mitigation credit.

Tonseth said each program has individual and total release targets, and he had to make an immediate decision regarding this overage. He said the issue that forced this decision was capacity. He said there are two points at which staff can estimate numbers of fish on hand—the eyed-egg stage and during tagging. He said during the eyed-egg stage, it appeared that there might be an overage, but not more than the acceptable 110% limit. He apologized for the lack in communication about the transfer and decision, and suggested that as many management caveats and options should be included in agreed-to protocols as possible. He said decisions like this can be avoided in the future if program prioritization is built into protocols. He said, for example, if there is a known group of fish with very high assignment rates, that group could be kept separate from rearing to tagging then potentially could be transferred to a different program. He summarized that better communication and building more options and caveats into agreed-to protocols will help prevent something like this from occurring again.

V. HCP Administration

A. Next Meetings

The next Hatchery Committees meetings are on October 18, 2017 (to be decided; perhaps Wells Fish Hatchery or Grant PUD), November 15, 2017 (Grant PUD), and December 20, 2017 (Grant PUD).

VI. List of Attachments

Attachment A List of Attendees

Attachment B	Draft Statement of Agreement Regarding the District's Coho Obligation
Attachment C	Transition Plan Outline
Attachment D	Lifecycle modeling in the Wenatchee River Basin
Attachment E	Draft 2017 Update - M&E Plan for PUD Hatchery Programs
Attachment F	Chelan PUD and Grant PUD Hatchery Programs M&E Progress Report – August 2017

Attachment A
List of Attendees

Name	Organization
Tracy Hillman	BioAnalysts, Inc.
Sarah Montgomery†	Anchor QEA, LLC
Catherine Willard*	Chelan PUD
Alene Underwood	Chelan PUD
Greg Mackey*	Douglas PUD
Tom Kahler*	Douglas PUD
Peter Graf‡	Grant PUD
Deanne Pavlik-Kunkel‡	Grant PUD
Curt Dotson†	Grant PUD
Mike Tonseth*	Washington Department of Fish and Wildlife
Andrew Murdoch	Washington Department of Fish and Wildlife
Alf Haukenes†	Washington Department of Fish and Wildlife
Bill Gale*	U.S. Fish and Wildlife Service
Michael Humling†	U.S. Fish and Wildlife Service
Brett Farman*†	National Marine Fisheries Service
Keely Murdoch*	Yakama Nation
Kirk Truscott*	Colville Confederated Tribes
Jeff Jorgensen	Ocean Associates, Inc.
Tom Skiles†	Columbia River Inter-Tribal Fish Commission
Denny Rohr†	D. Rohr and Associates

Notes:
* Denotes Hatchery Committees member or alternate
† Joined by phone
‡ Joined for the joint HCP-HC/PRCC HSC discussion

Rocky Reach and Rock Island HCP Hatchery Committees
DRAFT Statement of Agreement
Regarding District's Coho Obligation
September 20th, 2017

Deleted: August 16

Statement

The Rocky Reach and Rock Island HCP Hatchery Committees (hereafter "Committees") agree that Chelan PUD shall provide coho compensation for the Methow River and Wenatchee River sub-basins at a rate equivalent to 7.0% at each project to meet Chelan PUD's No Net Impact hatchery obligations for brood years 2017 to 2021 (release years 2019 to 2023); therefore, 7.0% will be used as the coho hatchery compensation rate until the next scheduled hatchery compensation recalculation (2023). Methodology described in the SOA Regarding the 2013 No Net Impact Recalculation Methodology (dated July 20th, 2011) will be used to calculate hatchery compensation levels for coho.

In order to meet this obligation, Chelan PUD and the Yakama Nation intend to enter into an agreement where Chelan PUD will provide funding for the Mid-Columbia Coho Reintroduction Project (facility use may be included as part of the agreement). As long as Chelan PUD is meeting the terms of the agreement with the Yakama Nation, and remains consistent with any future recalculated hatchery compensation obligations, the Committees agree that Chelan PUD is fulfilling its coho hatchery obligation for the term of the Rocky Reach and Rock Island Habitat Conservation Plans.

Background

On June 20, 2007, the Committees agreed to implement coho hatchery compensation as detailed in Section 8.4.3.a of the Rocky Reach and Rock Island HCPs and agreed that the District shall begin providing hatchery compensation no later than October 1, 2007. On March 28, 2017, the Rocky Reach and Rock Island Coordinating Committees agreed to use Chelan PUD's yearling Chinook acoustic tag survival estimates and coho PIT-tag based survival estimates to estimate juvenile coho survival of 93.98% at Rock Island and 92.94% at Rocky Reach (Skalski and Townsend 2017) which culminated in a 93% survival value at both projects.

Calculations for the Methow Sub-basin Coho Reintroduction Project

Deleted: Rocky Reach
Deleted: Obligation
Deleted: hatchery program

Compensation for **hatchery-origin smolts** will be determined by multiplying the Program's annual release targets from the Methow sub-basin coho reintroduction project by the unavoidable project mortality (1-(0.93 x 0.93)) for Rocky Reach and Rock Island.

Compensation for **natural-origin smolts** produced is determined by:

- Mean NOR[1] to Rocky Reach (return years 2008 to 2011 and 2013 to 2015) = 43
- Mean NOR in absence of project mortality: 43/0.9300 = 46
- Adult equivalents to meet NNI: 46-43=3
- Mean 8 year SAR (release years 2008-2015 Methow sub-basin hatchery program) = 0.59%
- Compensation for natural-origin smolts: 3/0.0059 = 508 smolts

Calculations for the Wenatchee Sub-basin Coho Reintroduction Project

Deleted: Rock Island
Deleted: Obligation
Deleted: hatchery program

Compensation for **hatchery-origin smolts** will be determined by multiplying the Program's annual release targets from the Wenatchee sub-basin coho reintroduction project by the unavoidable project mortality (1-0.93) for Rock Island.

Compensation for **natural-origin smolts** is determined by:

- Mean NOR to Rock Island (return years 2007-2016) = 529
- Mean NOR in absence of project mortality: 529/0.9300 = 569
- Adult equivalents to meet NNI: 569-529 = 40
- Mean 10 year SAR[2] (release years 2006-2015 Wenatchee sub-basin hatchery program) = 0.75%
- Compensation for natural-origin smolts: 40/0.0075 = 5,333 smolts

[1]Natural-origin return=NOR
[2]SAR=releases from the Wenatchee hatchery programs and returns to Priest Rapids Dam (versus Rock Island Dam due to historic variable PIT tag detection efficiency at the adult ladders).

TRANSITION PLAN FOR WELLS AND METHOW FISH HATCHERIES

WELLS HYDROELECTRIC PROJECT NO. 2149

September 13, 2017

1.0 Personnel and Staffing

1.1 Timing and Strategy for Hiring Personnel

1.2 Job Descriptions

1.3 Duties

- 1.3.1 Worker Training
- 1.3.2 Certifications
- 1.3.3 PUD Strategic Plan and Administrative Bulletin
- 1.3.4 Compensation

2.0 Culture/Tone of Work Place

3.0 Collective Bargaining Status

4.0 Fish Accounting Pre and Post Transition

4.1 Permits

- 4.1.1 ESA Permits
- 4.1.2 NPDES Permits
- 4.1.3 Hydraulic Permit Application
- 4.1.4 Fish Transfer Permits

5.0 Monitoring and Evaluation Plan

6.0 Pathology

7.0 Outreach Plan

8.0 Marking Plan

9.0 Trapping

10.0 Adult Management and Surplusing

11.0 Fish Husbandry

- 11.1 Fish Feed Contract

12.0 Equipment Inventory

- 12.1 Transfer titles
- 12.2 Insurance

13.0 Housing

- 13.1 Titles for Houses
- 13.2 Land Titles
- 13.3 Upgrades

14.0 Computers, Phones and Communication Equipment

- 14.1 Software Technology

15.0 Hazard Materials List

16.0 Security Badges

17.0 Keys

18.0 Off-license Settlement

Life cycle modeling in the Wenatchee River Basin

Jeff Jorgensen
OAI, contracted to NWFSC

Columbia River Basin LCMs in the literature and reviewed

- Kareiva et al. 2000; Zabel et al. 2006; Crozier et al. 2008, 2010
- ISAB reviews: 2013, 2017

$$\mathbf{n}(t+1) = \mathbf{A}(t) \cdot \mathbf{n}(t)$$

$$\mathbf{n}_t = \begin{bmatrix} n_1 \\ n_2 \\ n_3 \\ n_4 \\ n_5 \end{bmatrix}$$

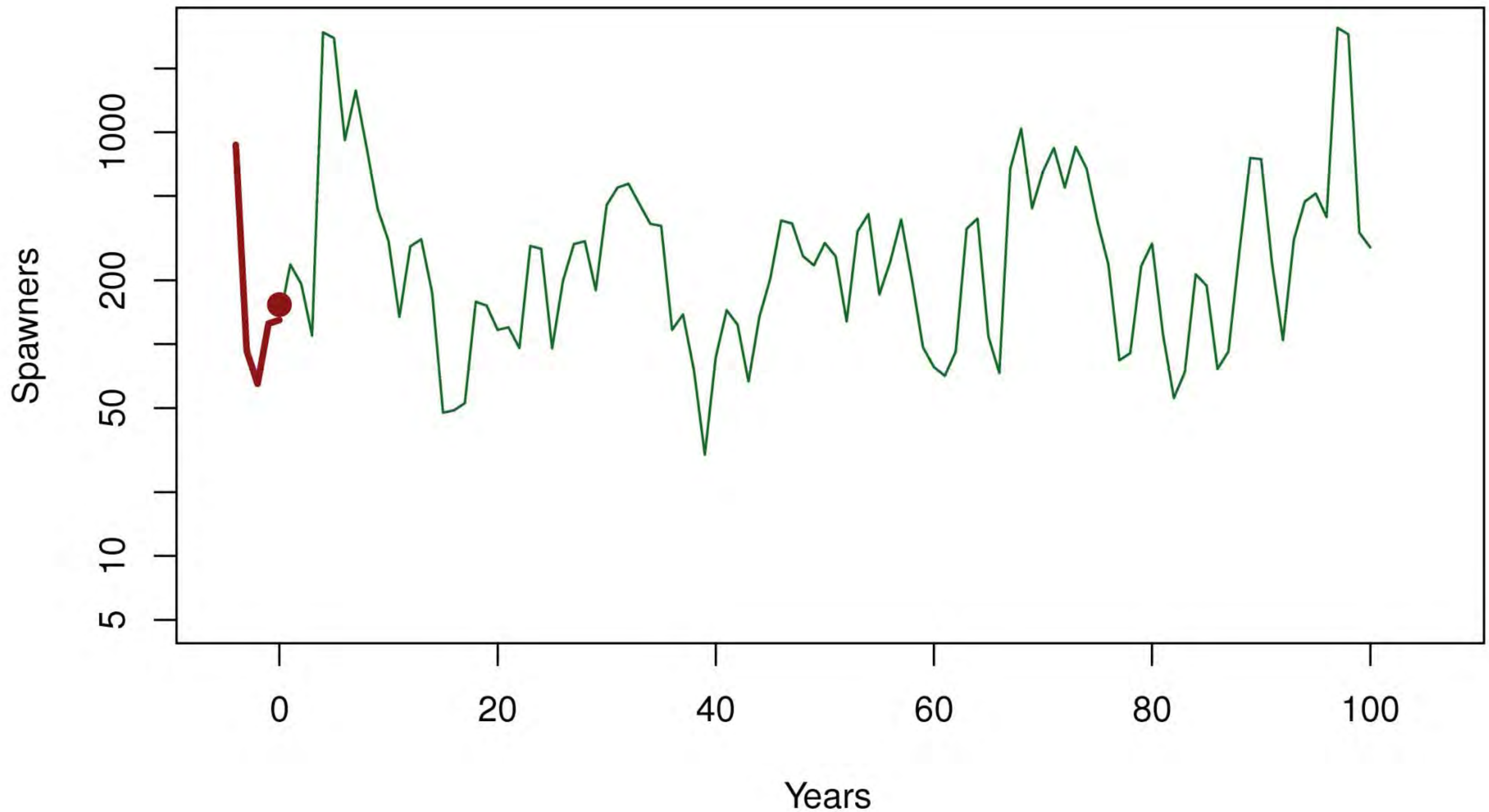
$$\mathbf{A}(t) = \begin{bmatrix} 0 & 0 & 0 & b_4 \cdot s_A \cdot F_4(t) & s_A \cdot F_5(t) \\ s_2 & 0 & 0 & 0 & 0 \\ 0 & s_3(t) & 0 & 0 & 0 \\ 0 & 0 & (1-b_3) \cdot s_o & 0 & 0 \\ 0 & 0 & 0 & (1-b_4) \cdot s_o & 0 \end{bmatrix}$$

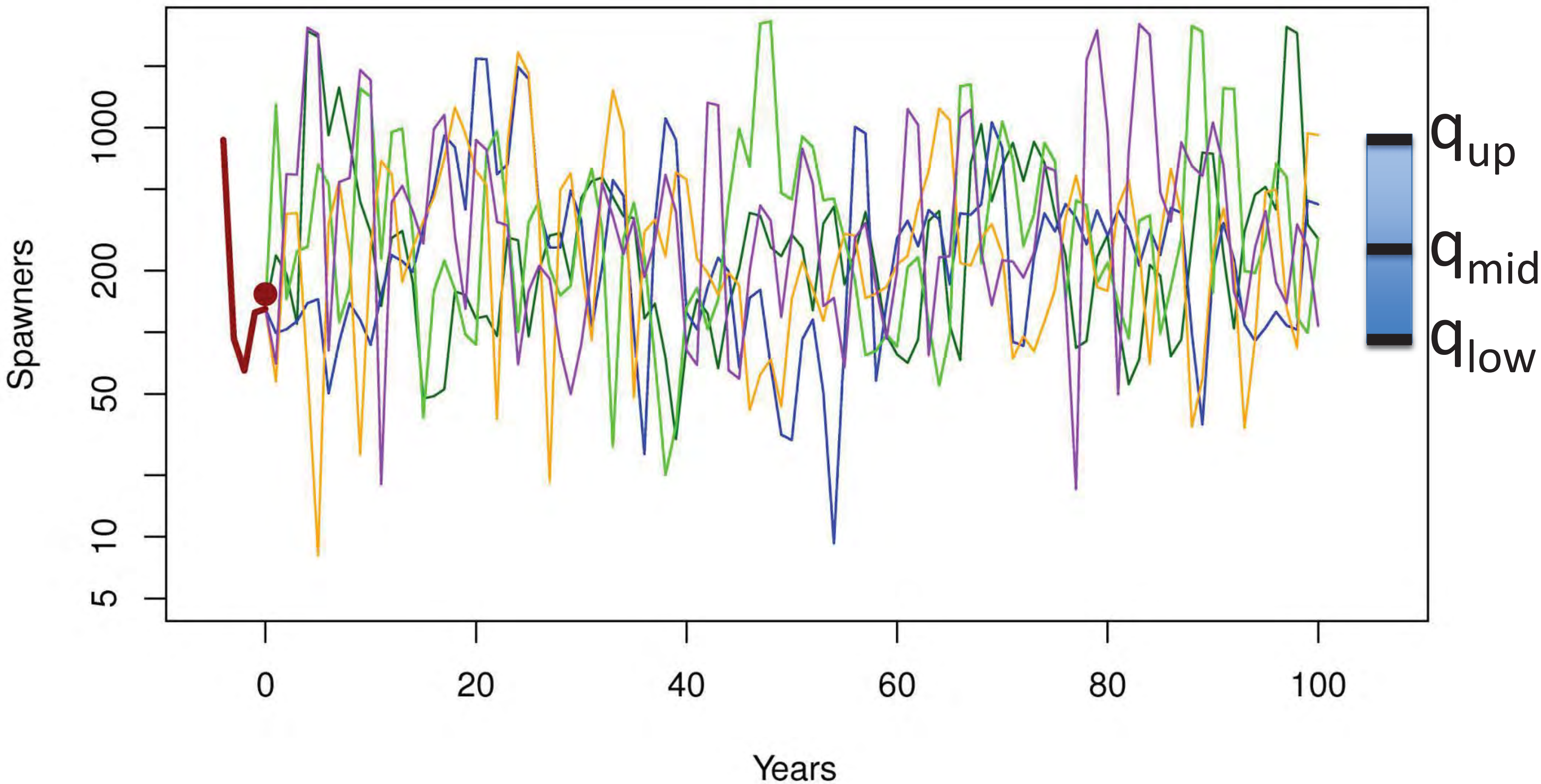
(Zabel et al. 2006)

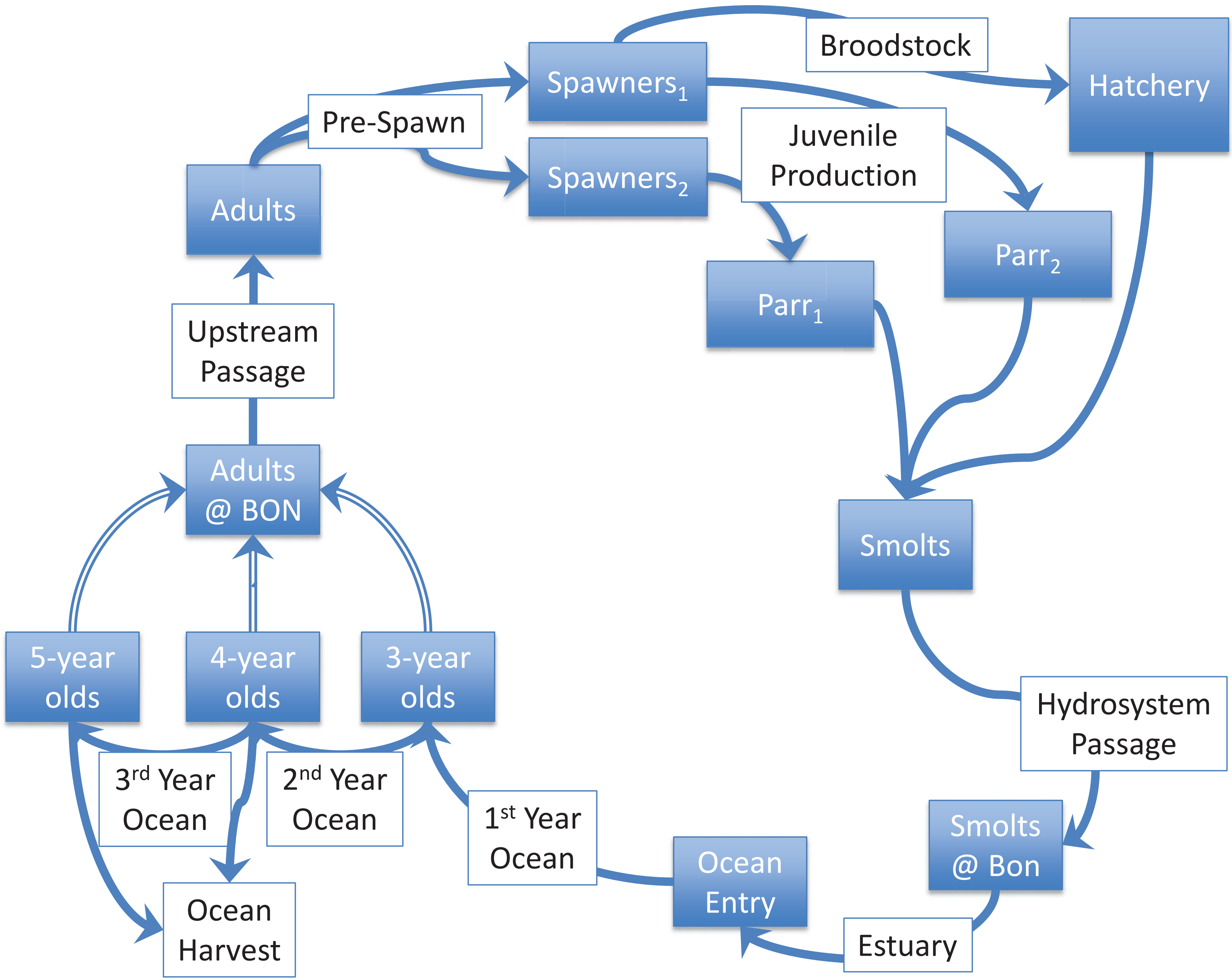
$$\mathbf{n}(t+1) = \mathbf{A}(t) \cdot \mathbf{n}(t)$$

$$\mathbf{n}_t = \begin{bmatrix} n_{1,1} & n_{1,2} & \cdots & n_{1,n} \\ n_{2,1} & n_{2,2} & \cdots & n_{2,n} \\ \vdots & \vdots & \ddots & \vdots \\ n_{5,1} & n_{5,2} & \cdots & n_{5,n} \end{bmatrix}$$

$$\mathbf{A}(t) = \begin{bmatrix} 0 & 0 & 0 & b_4 \cdot s_A \cdot F_4(t) & s_A \cdot F_5(t) \\ s_2 & 0 & 0 & 0 & 0 \\ 0 & s_3(t) & 0 & 0 & 0 \\ 0 & 0 & (1-b_3) \cdot s_o & 0 & 0 \\ 0 & 0 & 0 & (1-b_4) \cdot s_o & 0 \end{bmatrix}$$

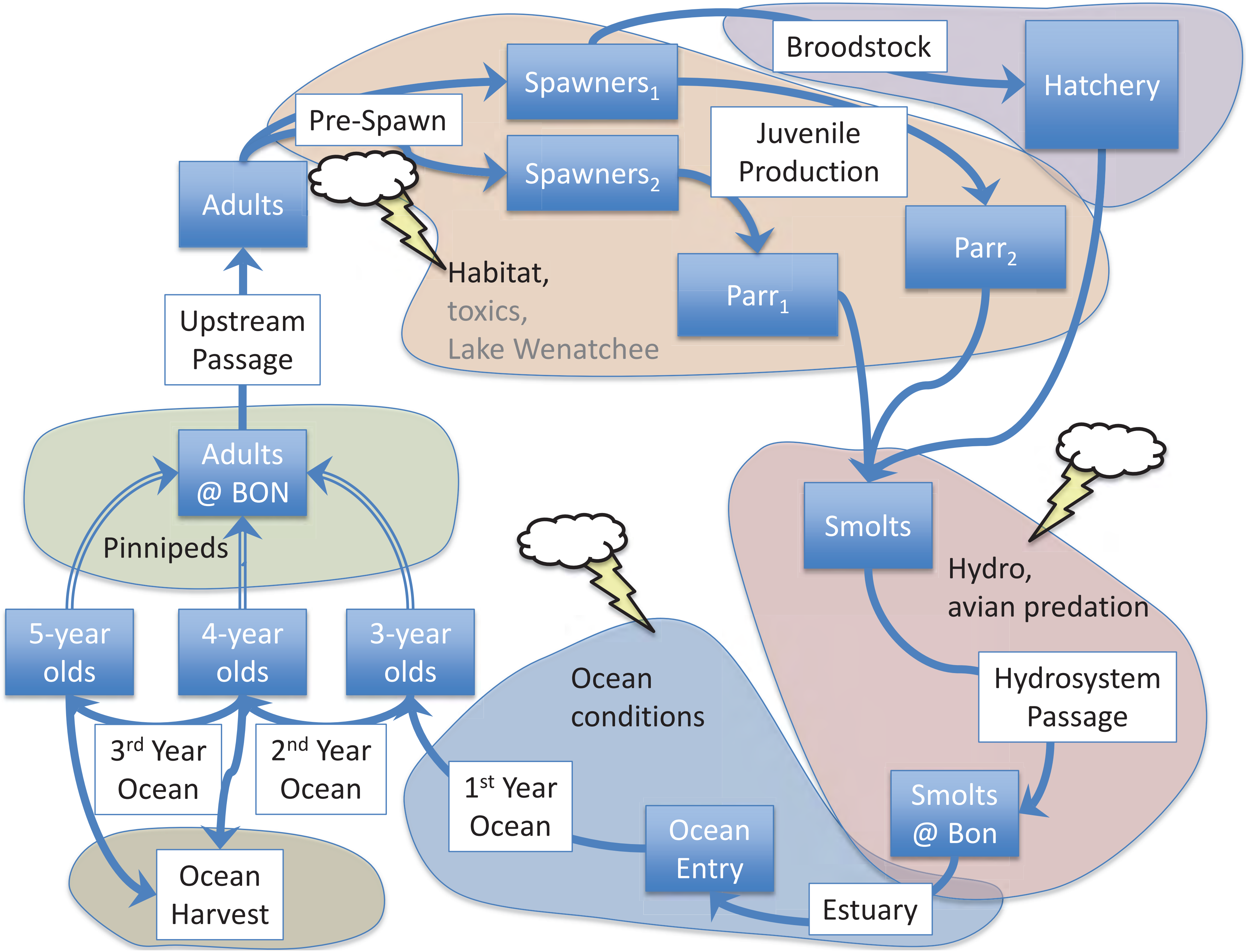

Spawners
1000
200
50
10
5
0
20
40
60
80
100
Years


Spawners
1000
200
50
10
5
0
20
40
60
80
100
Years
q_{up}
q_{mid}
q_{low}

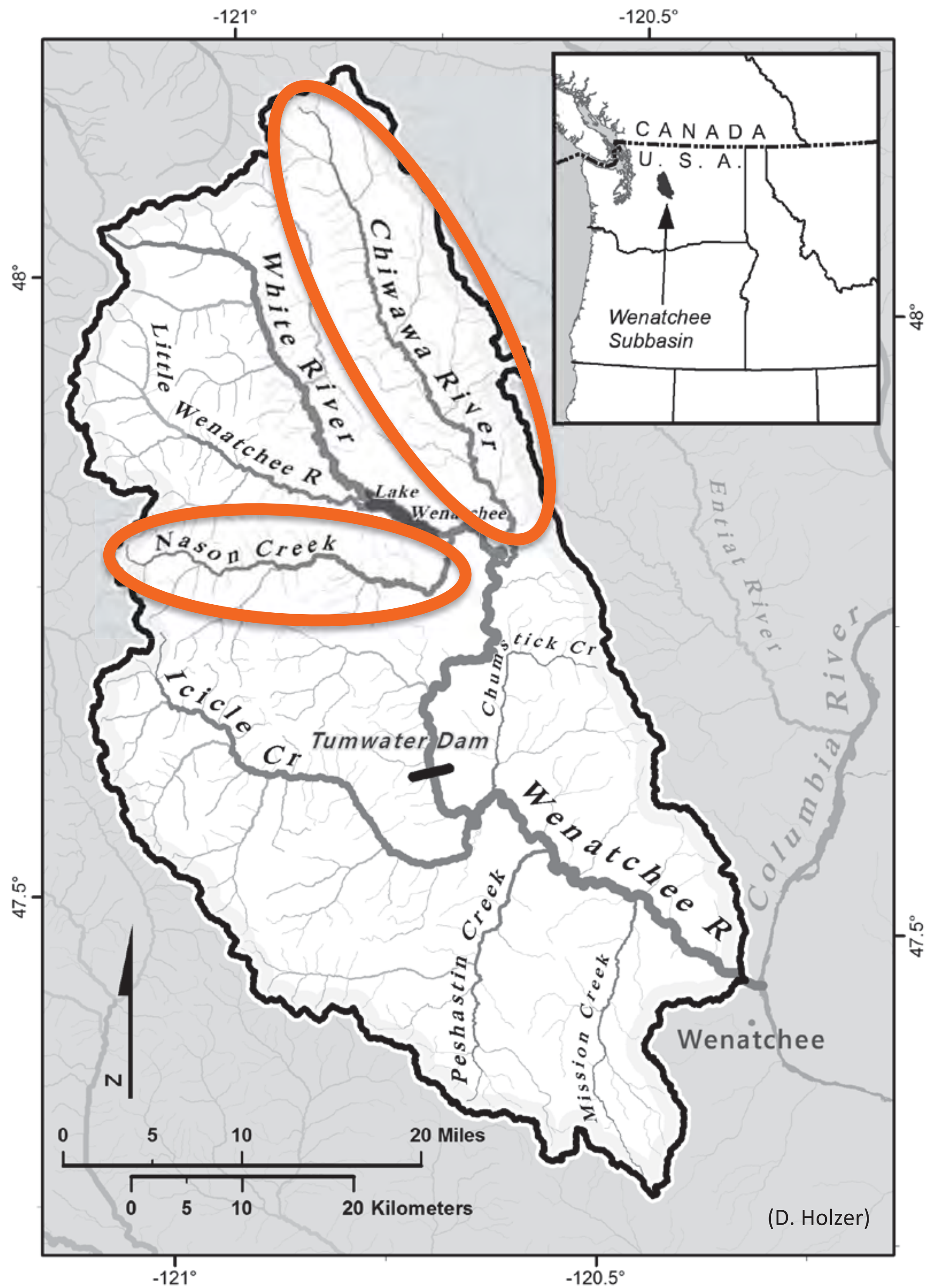


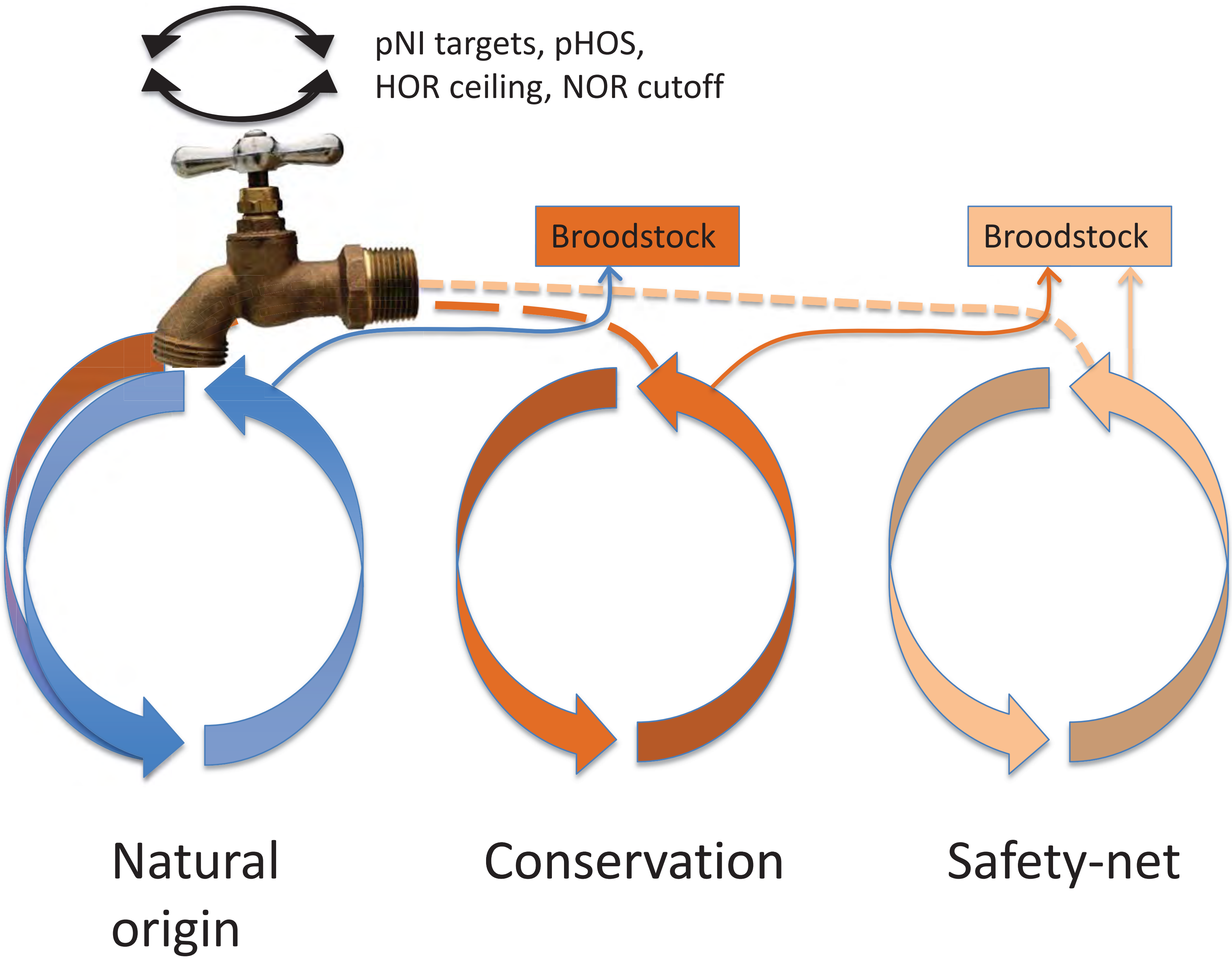
Broodstock
Hatchery
Spawners$_1$
Spawners$_2$
Pre-Spawn
Juvenile Production
Adults
Parr$_2$
Parr$_1$
Upstream Passage
Adults @ BON
Smolts
5-year olds
4-year olds
3-year olds
Hydrosystem Passage
3rd Year Ocean
2nd Year Ocean
1st Year Ocean
Smolts @ Bon
Ocean Entry
Ocean Harvest
Estuary

Attachment D

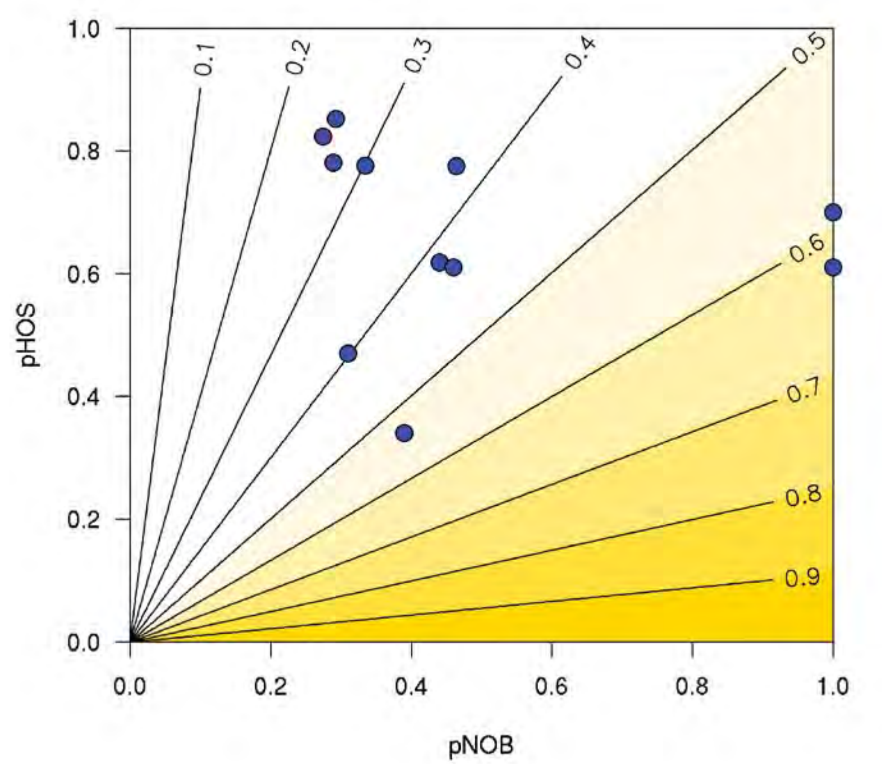


Attachment D

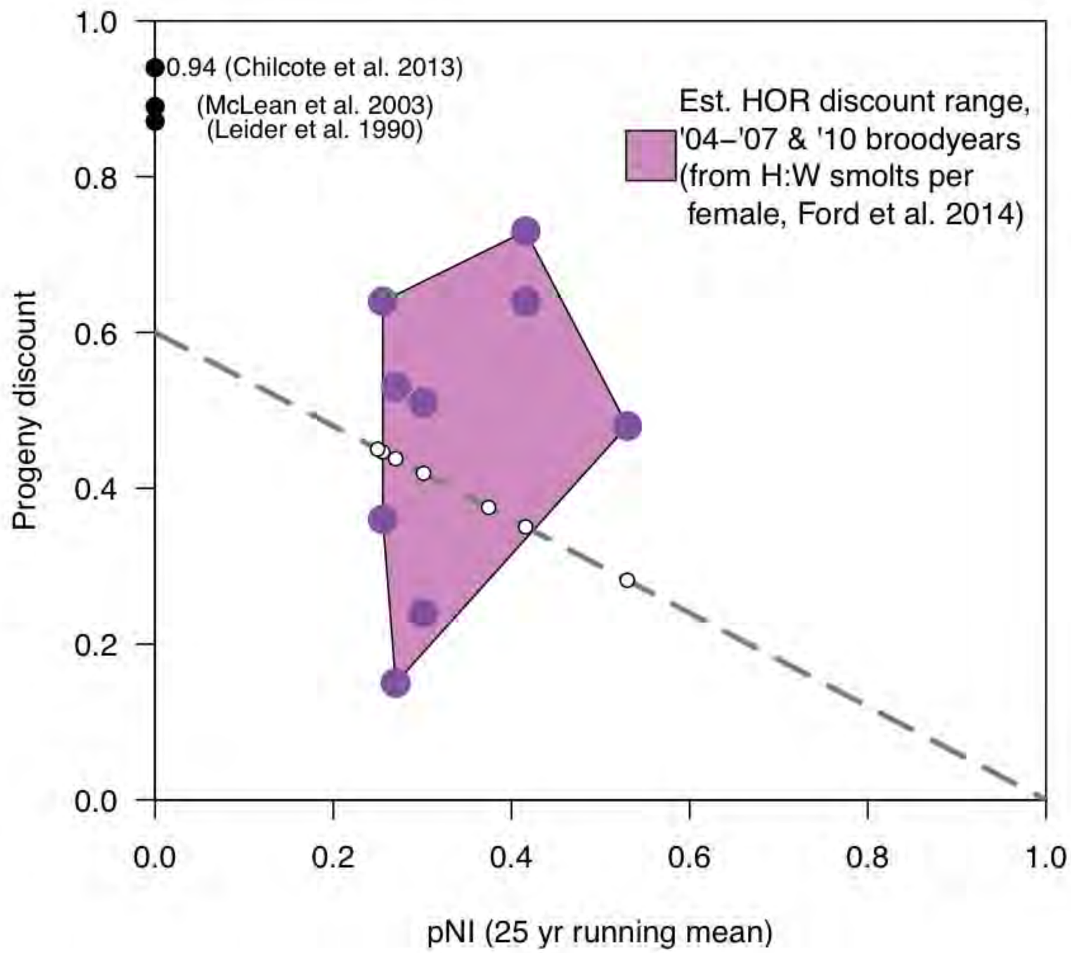



pNI targets, pHOS,
HOR ceiling, NOR cutoff
Broodstock
Broodstock
Natural origin
Conservation
Safety-net

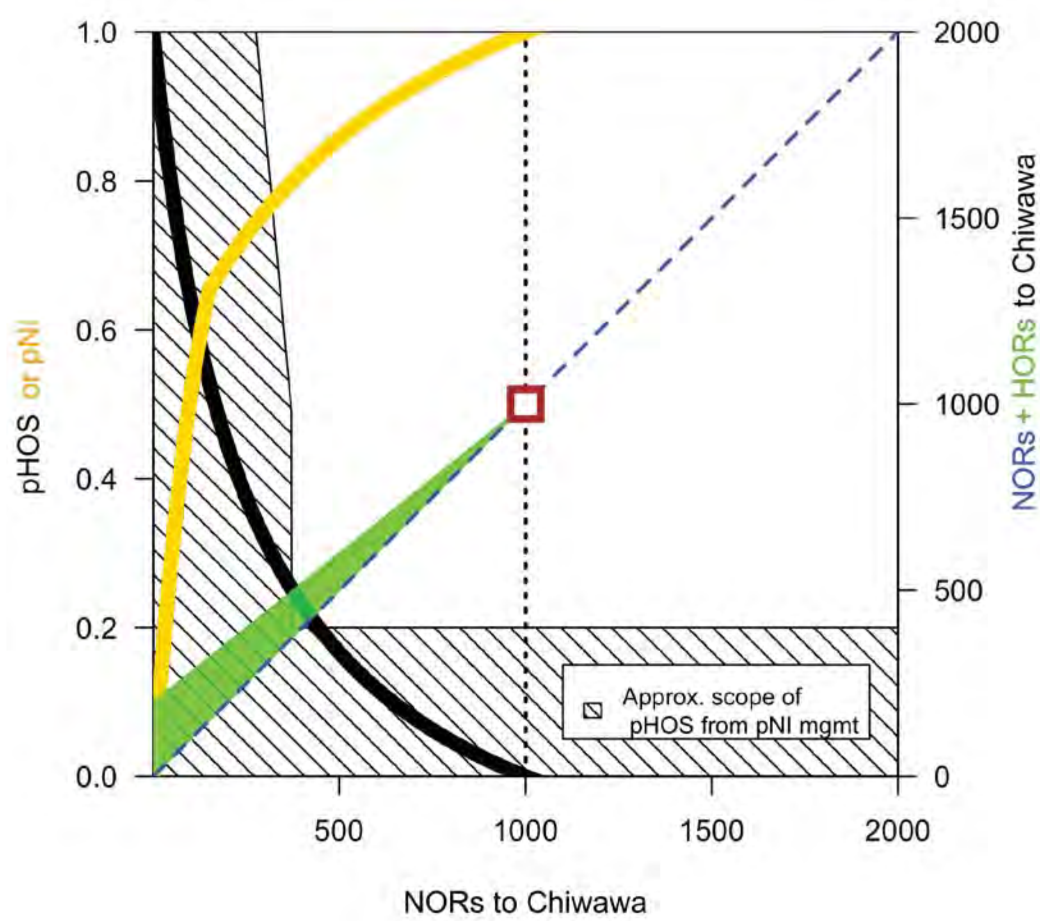
$$pNI = \frac{pNOB}{(pNOB + pHOS)}$$



Percentile	Chiwawa River	Nason Creek	Wenatchee basin	pNI
>75%	>372	>350	>910	≥0.80
50% – 75%	278 – 372	259 – 349	631 – 909	≥0.67
25% – 50%	208 – 277	176 – 258	525 – 630	≥0.50
10% – 25%	176 – 207	80 – 175	400 – 524	≥0.40
<10%	<176	<80	<400	Any pNI



1.0
0.8
0.6
0.4
0.2
0.0
Progeny discount
0.94 (Chilcote et al. 2013)
(McLean et al. 2003)
(Leider et al. 1990)
Est. HOR discount range,
'04–'07 & '10 broodyears
(from H:W smolts per
female, Ford et al. 2014)
0.0
0.2
0.4
0.6
0.8
1.0
pNI (25 yr running mean)

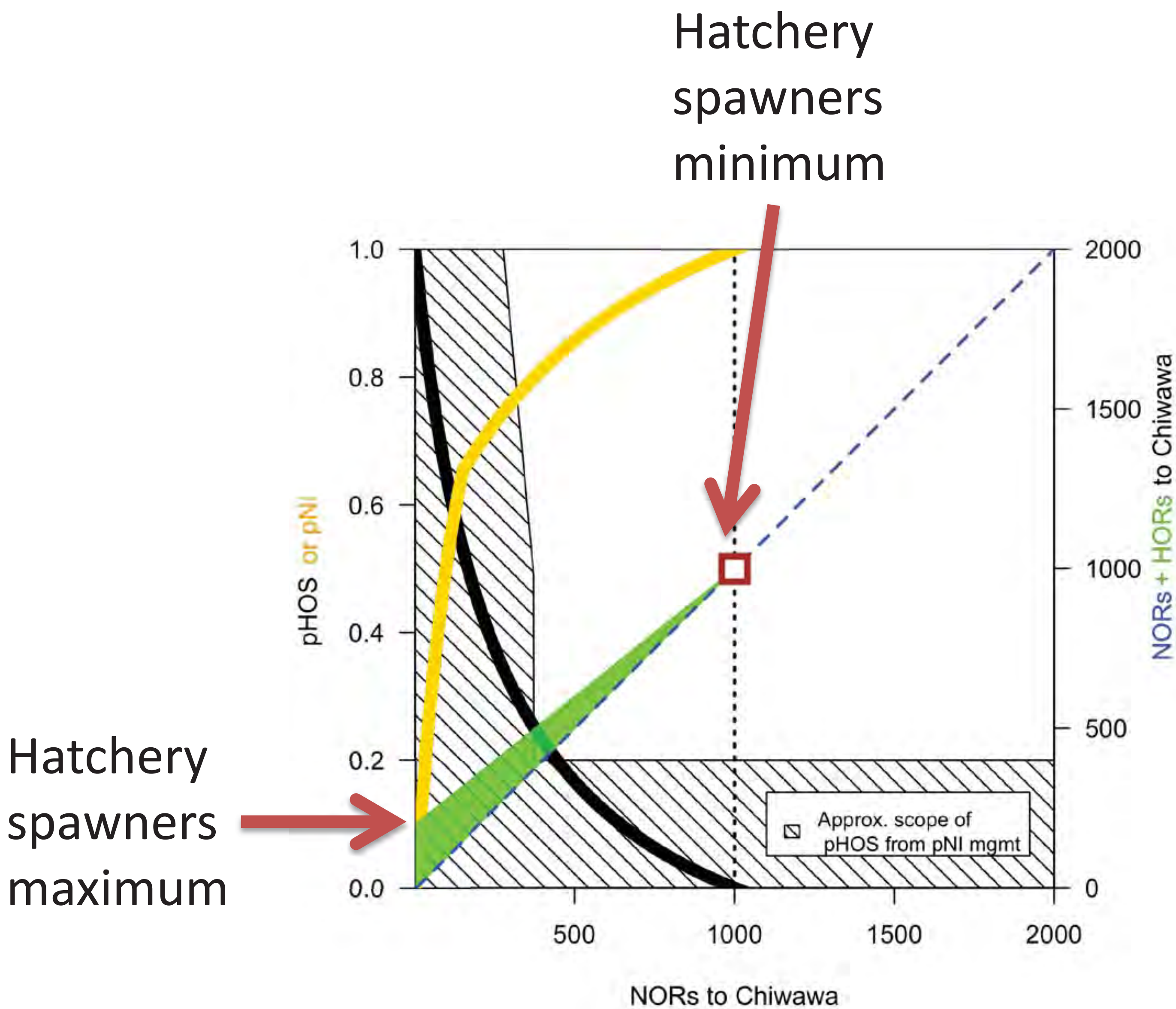

pHOS or pNI
1.0
0.8
0.6
0.4
0.2
0.0
500
1000
1500
2000
NORs to Chiwawa
NORs + HORs to Chiwawa
2000
1500
1000
500
0
Approx. scope of pHOS from pNI mgmt

Evaluation of hatchery programs

- Broodstock collection levels
- Numbers of smolt releases
- Max of hatchery fish spawning in wild at low NOR
- Min of hatchery fish spawning in wild at high NOR
- Domestication discount (slope, intercept, shape)

Evaluation of hatchery programs

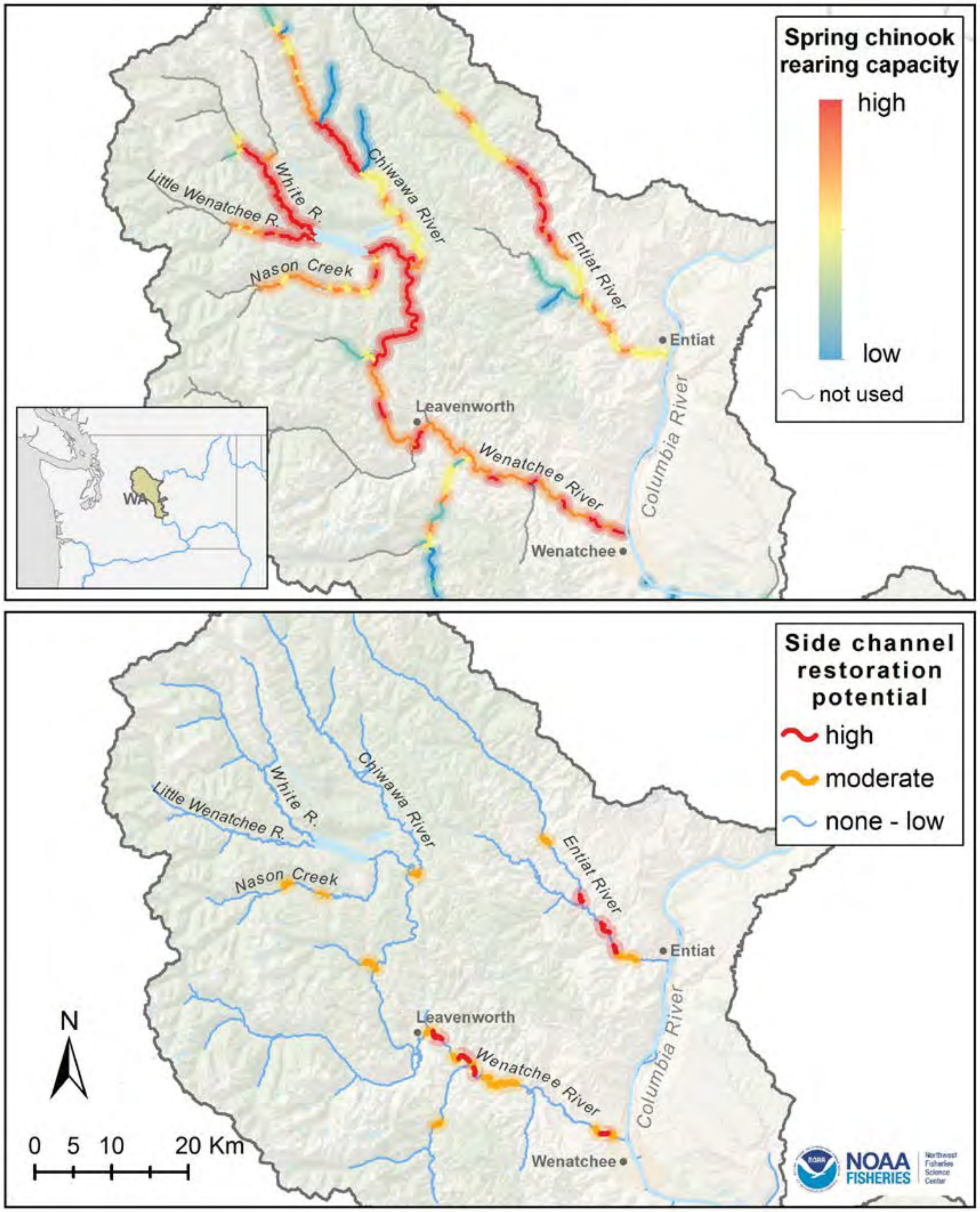
- Broodstock collection levels
- Numbers of smolt releases
- **Max of hatchery fish spawning in wild at low NOR**
- **Min of hatchery fish spawning in wild at high NOR**
- Domestication discount (slope, intercept, shape)

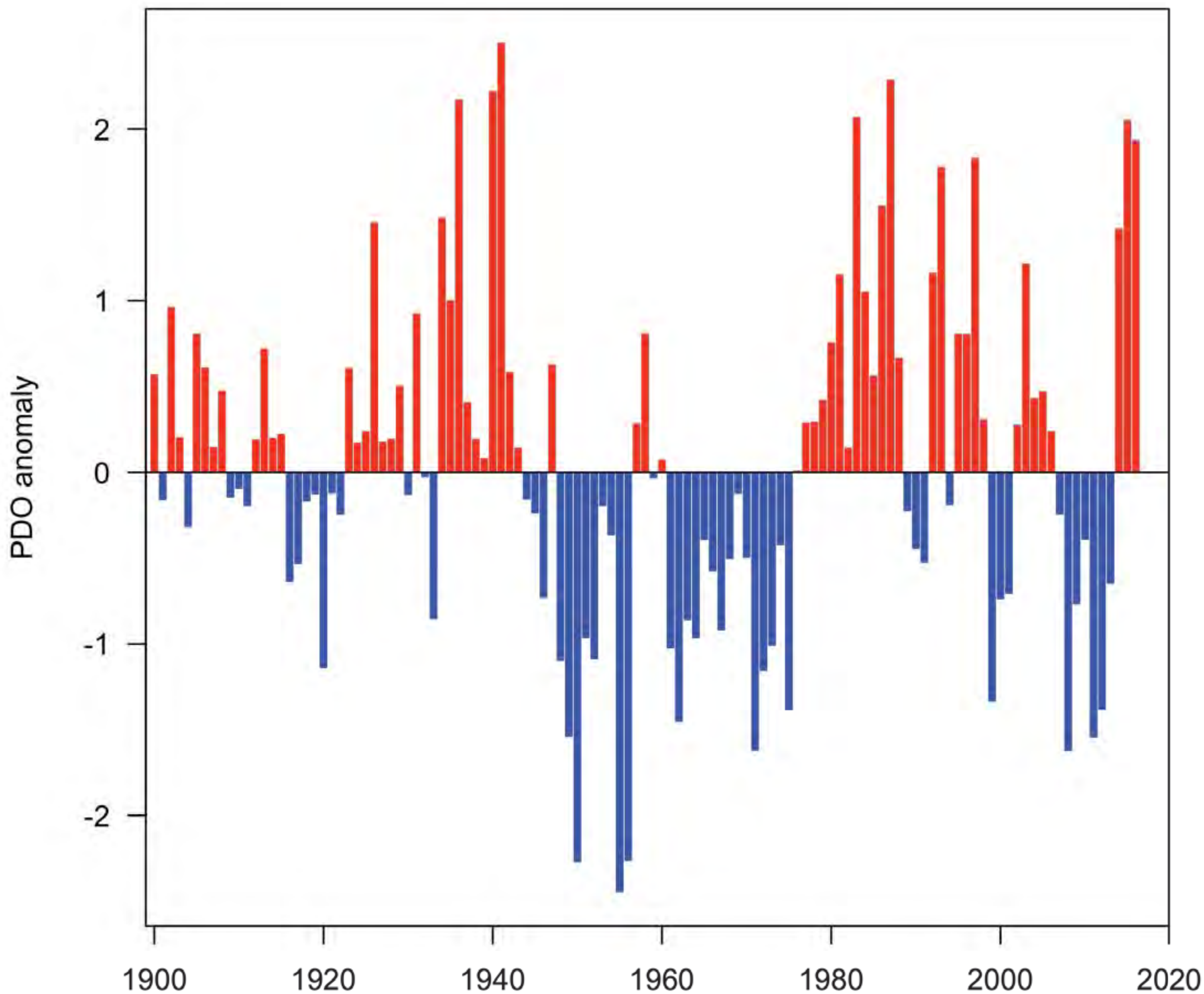

Hatchery spawners minimum
Hatchery spawners maximum
1.0
0.8
0.6
0.4
0.2
0.0
pHOS or pNI
500
1000
1500
2000
NORs to Chiwawa
2000
1500
1000
500
0
NORs + HORs to Chiwawa
Approx. scope of pHOS from pNI mgmt

Scenarios

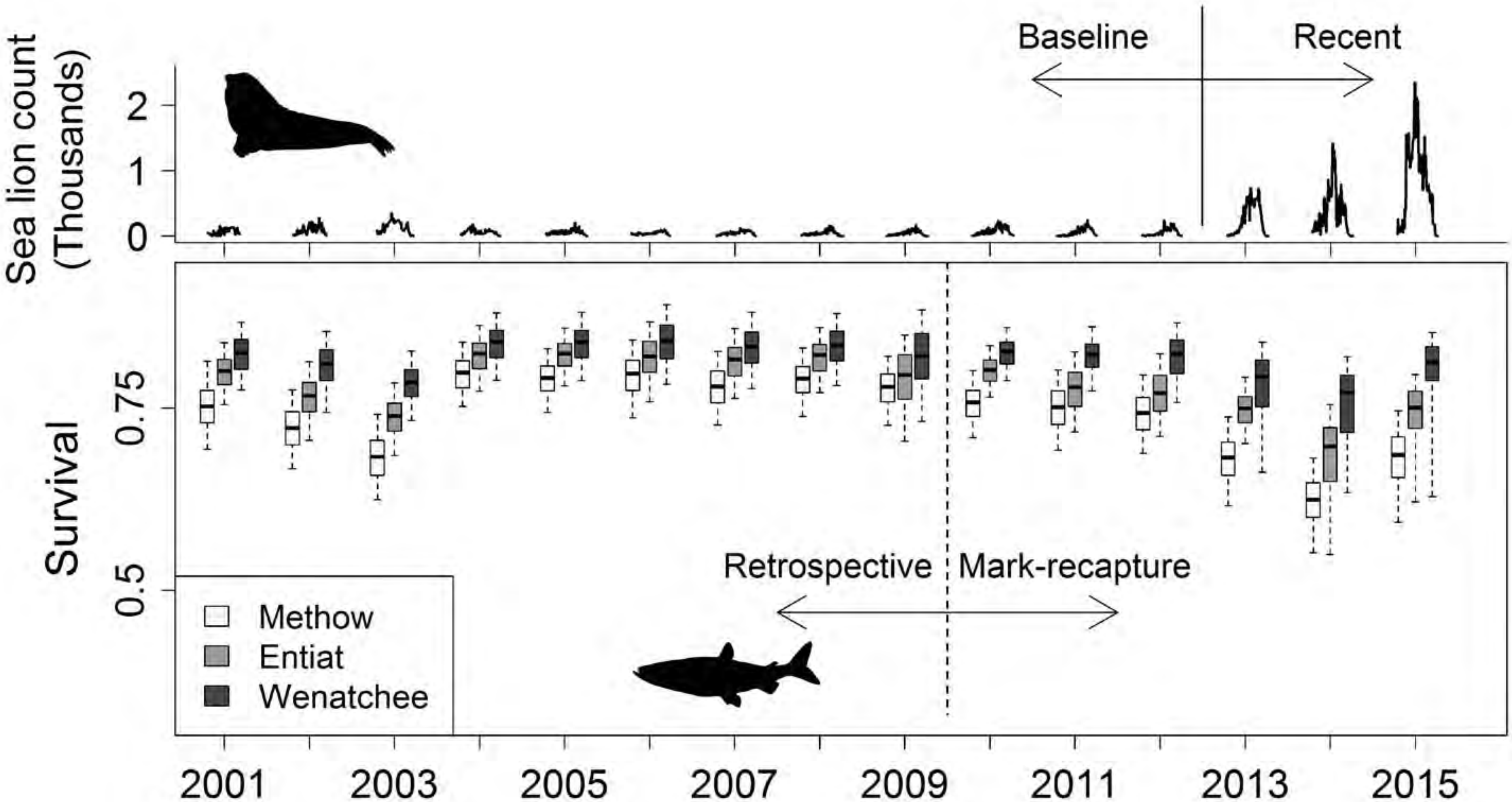
- Hatchery
- Habitat
- Lake Wenatchee
- Toxics
- Hydro
- Avian predation
- Ocean
- Harvest
- Pinnipeds

Wenatchee/Entiat Basins





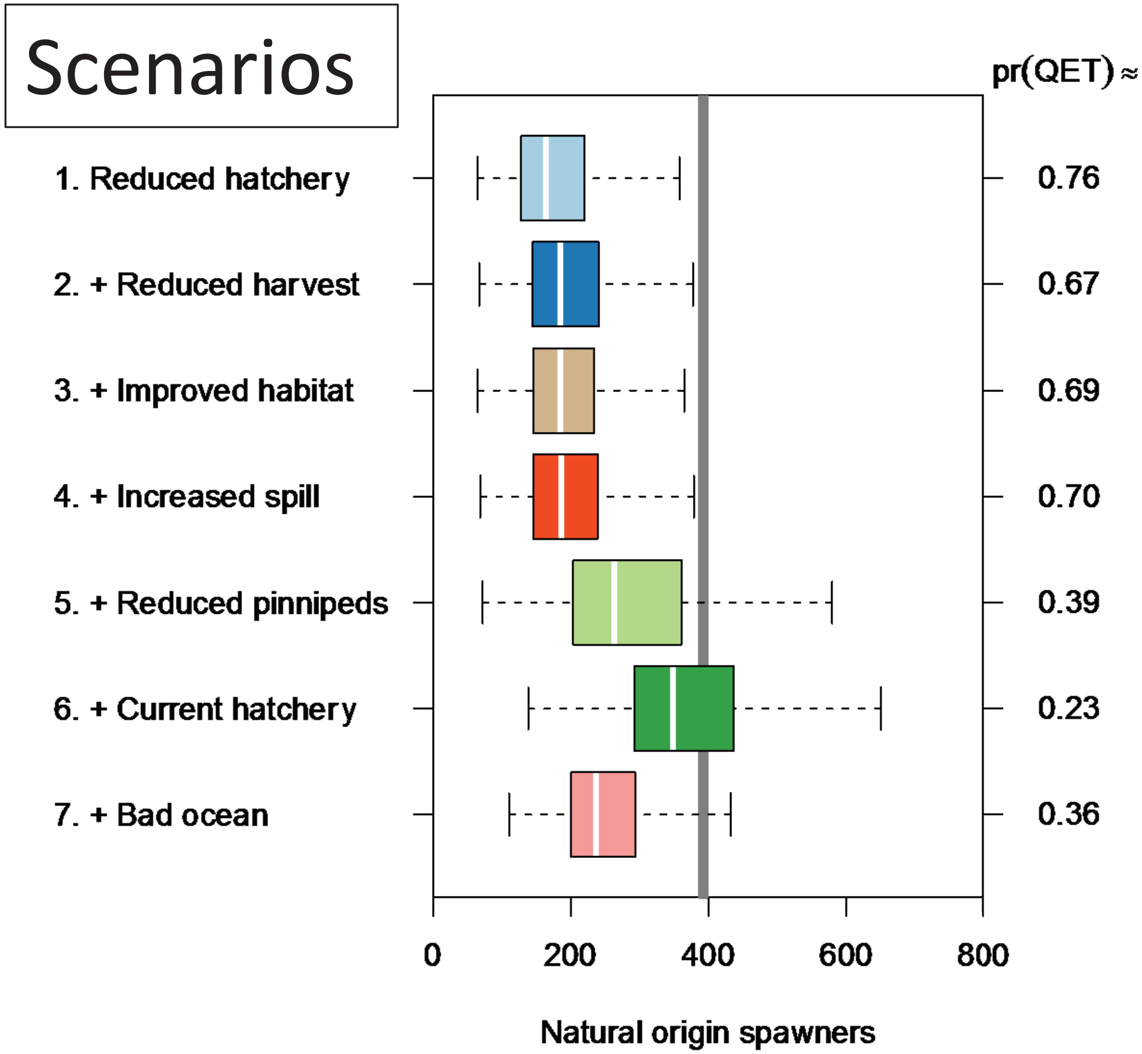
PDO anomaly
2
1
0
-1
-2
1900
1920
1940
1960
1980
2000
2020

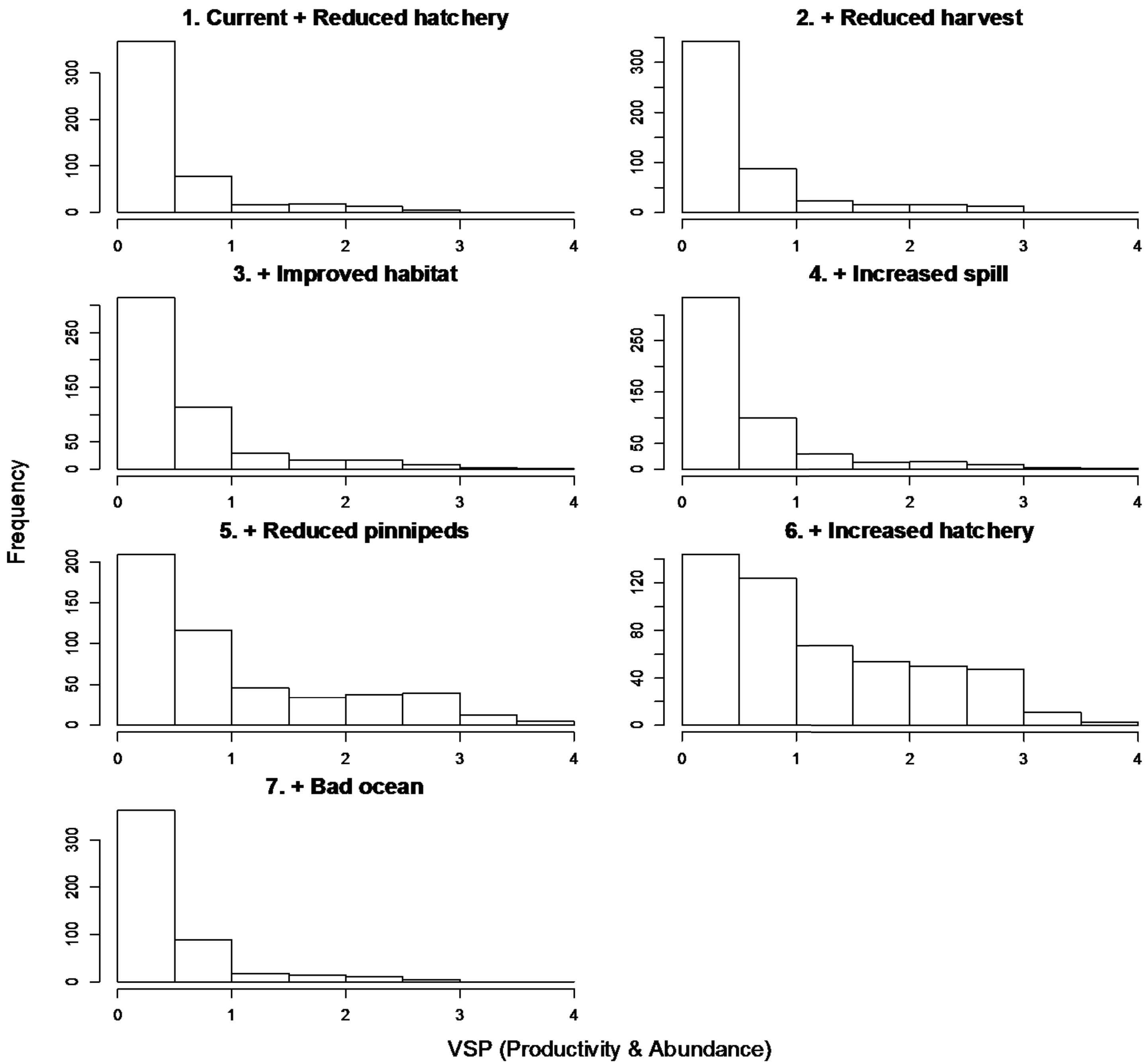


Sorel et al. in prep

Scenarios

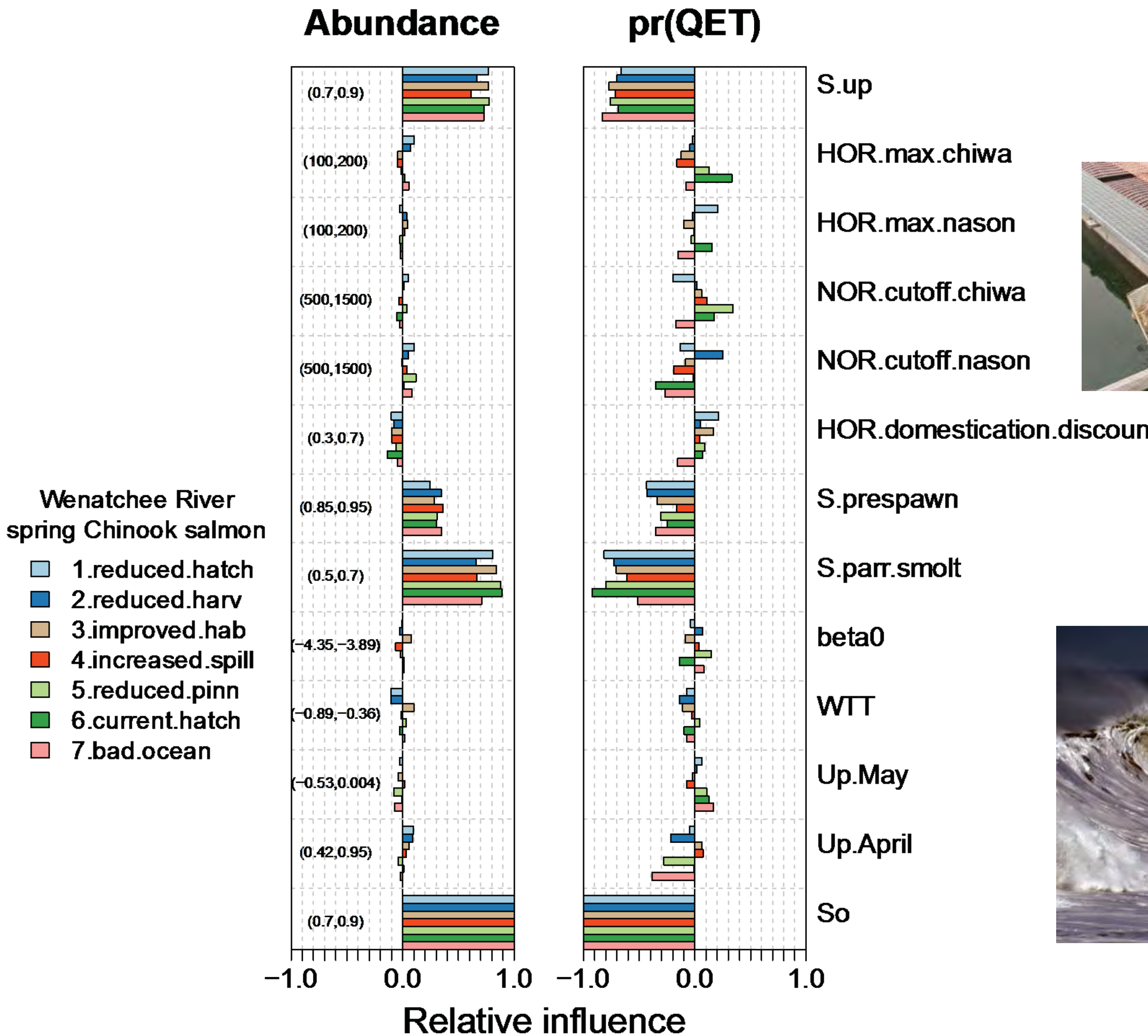
#	Harvest	Habitat	Hydro	Pinnipeds	Hatchery	Ocean
1	Current	Current	Current	Higher	Reduced	Recent
2	**Reduced**	Current	Current	Higher	Reduced	Recent
3		**Improved**	Current	Higher	Reduced	Recent
4			**Improved**	Higher	Reduced	Recent
5				**Reduced**	Reduced	Recent
6					**Current**	Recent
7						**Bad**

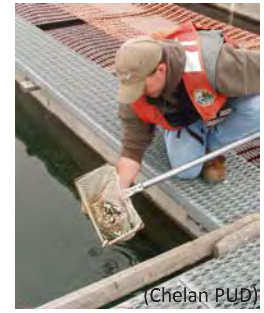

Scenarios
pr(QET) ≈
1. Reduced hatchery
2. + Reduced harvest
3. + Improved habitat
4. + Increased spill
5. + Reduced pinnipeds
6. + Current hatchery
7. + Bad ocean
0.76
0.67
0.69
0.70
0.39
0.23
0.36
0
200
400
600
800
Natural origin spawners


1. Current + Reduced hatchery
2. + Reduced harvest
3. + Improved habitat
4. + Increased spill
5. + Reduced pinnipeds
6. + Increased hatchery
7. + Bad ocean
Frequency
VSP (Productivity & Abundance)
0
1
2
3
4
0
100
200
300
50
150
250
40
80
120

Model outputs

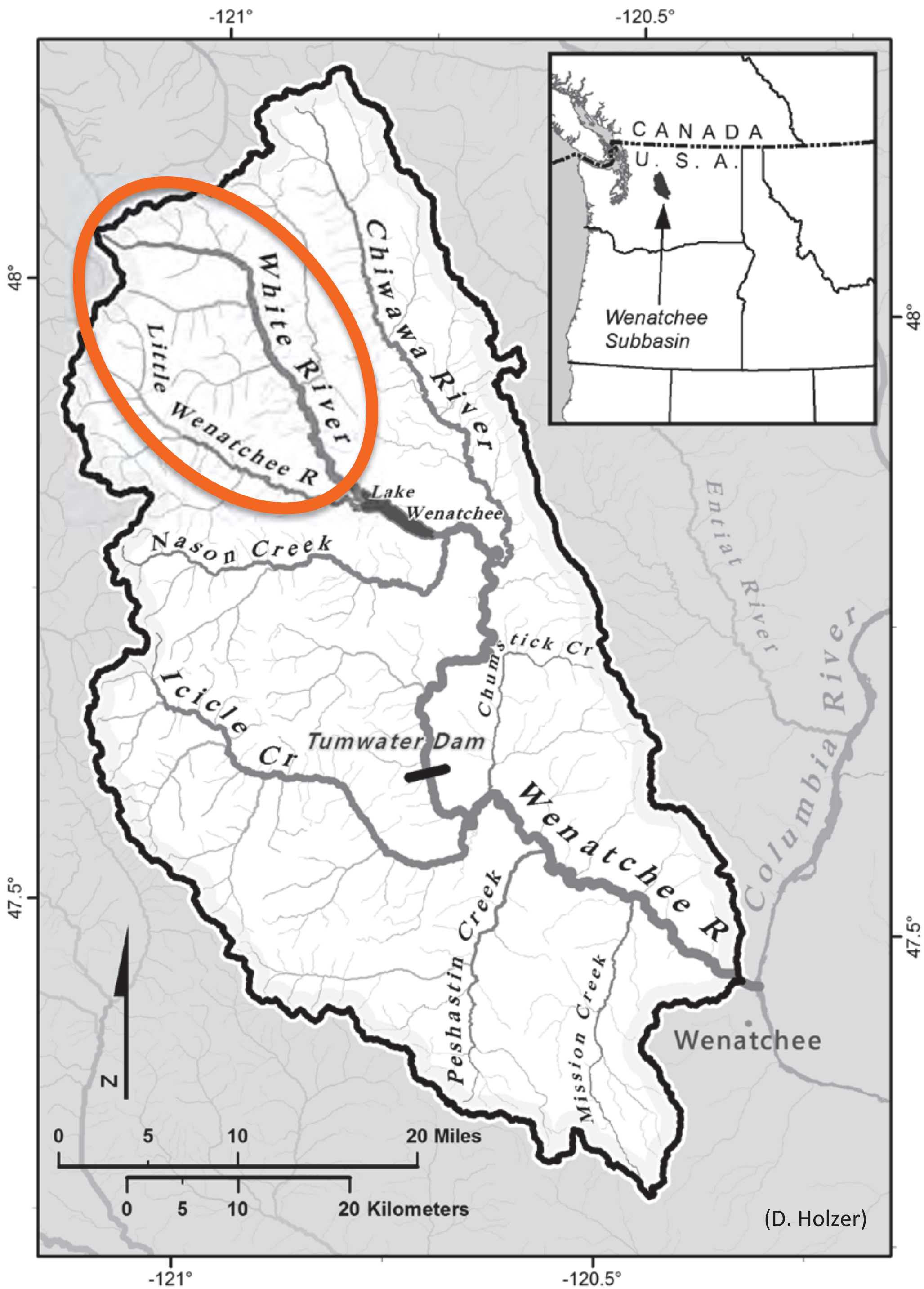
- Spawning adults
- QET
- VSP (A & P)
- pNI, pHOS, pNOB
- Productivity; recruits per spawner
- Smolts


Abundance
pr(QET)
Wenatchee River
spring Chinook salmon
1.reduced.hatch
2.reduced.harv
3.improved.hab
4.increased.spill
5.reduced.pinn
6.current.hatch
7.bad.ocean
(0.7,0.9)
(100,200)
(100,200)
(500,1500)
(500,1500)
(0.3,0.7)
(0.85,0.95)
(0.5,0.7)
(−4.35,−3.89)
(−0.89,−0.36)
(−0.53,0.004)
(0.42,0.95)
(0.7,0.9)
S.up
HOR.max.chiwa
HOR.max.nason
NOR.cutoff.chiwa
NOR.cutoff.nason
HOR.domestication.discount
S.prespawn
S.parr.smolt
beta0
WTT
Up.May
Up.April
So
−1.0
0.0
1.0
−1.0
0.0
1.0
Relative influence

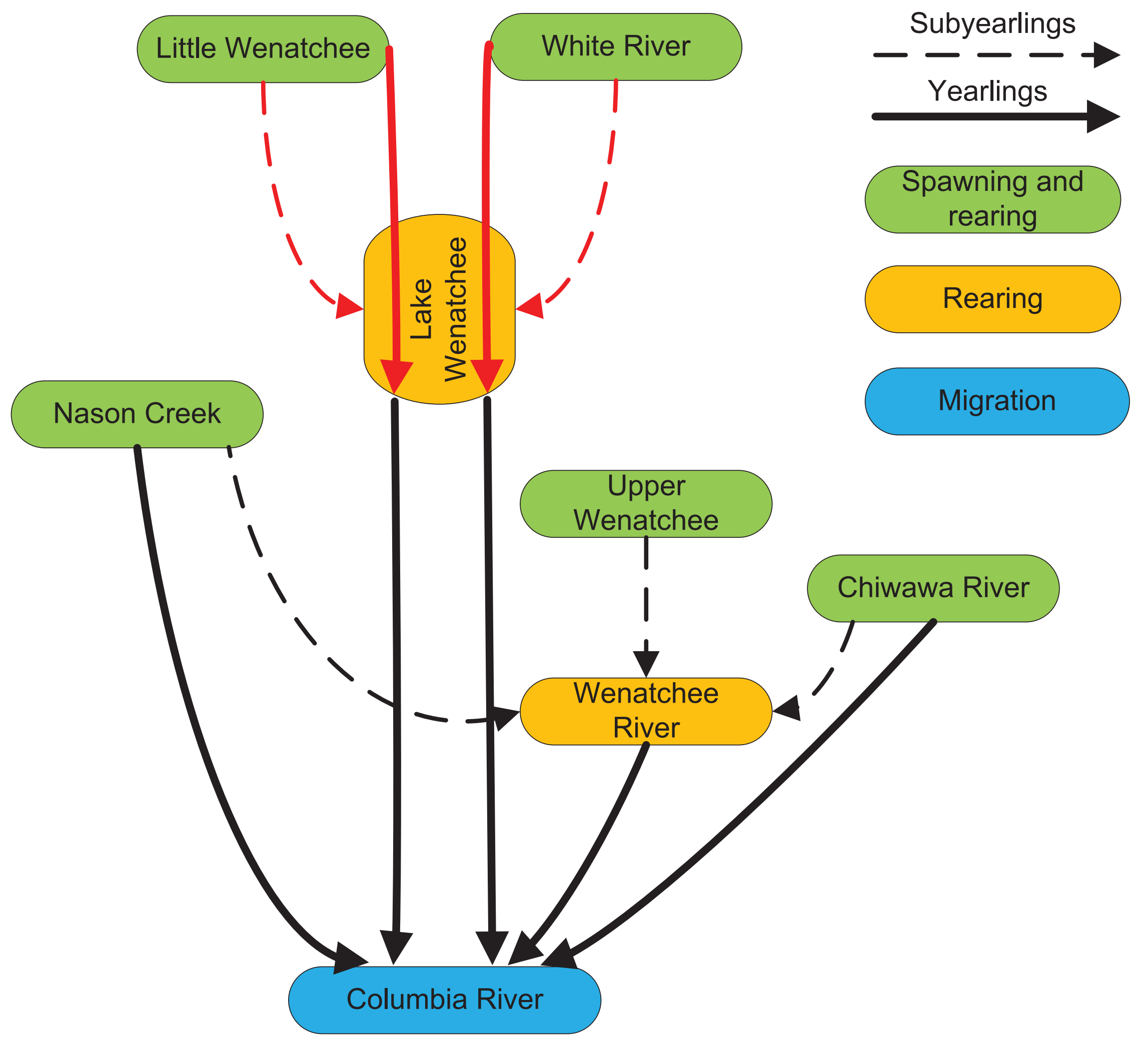

(Chelan PUD)

Lake Wenatchee

Attachment D



Juvenile Life History Strategies



Potential Scenarios

#	Hatchery	Habitat (eggs)	Habitat (parr)	Habitat (lake)	Lake survival
1	Current	Current	Current	Current	Current
2	**75,000**	Current	Current	Current	Current
3	Current	**Improved**	Current	Current	Current
4	Current	Current	**Improved**	Current	Current
5	Current	Current	Current	**Improved**	Current
6	Current	Current	Current	Current	**Improved**
7	**40,000**	Current	Current	Current	**Improved**
8	Current	**Improved**	**Improved**	Current	**Improved**
9	**HSC defined**	**HSC defined**	**HSC defined**	**HSC defined**	**HSC defined**

Potential LCM outputs

- Change in number of smolts leaving Lake Wenatchee
- Change in natural origin spawners
- Change in population QET
- Change in VSP scores
- Other?

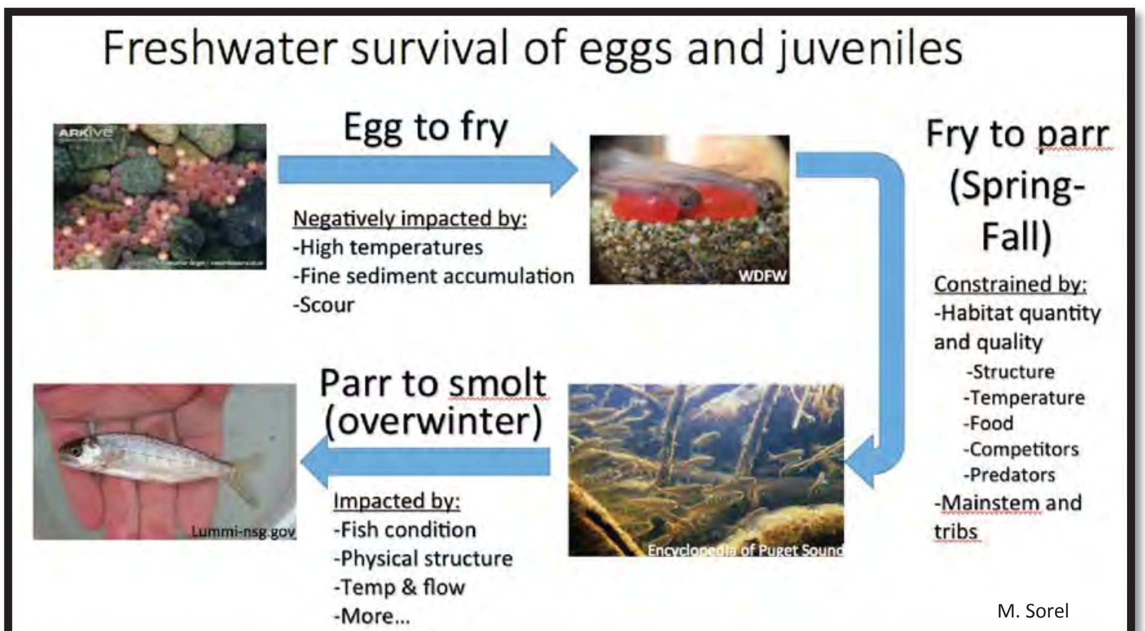
In progress...

water

Article

Developing an Effective Model for Predicting Spatially and Temporally Continuous Stream Temperatures from Remotely Sensed Land Surface Temperatures

Kristina M. McNyset [1,*], Carol J. Volk [1] and Chris E. Jordan [2]



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Thank you!

MONITORING AND EVALUATION PLAN FOR PUD HATCHERY PROGRAMS

2017 UPDATE

September 1, 2017

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Citation: Hillman, T., T. Kahler, G. Mackey, Andrew Murdoch, K. Murdoch, T. Pearsons, M. Tonseth, and C. Willard. 2017. Monitoring and evaluation plan for PUD hatchery programs: 2017 update. Report to the HCP and PRCC Hatchery Committees, Wenatchee and Ephrata, WA.

TABLE OF CONTENTS

SECTION 1: INTRODUCTION 1

SECTION 2: ADULT PRODUCTIVITY 9
2.1 Natural Replacement Rates of Supplemented Populations 9
2.2 Natural-Origin Recruits of Supplemented Populations 11

SECTION 3: JUVENILE PRODUCTIVITY 13
3.1 Freshwater Juvenile Productivity 13

SECTION 4: NATURAL ENVIRONMENT MONITORING INDICATORS 17
4.1 Hatchery Replacement Rates (HRRs) 17
4.2 Proportion of Hatchery-Origin Spawners (pHOS or PNI) 18
4.3 Run Timing, Spawn Timing, and Spawning Distribution 19
4.4 Stray Rates 22
4.5 Population Genetics 26
4.6 Phenotypic Traits 28

SECTION 5: HATCHERY ENVIRONMENT MONITORING INDICATORS 33
5.1 Release Targets 33

SECTION 6: HARVEST MONITORING INDICATORS 37
6.1 Harvest Rates 37

SECTION 7: REGIONAL OBJECTIVES 39
7.1 Incidence of Disease 39
7.2 Non-Target Taxa of Concern (NTTOC) 40

SECTION 8: ADAPTIVE MANAGEMENT 43

SECTION 9: REFERENCES 45

SECTION 10: GLOSSARY 47

APPENDIX 1: ESTIMATION OF CARRYING CAPACITY 51

APPENDIX 2: HATCHERY REPLACEMENT RATES 53

APPENDIX 3: PNI AND PHOS TARGETS AND SLIDING SCALES 55

APPENDIX 4: SPATIAL DISTRIBUTION OF SPAWNERS OR REDDS 59

APPENDIX 5: WITHIN HATCHERY REARING TARGETS 61

APPENDIX 6: IDENTIFYING AND ANALYZING REFERENCE POPULATIONS 63

LIST OF APPENDICES

Appendix 1: **Estimation of Carrying Capacity**

Appendix 2: **Hatchery Replacement Rates**

Appendix 3: **PNI and pHOS Management Targets and Sliding Scales**

Appendix 4: **Spatial Distribution of Spawners or Redds**

Appendix 5: **Within Hatchery Rearing Targets**

Appendix 6: **Identifying and Analyzing Reference Populations**

SECTION 1: INTRODUCTION

This document is an update of the monitoring and evaluation (M&E) plan of the salmon and steelhead hatchery programs funded by Douglas, Chelan, and Grant County Public Utility Districts (PUDs). Programmatic changes, evaluation of data collection methods, and M&E results from the past several years, along with shifting management paradigms affect M&E needs, all of which have occurred under advancing fish culture and monitoring techniques. As required by the programs, this document is a result of a five-year review intended to expand on and coalesce previous M&E documents (BAMP 1998; Cates et al. 2005; Murdoch and Peven 2005; Hays et al. 2006; Pearsons and Langshaw 2009a, 2009b; Hillman et al. 2013) with inclusion of new information.

Fishery management agencies developed the following general goal statements for hatchery programs, which were adopted by the HCPs Hatchery Committees and PRCC Hatchery Sub-Committee (hereafter, Hatchery Committees):

1. Support the recovery of ESA-listed species by increasing the abundance of the natural adult population, while ensuring appropriate spatial distribution, genetic stock integrity, and adult spawner productivity.
2. Increase the abundance of the natural adult population of unlisted plan species, while ensuring appropriate spatial distribution, genetic stock integrity, and adult spawner productivity. In addition, provide harvest opportunities in years when spawning escapement is sufficient to support harvest.
3. Provide salmon for harvest and increase harvest opportunities, while segregating returning adults from natural tributary spawning populations.

Following the development of Hatchery and Genetic Management Plans (HGMPs), artificial supplementation programs are now characterized into three categories. The first type, integrated conservation programs, are intended to support or restore natural populations. These programs focus on increasing the natural production of targeted fish populations. A fundamental assumption of this strategy is that hatchery fish returning to the spawning grounds are reproductively similar to naturally produced fish. The second type, safety-net programs, are extensions of conservation programs, but are intended to function as reserve capacity for conservation programs in years of low returns. The safety-net provides a demographic and genetic reserve for the natural population. That is, in years of abundant returns they function like segregated programs, and in low return years they can be managed as conservation programs. Lastly harvest augmentation programs are intended to increase harvest opportunities while limiting interactions with wild-origin counterparts.

Monitoring is needed to determine if the hatchery programs are meeting the intended management objectives of conservation, safety-net, or harvest augmentation programs. Objectives for hatchery programs are generally grouped into three categories of performance indicators:

1. In-Hatchery: Is the program meeting the hatchery production objectives?
2. In-Nature: How do fish from the program perform after release?
    a. Conservation Program:

- How does the program affect target population abundance and productivity?
- How does the program affect target population long-term fitness?

b. Safety-Net Program:
   - How does the program affect target population long-term fitness?

c. Harvest Augmentation Program:
   - Does the program provide harvest opportunities?

3. Risk Assessment: Does the program pose risks to other populations?

Objectives in this plan have been organized in a hierarchy where productivity indicators are the primary metrics used to assess if conservation and safety-net program goals have been met; harvest rates and effects on non-targeted populations are used for harvest programs. In cases where productivity indicators are not available or results are equivocal, monitoring indicators may be used to help evaluate the performance of the program. Evaluations of monitoring indicators may not provide sufficiently powerful conclusions on which to base management actions, although they may provide insight as to why a productivity indicator did or did not meet the program goal. Therefore, the relationship between hatchery programs and indicators can be viewed in a chain-of-causation: management actions within the hatchery programs affect the status of monitoring indicators, which in turn influence productivity indicators (Figure 1).

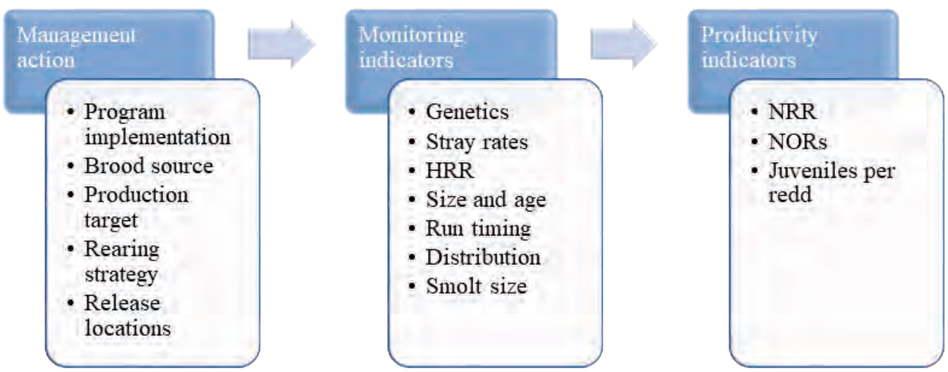

Figure 1. Relationship of indicators to the assessment of supplementation programs. Management actions affect monitoring indicators, which influence productivity indicators. Monitoring indicators may be used to hypothesize the magnitude of influence on productivity.

The primary goal of a conservation program is to contribute to the rebuilding and recovery of naturally reproducing populations within their native habitat. In this plan, natural replacement rates (NRR), recruitment of naturally-produced fish (NOR), and juvenile productivity (juveniles per redd) are important indicators for assessing the success of supplementation. These indicators are difficult to measure precisely and are quite variable in space and time. Therefore, monitoring indicators can be evaluated to help assess if productivity was related to the hatchery programs or other factors (Table 1).

Table 1. Program objectives, indicators, and goals for conservation hatchery programs including productivity and monitoring indicators (also applies to safety-net programs when used to support a conservation program).

	Objective	Indicator	Target	Program goals: Rebuild natural populations	Program goals: Maintain genetic diversity	Program goals: Opportunity for harvest
Productivity indicators	Determine if the program has increased the number of naturally spawning adults	Abundance of natural spawners	Increase	✓		✓
		Adult productivity (NRR)	No decrease	✓		
	Determine if the proportion of hatchery fish affects freshwater productivity	Residuals vs. pHOS	No relationship	✓		
		Juveniles per redd vs. pHOS	No relationship	✓		
Monitoring indicators	Determine if run timing and distribution meets objectives	Migration timing	No difference	✓	✓	
		Spawn timing[1]	No difference	✓	✓	
		Redd distribution[2]	No difference	✓	✓	
	Determine if program has affected genetic diversity and population structure	Allele frequency (hatchery vs. wild)	No difference		✓	
		Genetic distance between populations	No difference		✓	
		Effective population size	Increase		✓	
		Age and size at maturity	No difference		✓	
	Determine if hatchery survival meets expectations	HRR	HRR > NRR	✓		
		HRR	HRR ≥ Goal[3]	✓		
	Determine if recipient stray rate of hatchery fish is acceptable	Out of basin	≤ 5%	✓	✓	
		Within basin	≤ 10%	✓	✓	
	Determine if hatchery fish were released at program targets	Size and number	= Target[4]	✓		
	Provide harvest opportunities when appropriate	Harvest	Escapement goals			✓

[1] Hatchery and natural-origin fish should spawn at the same time across the range of elevations within the spawning distribution of each stock.

[2] Hatchery and natural-origin fish should spawn in the same locations. Exceptions are the Carlton and Dryden Summer Chinook programs (see Appendix 4).

[3] HRR targets are identified in Appendix 2.

[4] Number and size targets are identified in Table 3 and Appendix 5.

A flow of information following sequential, logical steps will be employed to evaluate supplementation programs, consistent with the indicators described in Table 1. For example, a hatchery program, at a minimum, must be able to produce more adults per spawner than would occur in the natural environment. Should the program fail this test, hatchery operations should be evaluated to determine if improvements can correct the problem. If a program successfully replaces the required number of adults, it is then evaluated against a reference population or condition, if available, to determine if it has increased the overall number of naturally spawning fish (including both hatchery- and natural-origin adults), increased the number of natural-origin spawners, and to test if productivity of the natural population has changed. When these goals are met, the program is considered successful. When these goals are not met, monitoring indicators may infer why the program is not achieving its goals

If suitable reference populations are not available, other comparisons can be used to help evaluate treatment responses. Evaluation of programs may pursue the following approaches:

- Comparison to reference population(s) that do not contain pre-treatment data.
- Before treatment and after treatment comparisons.
- Comparison to standard(s).
- Comparison to other suitable reference conditions.

Methodologies for selecting reference streams, analyzing data from treatment and reference stream comparisons, and other comparisons are presented in Hillman et al. (2012) (see Appendix 6).

The primary goals of a safety-net program are to provide demographic and genetic reserves for a population that is supplemented by a conservation program (Table 2). Harvest and adult management may be used to control escapement of spawners when appropriate. Monitoring focuses on estimating the number of fish that escape to spawn naturally and stray rates and in-hatchery performance evaluation.

Table 2. Program objectives, indicators, and goals for segregated harvest augmentation hatchery programs including monitoring indicators.

	Objective	Indicator	Target	Program goals: Rebuild natural populations	Program goals: Maintain genetic diversity	Program goals: Opportunity for harvest
Monitoring indicators	Determine if hatchery survival meets expectations	HRR	HRR > NRR			✓
		HRR	HRR ≥ Goal[1]			✓
	Determine if stray rate of hatchery fish is acceptable	Out of basin	≤ 5%		✓	
		Within basin	≤ 10%		✓	
	Determine if hatchery fish were released at program targets	Size and number	= Target[2]			✓
	Provide harvest opportunities when appropriate	Harvest	When greater than escapement goals			✓

[1] HRR targets are identified in Appendix 2.

[2] Number and size targets are identified in Table 3 and Appendix 5.

The primary goal of a harvest augmentation program is to increase harvest opportunities, while segregating adults from natural spawning populations. In this plan, harvest opportunity, survival rates, and stray rates are important indicators for assessing the success of harvest augmentation. These indicators are more readily quantified compared to productivity indicators (Table 2). A flow of information will be employed to evaluate harvest augmentation programs. Since harvest augmentation programs are typically segregated, monitoring indicators will be used to determine the success of a program.

Both monitoring and productivity indicators will be used to evaluate the success of hatchery programs. In the event that the statistical power of tests that involve productivity indicators is insufficient to inform sound management decisions, some of the monitoring indicators may be used to guide management. Figure 2 show the categories of indicators associated with each component of monitoring.

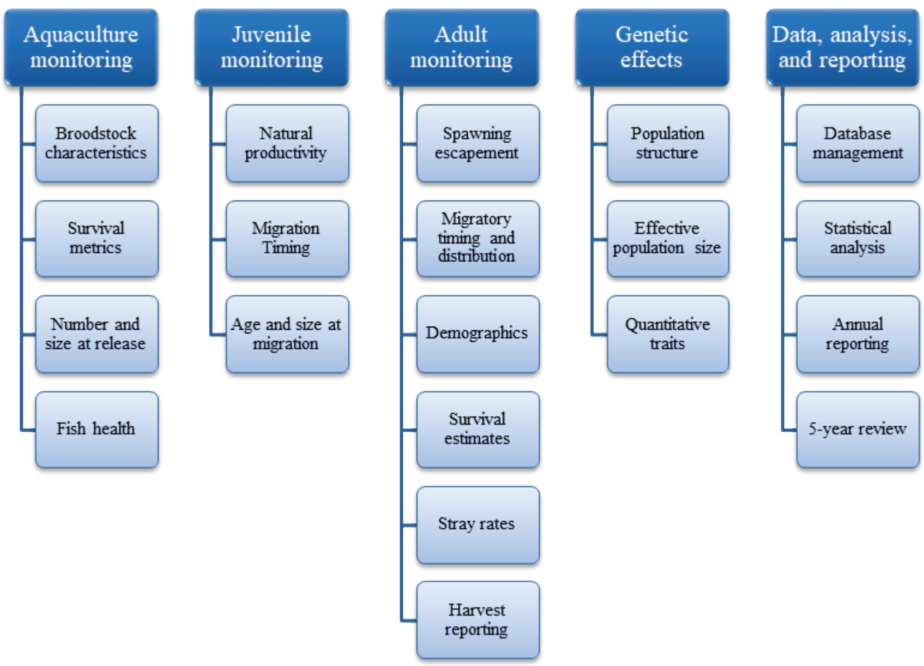

Figure 2. Overview of Monitoring and Evaluation Plan Categories and Components (not including regional objectives).

The overarching goals of conservation, safety-net, and harvest augmentation programs, as described above, are shown in detail in Figure 3. The flow chart (Figure 3) shows the relationship of overarching program goals, the strategies used to meet the goals, the monitoring and evaluation objectives used to evaluate the strategies and determine if goals are being met, and the adaptive

management cycle associated with the programs (see Tables 1 and 2 for the indicators under each objective). The logic depicted in this flow chart shall be used to assess M&E results and apply those results to management decisions. Table 3 presents the current hatchery programs releasing fish in the Upper Columbia Basin.

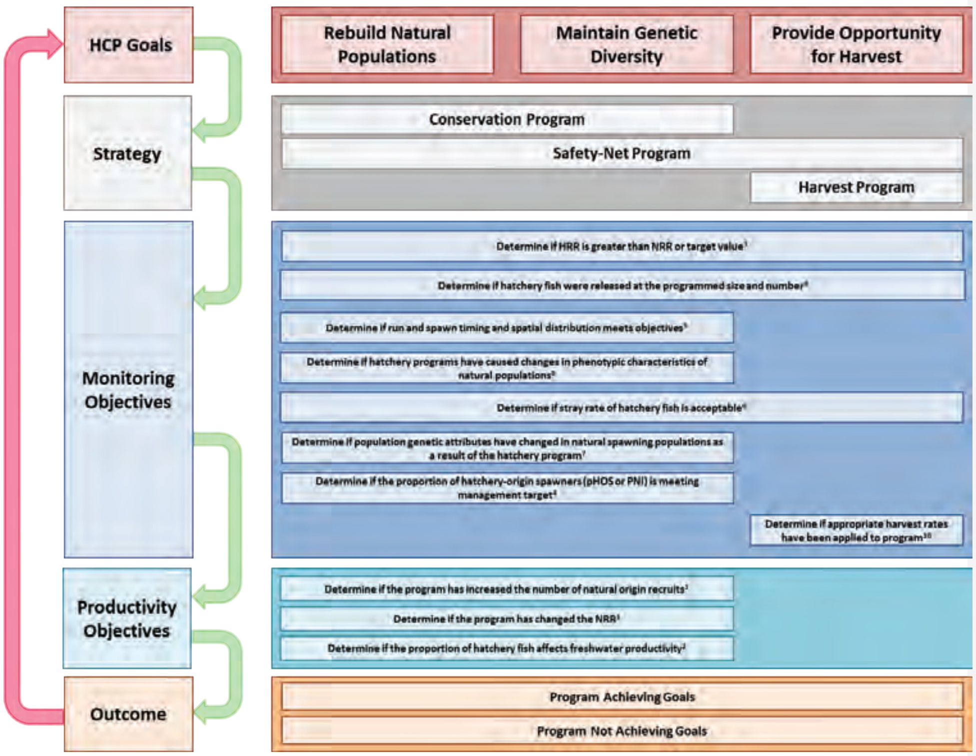

Figure 3. Adaptive management flow chart depicting HCP goals, associated strategies to meet the goals, the monitoring and evaluation objectives (indicated in superscript), and the adaptive management feedback cycle. The strategies, objectives, and outcomes are aligned vertically under the corresponding goals.

Table 3. Hatchery programs in the mid-Columbia River Basin, 2012. Funding entities included Douglas PUD (D), Chelan PUD (C), Grant PUD (G), Bonneville Power Administration (B), Bureau of Reclamation (O), and Army Corps of Engineers (A) and are listed in order of contribution. Total artificial production targets in the mid-Columbia River exceeds 20 million juveniles annually.

Program	Species	Basin	Purpose	Funding Entity	Production
Methow[5]	Spring Chinook [1]	Methow	NNI/Conservation	G, C, D	223,765
Chief Joseph[7]	Spring Chinook	Okanogan	Reintroduction/Harvest	B, G, C, D	900,000
Chiwawa[5]	Spring Chinook [1]	Wenatchee	NNI/Conservation	C	144,026
Nason[5]	Spring Chinook [1]	Wenatchee	NNI/Conservation	G	223,670
Winthrop[7]	Spring Chinook [2]	Methow	Safety-Net	O	400,000
Leavenworth	Spring Chinook [2]	Wenatchee	Harvest	O	1,200,000
Wells[5]	Steelhead [1]	Columbia	Inundation/Safety-Net	D	160,000
Winthrop[7]	Steelhead [1]	Methow	Conservation	O	100,000-200,000
Wells[5]	Steelhead [1]	Methow	Inundation/Safety-Net	D	100,000
Wells/Omak[5, 6]	Steelhead [1]	Okanogan	NNI/Conservation	G	100,000
Wells[5]	Steelhead [1]	Twisp	Inundation/Conservation	D	40,000
Wells[5]	Steelhead [1]	Twisp	NNI/Conservation	D	8,000
Chiwawa[5]	Steelhead [1]	Wenatchee	NNI/Conservation	C	22,000
Chiwawa[5]	Steelhead [1]	Wenatchee	Inundation/Harvest	C	165,000
Chiwawa[5]	Steelhead [1]	Wenatchee	Species trade	C	60,300
Ringold	Steelhead [9]	Columbia	Harvest	Mitchell Act	180,000
Wells[5]	Summer Chinook [2, 3]	Columbia	Inundation/Harvest	D	484,000
Chief Joseph[7]	Summer Chinook [3]	Okanogan	NNI/Cons./Harvest	B, C, D	700,000
Chelan Falls[5]	Summer Chinook [2]	Chelan	Inundation/Harvest	C	400,000
Chelan Falls[5]	Summer Chinook [2]	Chelan	NNI/Conservation	C	176,000
Wells[5]	Summer Chinook [2]	Columbia	Inundation/Harvest	D	320,000
Entiat	Summer Chinook	Entiat	Harvest	O	400,000
Carlton[5]	Summer Chinook	Methow	NNI/Conservation	G	200,000
Chief Joseph[7]	Summer Chinook	Okanogan	NNI/Cons./Harvest	B, G, C, D	1,300,000
Dryden[5]	Summer Chinook	Wenatchee	NNI/Conservation	C, G	500,000
Priest[5]	Fall Chinook[3]	Columbia	Inundation/Harvest	G	5,000,000
Priest[5]	Fall Chinook[3]	Columbia	NNI/Harvest	G	325,543
Priest[5]	Fall Chinook[4]	Columbia	Fry loss/Harvest	G	273,961
Priest[5, 7]	Fall Chinook[3]	Columbia	Harvest	A	1,700,000
Ringold[7]	Fall Chinook[3]	Columbia	Harvest	A	3,500,000
Yakama Nation	Coho	Wenatchee	Reintroduction/Harvest	B, G, C, D	1,000,000
Yakama Nation[8]	Coho	Methow	Reintroduction/Harvest	B, G, C, D	500,000
Skaha	Sockeye	Okanogan	Reintroduction/Harvest	C, G	≤ 5 M eggs

[1] Species listed under the Endangered Species Act.
[2] Segregated program.
[3] Sub-yearling production.
[4] Fry production.
[5] Program covered by this M&E Plan.
[6] Program also partially covered by CCT M&E Plan.
[7] Program affects PUD-funded programs covered by this plan.
[8] Planned to increase to 1,000,000.
[9] Part of the Mitchell Act suite of mitigation programs under the FCRPS BiOp.

SECTION 2: ADULT PRODUCTIVITY

2.1 Natural Replacement Rates of Supplemented Populations[1]

Objective 1: Determine if conservation programs have increased the number of naturally spawning and naturally produced adults of the target population and if the program has reduced the natural replacement rate (NRR) of the supplemented population.

At the core of a conservation program is the objective of increasing the number of spawning adults (i.e., the combined number of naturally produced and hatchery fish) in order to affect a subsequent increase in the number of returning naturally produced fish or natural-origin recruits (NOR). In order for the natural population to remain stable or to increase, the Natural Replacement Rate (NRR), or the ratio of NORs to the parent spawning population, must be at a level where parents are being replaced by their offspring as spawners in the next generation. It is possible to affect an increase in natural-origin spawners through supplementation with a stable or decreasing NRR. However, if the NRR is below replacement (NRR<1.0), termination of the supplementation program will result in a declining natural population should that state of NRR persist. The proportion of the hatchery-origin spawners (pHOS) that will increase natural production without creating adverse effects to the genetic diversity or reproductive success rate of the natural population is unknown, and may be dependent on how individual hatchery programs are operated, as well as available spawning and rearing habitat. Some programs restrict pHOS to reduce the risk to the natural population with the intent of optimizing productivity, concomitantly reducing the overall number of spawners. All other objectives of the M&E Plan either directly support this objective or seek to minimize negative effects of the conservation programs on non-target stocks of concern.

Differences in carrying capacities of supplemented and non-supplemented streams can confound the analysis of the effects of supplementation on total number of spawners returning to the streams. For example, if the supplemented population is at carrying capacity and the non-supplemented population is not, the total number of spawners returning to the non-supplemented population may show an increasing trend over time, while the supplemented population would show no increasing trend. To avoid concluding that the supplementation program has no effect or perhaps a negative effect on total spawners, density corrections should be included in the analyses. Hypotheses that may require density corrections are noted under each monitoring question. Appendix 1 describes methods for estimating carrying capacities.

Monitoring Questions:

Q1.1.1 Has the supplementation program changed the adult productivity (NRRs) of the supplemented populations?[2]

Target Species/Populations:

[1] Supplementation programs may include a safety-net component.

[2] Because adult productivity is affected by the abundance of the population (i.e., productivity decreases with increasing abundance), the goal of supplementation is to increase or maintain productivity, but not decrease it.

- Q1.1.1 applies to all conservation and safety-net stocks.

Statistical Hypotheses 1.1.1[3]:

- $Ho_{1.1.1.1}$: Slope in NRRs before supplementation ≤ slope in NRRs after supplementation.
- $Ho_{1.1.1.2}$: Differences in slopes in NRRs between supplemented and reference populations before supplementation ≤ differences in slopes in NRRs between supplemented and reference populations after supplementation.
- $Ho_{1.1.1.3}$: Mean NRRs before supplementation ≤ mean NRRs after supplementation.
- $Ho_{1.1.1.4}$: Mean ratio scores in NRRs before supplementation ≤ Mean ratio scores in NRRs during supplementation.
- $Ho_{1.1.1.5}$: Mean ratio scores in NRRs (adjusted for density dependence) before supplementation ≤ Mean ratio scores in NRRs (adjusted for density dependence) during supplementation. [This hypothesis adjusts NRRs for density-dependent effects (see Hillman et al. 2012 for details; Appendix 6).]
- $Ho_{1.1.1.6}$: There is no association between the proportion of hatchery-origin spawners (pHOS) and the residuals from the smooth hockey stick stock-recruitment curve; rho = 0. [If there is a significant negative association between pHOS and the residuals, then hatchery fish may be reducing the productivity of the wild population.]

Measured Variables:

- Number of hatchery and naturally produced fish on spawning grounds
- Number of naturally produced fish harvested

Derived Variables:

- Number of naturally produced recruits by brood year for both naturally produced parents and hatchery parents (≥age-3).
- NRRs (calculated as NORs/spawner).
- Stock-recruit models, parameters, and residuals.
- Includes ratio scores of NRRs (requires reference population[s]).
- Includes calculation of ratios NORs (requires reference population).
- Appendix 1: Spawning escapement and carrying capacity information (as applicable)

Spatial/Temporal Scale:

- Calculated annually based on brood year.
- Time series.

Possible Statistical Analysis:

[3] Quality and quantity of data will determine which hypotheses are evaluated. See Hillman et al. 2012 (Appendix 6) for details.

- These analyses shall be performed every 5-years. Use graphic analyses, trend analyses, t-tests, Aspin-Welch tests, and randomization tests to evaluate the statistical hypotheses (see Hillman et al. 2012; Appendix 6). The specific analysis used will depend on the availability of reference conditions.
- Correlation analysis will examine associations between hatchery adult composition and NRRs.
- On a five-year period, correlate productivity with extraneous factors such as ocean productivity indices.

Analytical Rules:

- This is a productivity indicator that will be used to assess the success of the supplementation program.
- Type I Error of 0.05.

2.2 Natural-Origin Recruits of Supplemented Populations

Monitoring Questions:

Q1.2.1: Has the supplementation program changed the abundance of NORs within the supplemented population?

Target Species/Populations:

- Q1.2.1 applies to all supplemented or safety net stocks.

Statistical Hypotheses 1.2.1[4]:

- $Ho_{1.2.1.1}$: Slope in NORs[5] before supplementation ≥ slope in NORs after supplementation.
- $Ho_{1.2.1.2}$: Differences in slopes in NORs between supplemented and reference populations before supplementation ≥ differences in slopes in NORs between supplemented and reference populations after supplementation.
- $Ho_{1.2.1.3}$: Mean NORs before supplementation ≥ mean NORs after supplementation.
- $Ho_{1.2.1.4}$: Mean ratio scores in NORs before supplementation ≥ Mean ratio scores in NORs during supplementation.
- $Ho_{1.2.1.5}$: Mean ratio scores in NORs/Maximum Recruitment before supplementation ≥ Mean ratio scores in NORs/Maximum Recruitment during supplementation. [This hypothesis adjusts NORs for the capacity of the habitat; it tests the fraction of the habitat saturated with NORs (see Hillman et al. 2012 for details).]
- $Ho_{1.2.1.6}$: There is no association between the proportion of hatchery-origin spawners (pHOS) and NORs; rho = 0. [If there is a significant negative association between

[4] Quality and quantity of data will determine which hypotheses are evaluated. See Hillman et al. 2012 (Appendix 7) for details.

[5] "Slope in NORS" refers to abundance of NORs across time (years).

pHOS and NORs, then hatchery fish may be reducing the reproductive success of the wild population.]

Measured Variables:

- Number of hatchery and naturally produced fish on spawning grounds.
- Number of hatchery and naturally produced fish taken for broodstock.
- Number of hatchery and naturally produced fish taken in harvest (if recruitment is to the Columbia).

Derived Variables:

- NORs (number of naturally produced recruits (total recruits) by brood year for both naturally produced parents and hatchery parents [≥age-3]).
- Stock-recruit models, parameters, and residuals.
- Includes ratio scores of NORs (requires reference population[s]).
- Estimates of carrying capacity (see Appendix 1).

Spatial/Temporal Scale:

- Calculate annually based on brood year.
- Time series.

Possible Statistical Analysis:

- These analyses shall be performed every 5-years. Use graphic analyses, trend analyses, t-tests, Aspin-Welch tests, and randomization tests to evaluate the statistical hypotheses (see Hillman et al. 2012). The specific analysis used will depend on the availability of reference conditions.
- Correlation analysis will examine associations between hatchery adult composition and NORs.
- On a five-year period, correlate NORs with extraneous factors such as ocean productivity indices.

Analytical Rules:

- This is a productivity indicator that will be used to assess the success of the supplementation program.
- Type I Error of 0.05.

SECTION 3: JUVENILE PRODUCTIVITY

3.1 Freshwater Juvenile Productivity

Objective 2: Determine if the proportion of hatchery fish on the spawning grounds affects the freshwater productivity of supplemented stocks.

Out-of-basin effects (e.g., smolt passage through the hydro system, harvest, and ocean productivity, etc.) influence the survival of smolts after they migrate from the tributaries. These effects introduce substantial variability into the adult-to-adult survival rates (NRRs and HRRs) and may mask in-basin effects (e.g., habitat quality, density-dependent mortality, and differential reproductive success of hatchery and naturally produced fish). Therefore, an estimate of freshwater productivity may help inform the performance of hatchery and natural-origin spawners.

The objective of estimating freshwater productivity in the Upper Columbia ESU/DPS is to estimate the survival from egg to a critical juvenile life stage(s) of target stocks. Smolt or juvenile production models generated from the information obtained through these programs will provide a level of predictability with greater sensitivity to in-basin effects than spawner-recruitment models that consider all effects.

Differences in the current carrying capacities of supplemented and non-supplemented streams can confound the effects of supplementation on numbers of juveniles per redd. For example, if the supplemented population is at or above carrying capacity and the non-supplemented population is not, numbers of juveniles per redd in the non-supplemented population may be significantly greater than the number of juveniles per redd in the supplemented population. In addition, pHOS may be correlated with overall spawner abundance. In these cases, it is difficult or impossible to separate density-dependent effects from the influence of pHOS on freshwater productivity. To avoid concluding that the supplementation program has no effect or perhaps a negative effect on juveniles per redd, the capacity of the habitats must be included in the analyses. The Supplementary Hypotheses presented below are designed to address the confounding effects of different densities on the analyses.

Monitoring Questions:

Q2.1.1: Has the supplementation program changed the number of juveniles (smolts, parr, and/or emigrants) per redd within the supplemented population?

Q2.2.1: Does the number of juveniles per redd decrease as the proportion of hatchery spawners increases?[6]

Target Species/Populations:

- Both Q2.1.1 and Q2.2.1 apply to all conservation stocks.

Statistical Hypotheses for 2.1.1[7]:

[6] Information is needed to estimate the effects of density dependence on these questions. Consider spatial distribution of redds.

[7] Quality and quantity of data will determine which hypotheses are evaluated. See Hillman et al. (2012) for details.

- $Ho_{2.1.1.1}$: Slope in juveniles/redd before supplementation ≤ slope in juveniles/redd after supplementation.
- $Ho_{2.1.1.2}$: Differences in slopes in juveniles/redd between supplemented and reference populations before supplementation ≤ differences in slopes in juveniles/redd between supplemented and reference populations after supplementation.
- $Ho_{2.1.1.3}$: Mean juveniles/redd before supplementation ≤ mean juveniles/redd after supplementation.
- $Ho_{2.1.1.4}$: Mean ratio scores in juveniles/redd before supplementation ≤ Mean ratio scores in juveniles/redd during supplementation.
- $Ho_{2.1.1.5}$: Mean ratio scores in juveniles/redd (adjusted for density dependence) before supplementation ≤ Mean ratio scores in juveniles/redd (adjusted for density dependence) during supplementation. [This hypothesis adjusts juveniles/redd for density-dependent effects (see Hillman et al. 2012 for details; Appendix 6).]
- $Ho_{2.1.1.6}$: There is no association between the proportion of hatchery-origin spawners (pHOS) and the residuals from the smooth hockey stick stock-recruitment curve; rho = 0. [If there is a significant negative association between pHOS and the residuals, then hatchery fish may be reducing the productivity of the wild population.]

Statistical Hypotheses for 2.2.1:

- $Ho_{2.2.1.1}$: There is no association between the proportion of hatchery-origin spawners (pHOS) and the residuals from the smooth hockey stick stock-recruitment curve; rho = 0. [If there is a significant negative association between pHOS and the residuals, then hatchery fish may be reducing the productivity of the wild population.]
- $Ho_{2.2.1.2}$: The slope between proportion of hatchery spawners and juveniles/redd is ≥ 0.

Measured Variables:

- Number of hatchery and naturally produced fish on spawning grounds.
- Numbers of redds.
- Number of juveniles (smolts, parr [where appropriate], and emigrants).

Derived Variables:

- Number of juveniles per spawner.
- Number of juveniles per redd.
- Carrying capacity (see Appendix 1).

Spatial/Temporal Scale:

- Calculate annually based on brood year.
- Time series.

Possible Statistical Analysis:

- These analyses shall be performed every five-years. Use graphic analyses, trend analyses, t-tests, Aspin-Welch tests, and randomization tests to evaluate the statistical hypotheses (see Hillman et al. 2012; Appendix 6). The specific analysis used will depend on the availability of reference conditions.
- Correlation analysis will examine associations between hatchery adult composition and juveniles/redd.

Analytical Rules:

- This is a productivity indicator that will be used to assess the success of the supplementation program.
- Type I Error of 0.05.

SECTION 4: NATURAL ENVIRONMENT MONITORING INDICATORS

4.1 Hatchery Replacement Rates (HRRs)

Objective 3: **Determine if the hatchery adult-to-adult survival (i.e., hatchery replacement rate, HRR) is greater than the natural adult-to-adult survival (i.e., natural replacement rate, NRR) and the target hatchery survival rate.**

The survival advantage from the hatchery (i.e., egg-to-smolt) must be sufficient to produce a greater number of returning adults than if broodstock were left to spawn naturally. If a hatchery program cannot produce a greater number of adults than naturally spawning fish, then the program should be modified or discontinued. Production levels were initially developed using historical run sizes and smolt-to-adult survival rates (BAMP 1998). Using the stock specific NRR and agreed upon target values (see Appendix 2), comparisons to actual survival rates will be made to ensure the expected level of survival has been achieved.

Monitoring Questions:

Q3.2.1: Is the adult-to-adult survival rate of hatchery fish (HRR) greater than or equal to the adult-to-adult survival rate (NRR) of naturally produced fish?

Q3.2.2: Is the adult-to-adult survival rate of hatchery fish (HRR) greater than or equal to the Target Value identified in Appendix 2[8]?

Target Species/Populations:

- Q3.2.1 applies to all conservation stocks.
- Q3.2.2 applies to all stocks.

Statistical Hypothesis 3.2.1:

- $Ho_{3.2.1.1}$: $HRR_{\text{Year x}} \geq NRR_{\text{Year x}}$

Statistical Hypothesis 3.2.2:

- $Ho_{3.2.2.1}$: HRR ≥ Target Value identified in Appendix 2

Measured Variables:

- Number of hatchery and naturally produced fish on spawning grounds.
- Number of hatchery and naturally produced fish harvested.
- Number of hatchery and naturally produced fish collected for broodstock.
- Number of broodstock used by brood year (hatchery and naturally produced fish).

Derived Variables:

- Number of hatchery and naturally produced adults by brood year (≥age-3).

[8] Target values may be adjusted by the hatchery committees.

- HRR (number of returning adults per brood year/broodstock)
- NRR (from Objective 1)
- Appendix 2: HRR targets identified in Appendix 2

Spatial/Temporal Scale:

- Calculate annually based on brood year.
- Time series.

Possible Statistical Analysis:

- For Q3.2.1 use graphic analysis and paired-sample quantile tests to compare HRR to NRR
- For Q3.2.2 use graphic analysis and one-sample quantile tests to compare HRR to the target value.
- On a five-year period, correlate HRRs with extraneous factors such as ocean productivity indices.

Analytical Rules:

- This is a monitoring indicator that will be used to support management decisions.
- Type I Error of 0.05.

4.2 Proportion of Hatchery-Origin Spawners (pHOS or PNI)

<u>**Objective 4**</u>**: Determine if the proportion of hatchery-origin spawners (pHOS or PNI) is meeting management target.**

Certain hatchery programs have pHOS or PNI targets, while other do not. HGMPs and permits inform the selection of targets, which are identified in Appendix 3.

Monitoring Questions:

Q4.1.1: Is the estimated proportion of hatchery-origin spawners (pHOS) less than or equal to the management target, and/or, is the estimated Percent Natural Influence (PNI) greater than or equal to the management target identified in Appendix 3?

Target Species/Populations:

- Q4.1.1 applies to all conservation and safety-net stocks that have a defined pHOS or PNI target or sliding scale (see Appendix 3).

Statistical Hypothesis 4.1.1:

- $Ho_{4.1.1.1}$: pHOS > target value or $PNI_{\text{Supplemented population}}$ < target value identified in Appendix 3

Measured Variables:

- Number of hatchery and naturally produced fish on spawning grounds

Derived Variables:

- pHOS or PNI
- Appendix 3: PNI and pHOS targets and sliding scales identified in Appendix 3

Spatial/Temporal Scale:

- Calculate annually.
- Analyzed as time series.

Possible Statistical Analysis:

- Use graphic analysis and summary statistics to compare pHOS or PNI to the target value in Appendix 3.

Analytical Rules:

- This is a monitoring indicator that will be used to support management decisions.

4.3 Run Timing, Spawn Timing, and Spawning Distribution

Objective 5: Determine if the run timing, spawn timing, and spawning distribution of the hatchery component is similar to the natural component of the target population or is meeting program-specific objectives.

Strategies for conservation programs typically intend that hatchery and natural-origin fish spawn together and in similar locations. However, in some cases, strategies may differ from this paradigm (e.g., summer Chinook salmon in the Wenatchee and Methow rivers; see Appendix 4). Phenotypic plasticity or selection resulting from the hatchery environment (i.e., domestication) may affect run (migration) timing, spawn timing, and spawning distribution. If conservation programs do not adequately represent the genetic diversity of the natural population, and if phenotypic traits in supplementation fish related to fitness deviate from the naturally produced spawning population, the goals of supplementation may not be achieved. Hatchery adults that migrate and/or spawn at different times or are spatially segregated from natural-origin fish may be subject to reduced fitness. Hatchery adults that spawn at different times or locations than natural-origin fish would be reproductively isolated from the natural population. The extent of such isolation, ranging from no isolation to substantial isolation, may be exploited for management purposes in some cases.

Migration Timing

Monitoring Questions:

Q5.1.1: Is the migration timing of hatchery and natural-origin fish from the same age class similar?

Target Species/Populations:

- Q5.1.1 applies to all conservation stocks.

Statistical Hypotheses 5.1.1:

- $Ho_{5.1.1.1}$: Migration timing $_{\text{Hatchery Age X}}$ = Migration timing $_{\text{Naturally produced Age X}}$

- $Ho_{5.1.1.2}$: The cumulative frequency of migration timing of hatchery-origin fish = the cumulative frequency of migration timing of natural-origin fish.
- $Ho_{5.1.1.3}$: The 10th percentile, 50th percentile (mode), 90th percentile, and mean migration timing of hatchery-origin fish = the 10th percentile, 50th percentile (median), 90th percentile, and mean migration timing of natural-origin fish.

Measured Variables:

- Ages of hatchery and natural-origin fish sampled via PIT tags or stock assessment monitoring.
- Time (Julian date) of arrival at mainstem projects and within tributaries (e.g., traps, PIT arrays) with the intent to identify biologically significant differences.

Derived Variables:

- Mean Julian date for a given age class.

Spatial/Temporal Scale:

- Calculate annually based on return year and age class.
- Time series.

Possible Statistical Analysis:

- Use graphic analyses (cumulative frequency polygons), paired t-tests, Aspin-Welch tests, and randomization tests.

Analytical Rules:

- This is a monitoring indicator that will be used to support management decisions.
- Type I Error of 0.05.

Spawn Timing

Monitoring Questions:

Q5.2.1: Is the timing of spawning similar for conservation hatchery and natural-origin fish?

Target Species/Populations:

- Q5.2.1: Applies to all semelparous species and populations supplemented by conservation programs. Steelhead can only be assessed for natural spawning in situations where hatchery and natural-origin fish can be appropriately marked and detected.

Statistical Hypotheses 5.2.1:

- $Ho_{5.2.1.1}$: The cumulative frequency of spawn timing of hatchery-origin fish = the cumulative frequency of spawn timing of natural-origin fish.
- $Ho_{5.2.1.2}$: The 10th percentile, 50th percentile (mode), 90th percentile, and mean spawn timing of hatchery-origin fish = the 10th percentile, 50th percentile (mode), 90th percentile, and mean spawn timing of natural-origin fish.

- $Ho_{5.2.1.3}$: The relationship between elevation and spawn timing of hatchery-origin fish = the relationship between elevation and spawn timing of natural-origin fish.

Measured Variables:

- Time (Julian date) and elevation (m) of hatchery and natural-origin salmon carcasses or marked steelhead detected on spawning grounds within defined reaches.
- Time (Julian date) of ripeness of hatchery and natural-origin steelhead captured for broodstock.

Derived Variables:

- Mean Julian date.

Spatial/Temporal Scale:

- Calculate annually based on return year.
- Time series.

Possible Statistical Analysis:

- Use graphic analyses (cumulative frequency polygons), paired t-tests, Aspin-Welch tests, and randomization tests.
- Use graphic analyses, ANCOVA, and/or regression analysis to assess relationships between elevation and spawn timing.

Analytical Rules:

- This is a monitoring indicator that will be used to support management decisions.
- Type I Error of 0.05.

Spatial Distribution of Redds

Monitoring Questions:

Q5.3.1: Is the distribution of redds similar for conservation hatchery and natural-origin fish?

Q5.3.2: Is the distribution of redds similar to defined management targets (see Appendix 4)?

Target Species/Populations:

- Q5.3.1 applies to all conservation program stocks.
- Q5.3.2 applies only to conservation program stocks with specific spawning distribution targets (Carlton and Dryden summer Chinook programs; Appendix 4).

Statistical Hypothesis 5.3.1:

- $Ho_{5.3.1.1}$: The distribution of hatchery-origin redds (hatchery females) = the distribution of natural-origin redds (natural-origin females).

Statistical Hypothesis 5.3.2:

- $Ho_{5.3.2.1}$: The distribution of hatchery-origin redds (hatchery females) = the target distribution identified in Appendix 4.

Measured Variables:

- Location (GPS coordinate) of female salmon carcasses observed on spawning grounds. The distribution of hatchery and naturally produced steelhead redds may be evaluated if marking or tagging efforts provide reasonable results.

Derived Variables:

- Location of female salmon carcass at the historic reach scale and at the 0.1 km scale.
- Calculate percent overlap in distribution across available spawning habitat or historical reaches.
- Appendix 4: Management targets for spatial distribution of spawners or redds (as applicable).

Spatial/Temporal Scale:

- Calculate annually based on return year.
- Time series.

Possible Statistical Analysis:

- Use graphic analysis and Yates' Chi-square analysis for both Q5.3.1 and Q5.3.2.

Analytical Rules:

- This is a monitoring indicator that will be used to support management decisions.
- Type I Error of 0.05.

4.4 Stray Rates

<u>Objective 6</u>: Determine if the recipient stray rate of hatchery fish is below the acceptable levels to maintain genetic variation among stocks.

Maintaining locally adapted traits among independent fish populations requires that returning hatchery fish have a high rate of site fidelity to the target population or stream. Hatchery practices (e.g., imprinting on water sources at key life history stages, release methodology, release location, age at return, broodstock used, spawner density, spawning habitat quality and access, and environmental conditions) are the main variables thought to affect stray rates. Regardless of the magnitude of homing of adult returns, if adult hatchery fish do not contribute to the natural population, the program will not meet the basic condition of a supplementation program.

Independent populations are populations that are genetically differentiated from other populations. In some cases, genetic differentiation may be assumed based on phenotypic traits or geographic isolation when molecular genetics analyses are not available. When populations are not independent, straying among them does not pose a risk of genetic homogenization. In addition, stray rates of hatchery-origin fish cannot be expected to be lower than for natural-origin fish. When estimates of stray rates for natural-origin fish are available and if they exceed the 5% among population stray rate or 10% within population stray rate thresholds identified in this plan, analysis

and interpretation of stray rates must take into account the concept that hatchery programs may be held to unattainable standards based on the natural stray rate. Current criteria established by the ICBTRT (2005) and the Upper Columbia Spring Chinook Salmon and Steelhead Recovery Plan (2007) indicate that fish that do stray to other non-target populations should not comprise greater than 5% of the non-target spawning population. Likewise, fish that stray into non-target spawning areas within an independent population should not comprise greater than 10% of the non-target spawning aggregate (see Tables 6.1 and 6.2).

This plan identifies three stray rate metrics; brood-year stray rate, among population return-year stray rate, and within population return-year stray rate. The return-year stray rates have specific targets that are from the ICBTRT (2005) and Upper Columbia Spring Chinook Salmon and Steelhead Recovery Plan (2007), and are linked to extinction risk. That is, hatchery strays from other populations cannot make up more than 5% of the spawning escapement within a non-target, recipient population. In addition, hatchery strays from other spawning aggregations within a population (e.g., Chiwawa spring Chinook) cannot make up more than 10% of the spawning escapement within a non-target, recipient spawning aggregate (e.g., White River). Brood-year stray rate, on the other hand, is not discussed in the Upper Columbia Spring Chinook Salmon and Steelhead Recovery Plan (2007) or ICBTRT (2005) and therefore has no specific target. Nevertheless, it is important to track brood-year stray rates to determine if hatchery operations affect the homing and straying of specific brood years. These data support the return-year stray metrics and are used to inform possible changes in genetic variation among stocks.

Brood-Year Stray Rates

Monitoring Questions:

Q6.1.1: What is the brood-year stray rate of hatchery fish?

Target Species/Populations:

- Q6.1.1 applies to all hatchery stocks.

Statistical Hypothesis 6.1.1:

- $Ho_{6.1.1.1}$: None.

Measured Variables:

- Number of hatchery carcasses found in non-target and target spawning areas or number of returning spawners counted via PIT-tag detection or at weirs in close temporal proximity to spawning areas.
- Number of hatchery fish collected for broodstock.
- Number of hatchery fish taken in fishery.
- Locations of live and dead strays (used to tease out overshoot).

Derived Variables:

- Total number of hatchery carcasses and take in fishery estimated from expansion analysis.
- Percent of the total brood return that strays.

Spatial/Temporal Scale:

- Calculate annually based on brood year.
- Time series.

Possible Statistical Analysis:

- Use graphical analysis to track brood-year stray rates over time.

Analytical Rules:

- This is a monitoring indicator that will be used to support management decisions.

Among-Population Return-Year Stray Rates

Monitoring Questions:

Q6.2.1: Do hatchery strays make up less than 5% of the spawning escapement within their non-target independent populations?

Target Species/Populations:

- Q6.2.1 applies to all hatchery stocks.

Statistical Hypothesis 6.2.1:

- $Ho_{6.2.1.1}$: Stray hatchery fish make up ≥ 5% of the spawning escapement (based on run year) within other independent populations [9]

Measured Variables:

- Number of hatchery carcasses (PIT-tagged steelhead) found in non-target and target spawning areas or number of returning spawners counted via PIT-tag detection or at weirs in close temporal proximity to spawning areas.

Derived Variables:

- Total number of hatchery salmon carcasses (PIT-tagged steelhead, spawners counted at weirs) estimated from expansion analysis.
- Percent of the non-target population that is made up of hatchery strays.

Spatial/Temporal Scale:

- Calculate annually based on return year.
- Time series.

Possible Statistical Analysis:

[9] This stray rate is suggested based on a literature review and recommendations by the ICBTRT (2005) and is identified in the Upper Columbia Spring Chinook Salmon and Steelhead Recovery Plan (2007). It can be re-evaluated as more information on naturally-produced Upper Columbia salmonids becomes available. This will be evaluated on a species and program specific basis and decisions made by the HCP HC and PRCC HSC. It is important to understand the actual spawner composition of the population to determine the potential effect of straying.

- Use graphical analysis and one-sample quantile tests to compare the estimated stray rate with the target (5%) stray rate.

Analytical Rules:

- This is a monitoring indicator that will be used to support management decisions.
- Type I Error of 0.05.

Within-Population Return-Year Stray Rates

Monitoring Questions:

Q6.3.1: Do hatchery strays make up less than 10% of the spawning aggregate within non-target spawning areas within the target population?

Target Species/Populations:

- Q6.3.1 applies to all hatchery stocks.

Statistical Hypothesis 6.3.1:

- $Ho_{6.3.1}$: Stray hatchery fish make up ≥ 10% of spawning escapement (based on run year) within non-target spawning areas within the target population

Measured Variables:

- Number of hatchery carcasses (possibly PIT-tagged steelhead) found in non-target and target spawning aggregates or number of returning spawners counted via PIT-tag detection or at weirs in close temporal proximity to spawning areas.

Derived Variables:

- Total number of hatchery salmon carcasses (possibly PIT-tagged steelhead or spawners counted at weirs) estimated from expansion analysis.
- Percent of the non-target spawning aggregate that is made up of hatchery strays.

Spatial/Temporal Scale:

- Calculate annually based on return year.
- Time series.

Possible Statistical Analysis:

- Use graphical analysis and one-sample quantile tests to compare the estimated stray rate with the target (10%) stray rate.

Analytical Rules:

- This is a monitoring indicator that will be used to support management decisions.
- Type I Error of 0.05.

4.5 Population Genetics

<u>Objective 7</u>: Determine if genetic diversity, population structure, and effective population size have changed in natural spawning populations as a result of the hatchery program.

The genetic component of the M&E Plan specifically addresses the potential for changes in genetic diversity in natural populations as a result of a hatchery program(s). The long-term fitness of populations is assumed to be related to maintaining the genetic diversity of natural populations. However, hatchery programs select a subset of individuals from the population to pass on genetic material to the next generation. This is often a relatively small number of individuals that produce a large number of offspring, and can result in changes in allele frequencies and reductions of effective population size. Therefore, it is important to monitor the genetic status of the natural populations to determine if there are signs of changes in genetic distance among populations, changes in allele frequencies, and to estimate effective population size. Assessing the genetic effects of the hatchery program does not require annual sampling, but does require regular sampling at generational scales. Meeting stray-rate targets (hypotheses tested under Objective 5) should reduce significant changes in population genetics. Stray rates may inform population genetic analyses. Testing statistical hypotheses associated with genetic components (Hypotheses 3.1, 3.2, and 3.3) should be conducted every ten years or two generations.

Allele Frequency

Monitoring Questions:

Q7.1.1: Is the allele frequency of hatchery fish similar to the allele frequency of naturally produced and donor (broodstock) fish?

Target Species/Populations:

- Q7.1.1 applies to all conservation stocks.

Statiscial Hypotheses 7.1.1:

- $Ho_{7.1.1.1}$: Allele frequency $_{\text{Hatchery}}$ = Allele frequency $_{\text{Naturally produced}}$ = Allele frequency $_{\text{Donor pop.}}$
- $Ha_{7.1.1.1}$: Allele frequency $_{\text{Hatchery}}$ ≠ Allele frequency $_{\text{Naturally produced}}$ = Allele frequency $_{\text{Donor pop.}}$ or
- $Ha_{7.1.1.1}$: Allele frequency $_{\text{Hatchery}}$ = Allele frequency $_{\text{Naturally produced}}$ ≠ Allele frequency $_{\text{Donor pop.}}$ or
- $Ha_{7.1.1.1}$: Allele frequency $_{\text{Hatchery}}$ ≠ Allele frequency $_{\text{Naturally produced}}$ ≠ Allele frequency $_{\text{Donor pop.}}$

Measured Variables:

- SNP genotypes

Derived Variables:

- Allele frequency

Spatial/Temporal Scale:

- Analyze as a time series, initially comparing pre- and post-hatchery samples and thereafter every 10 years.
- Compare samples within drainages.

Possible Statistical Analysis:

- Population differentiation tests, analysis of molecular variance (AMOVA), and relative genetic distances.

Analytical Rules:

- This is a monitoring indicator that will be used to support management decisions.
- Type I Error of 0.05.

Genetic Distance Between Populations

Monitoring Questions:

Q7.2.1: Does the genetic distance among subpopulations within a supplemented population remain the same over time?

Target Species/Populations:

- Q7.2.1 applies to all conservation and safety-net stocks.

Statistical Hypothesis 7.2.1:

- $Ho_{7.2.1.1}$: Genetic distance between subpopulations $_{\text{Year } x}$ = Genetic distance between subpopulations $_{\text{Year } y}$

Measured Variables:

- SNP genotypes

Derived Variables:

- Allele frequencies

Spatial/Temporal Scale:

- Analyze as a time series, initially comparing pre- and post-hatchery samples and thereafter every 10 years.
- Compare samples among spawning aggregates.

Possible Statistical Analysis:

- Population differentiation tests, AMOVA, and relative genetic distances.

Analytical Rules:

- This is a monitoring indicator that will be used to support management decisions.
- Type I Error of 0.05.

Effective Spawning Population

Monitoring Questions:

Q7.3.1: Is the ratio of effective population size (N_e) to spawning population size (N) constant over time?

Target Species/Populations:

- Q7.3.1 applies to all supplemented stocks.

Statistical Hypothesis 3.3:

- $Ho_{7.3.1.1}$: $(N_e/N)_{t0} = (N_e/N)_{t1}$ for each population

Measured Variables:

- SNP genotypes

Derived Variables:

- Allele frequencies

Spatial/Temporal Scale:

- Analyze as a time series, initially comparing pre- and post-hatchery samples and thereafter every 10 years.

Possible Statistical Analysis:

- Population differentiation tests, relative genetic distances, statistics to calculate effective population size (e.g., harmonic means).

Analytical Rules:

- This is a monitoring indicator that will be used to support management decisions.
- Type I Error of 0.05.

4.6 Phenotypic Traits

Objective 8: Determine if hatchery programs have caused changes in phenotypic characteristics of natural populations.

Fitness, or the ability of individuals to survive and pass on their genes to the next generation in a given environment, includes genetic, physiological, and behavioral components.[10] Maintaining the long-term fitness of supplemented populations requires a comprehensive evaluation of genetic and phenotypic characteristics. Evaluation of some phenotypic traits (i.e., run timing, spawn timing, spawning location, and stray rates) is addressed under Objective 5. Objective 8 assess the potential effects of domestication, including size at maturity, age at maturity, sex ratio, and fecundity. Age and size at maturity shall be assessed for both fish arriving in the Columbia system, and those recovered on the spawning grounds. Size (or age) selective mortality during migration through the Columbia system, such as through fisheries, could alter the age and size of fish on the spawning grounds.

[10] These metrics are difficult to measure, and phenotypic expression of these traits may be all we can measure and evaluate.

Age at Maturity

Monitoring Questions:

Q8.1.1: Is the age at maturity of hatchery and natural-origin fish similar at the time they enter the Columbia River and when they spawn?

Target Species/Populations:

- Q8.1.1 applies to all conservation program stocks.

Statistical Hypotheses 8.1.1:

- $Ho_{8.1.1.1}$: Age at Maturity $_{\text{Hatchery produced spawners Gender X}}$ = Age at Maturity $_{\text{Naturally produced spawners Gender X}}$
- $Ho_{8.1.1.2}$: Age at Maturity $_{\text{All hatchery produced adults Gender X}}$ = Age at Maturity $_{\text{All naturally produced adults Gender X}}$

Measured Variables:

- Total and salt (ocean) age of hatchery and natural-origin salmon carcasses collected on spawning grounds.
- Total and salt age of broodstock.
- Total and salt age of fish at stock assessment locations (e.g., Dryden, Tumwater, Wells, Priest Rapids).
- Whenever possible, age at maturity will be measured at weirs or dams near the spawning stream to avoid the size-related carcass recovery bias on spawning grounds (carcass sampling).
- Assess age of fish, including harvested fish.

Derived Variables:

- Total age and saltwater age
- Age of fish entering the Columbia River.

Spatial/Temporal Scale:

- Calculate annually based on brood year.
- Time series.

Possible Statistical Analysis:

- Use graphic analysis and Yates' Chi-square.

Analytical Rules:

- This is a monitoring indicator that will be used to support management decisions.
- Type I Error of 0.05.

Size at Maturity

Monitoring Questions:

Q8.2.1: Is the size (length) at maturity of a given age and sex of hatchery fish similar to the size at maturity of a given age and sex of natural-origin fish?

Target Species/Populations:

- Q8.2.1 applies to all conservation and safety-net stocks.

Statistical Hypothesis 8.2.1:

- $Ho_{8.2.1.1}$: Size (length) at Maturity $_{\text{Hatchery Age X and Gender Y}}$ = Size (length) at Maturity $_{\text{Naturally produced Age X and Gender Y}}$
- $Ho_{8.2.1.2}$: Size (length) at Maturity $_{\text{All hatchery adults Gender X}}$ = Size (length) at Maturity $_{\text{All naturally produced adults Gender X}}$

Measured Variables:

- Size (length), age, and gender of hatchery and natural-origin salmon carcasses collected on spawning grounds.
- Size (length), age, and gender of broodstock.
- Size (length), age, and gender of fish at stock assessment locations (e.g., Priest Rapids, Dryden, Tumwater, Wells, Twisp Weir).
- Whenever possible, size at maturity will be measured at weirs or dams near the spawning stream to avoid the size-related carcass recovery bias on spawning grounds (carcass sampling).

Derived Variables:

- Total age and saltwater age

Spatial/Temporal Scale:

- Calculate annually based on brood year.
- Time series.

Possible Statistical Analysis:

- Use graphic analysis and three-way ANOVA by origin, gender, and age

Analytical Rules:

- This is a monitoring indicator that will be used to support management decisions.
- Type I Error of 0.05.

Fecundity at Size[11]

Monitoring Questions:

Q8.3.1: Is the fecundity vs. size relationship of hatchery and natural-origin fish similar?

[11] May not apply to all programs.

Q8.3.2: Is the gonadal mass vs. size relationship of hatchery and natural-origin fish similar?

Target Species/Populations:

- Both Q8.3.1 and Q8.3.2 apply to all conservation stocks using both natural- and hatchery-origin broodstock.

Statistical Hypothesis 8.3.1:

- $Ho_{8.3.1.1}$: Slope of Fecundity vs. Size $_{\text{Hatchery}}$ = Slope of Fecundity vs. Size $_{\text{Naturally produced}}$

Statistical Hypothesis 8.3.2:

- $Ho_{8.3.2.1}$: Gonadal Mass vs. Size $_{\text{Hatchery}}$ = Gonadal Mass vs. Size $_{\text{Naturally produced}}$

Measured Variables:

- Length, weight, and age (covariate) of hatchery and natural-origin broodstock after eggs have been removed.
- Number and weight of eggs

Derived Variables:

- Total age and saltwater age.
- Mean weight per egg.

Spatial/Temporal Scale:

- Calculate annually based on brood year.
- Time series.

Possible Statistical Analysis:

- Use graphic analysis, regression, t-test, and ANCOVA.

Analytical Rules:

- This is a monitoring indicator that will be used to support management decisions.
- Type I Error of 0.05.

Sex Ratio

Monitoring Questions:

Q8.4.1: Is the sex ratio of hatchery and natural-origin fish similar?

Target Species/Populations:

- Q8.4.1 applies to all conservation stocks.

Statistical Hypothesis 8.4.1:

- $Ho_{8.4.1.1}$: Sex Ratio $_{\text{Hatchery}}$ = Sex Ratio $_{\text{Naturally produced}}$

Measured Variables:

- Age and sex of hatchery and natural-origin salmon carcasses collected on spawning grounds or sampled at dams or weirs.
- Whenever possible sex ratio will be measured at weirs or dams near the spawning stream to avoid the size-related carcass recovery bias on spawning grounds (carcass sampling or ultrasound on live fish).

Derived Variables:

- Ratio of sexes based on brood year returns

Spatial/Temporal Scale:

- Calculate annually based on brood year.
- Time series.

Possible Statistical Analysis:

- Use graphic analysis and Yates'Chi-square.

Analytical Rules:

- This is a monitoring indicator that will be used to support management decisions.
- Type I Error of 0.05.

SECTION 5: HATCHERY ENVIRONMENT MONITORING INDICATORS

5.1 Release Targets

Objective 9: Determine if hatchery fish were released at the programmed size and number.

The HCP outlines the number and size of fish that are to be released to meet NNI and inundation compensation levels. The size of the fish at release may be altered according to an adaptive management process in the Hatchery Committee(s), and the number of fish can be altered by survival study results and adjustment of hatchery production for population dynamics. Size of fish at release can affect survival, sex ratios, age at return, stray rate, and fecundity. In addition, the variation in size at release may affect performance of the fish.

The coefficient of variation (CV) will be evaluated to ascertain if program performance is related to variation in size at release. Note also that variation in a population is a natural condition and striving to control this variation could result in directional or stabilizing artificial selection that could have unforeseen long-term consequences. Attaining uniform or multi-modal growth in a hatchery environment may not be adaptive for fitness in the wild. Therefore, pursuit of a CV target should be seen as an informative exercise, but is not in itself indicative of success or failure of a hatchery program. Furthermore, growth regimes may prove to be important in affecting adult returns and age structure. Although many factors can influence both the size and number of fish released, past hatchery cultural experience with these stocks should assist in meeting program production levels. Appendix 5 presents the target size at release and CVs for the programs. These targets shall be assessed annually to ensure they are optimized to inform management decisions.

Size at Release of Hatchery Fish

Monitoring Questions:

Q9.1.1: Is the size (fish per pound; fpp) of hatchery fish released equal to the program goal identified in Appendix 5?

Target Species/Populations:

- Q9.1.1 applies to all hatchery stocks.

Statistical Hypothesis 9.1.1:

- $Ho_{9.1.1.1}$: Hatchery fish $_{\text{fpp at release}}$ = Programmed $_{\text{fpp at release}}$ (see Appendix 5)

Measured Variables:

- Fork length and weights of random samples of hatchery juveniles at release.

Derived Variables:

- Mean length (FL), mean weight, and fish per pound
- Appendix 5: Rearing targets

Spatial/Temporal Scale:

- Calculate annually.
- Time series.

Possible Statistical Analysis:

- Use graphic analysis and descriptive statistics to compare the estimated fpp of hatchery fish at time of release with the program goal.

Analytical Rules:

- This is a monitoring indicator that will be used to support management decisions.

Coefficient of Variation (CV) of Hatchery Fish Released

Monitoring Questions:

Q9.2.1: Is the CV of hatchery fish released equal to the program target identified in Appendix 5?

Target Species/Populations:

- Q9.2.1 applies to all hatchery stocks.

Statistical Hypothesis 9.2.1:

- $Ho_{9.2.1.1}$: Hatchery fish $CV_{\text{at release}}$ = Programmed CV in Appendix 5

Measured Variables:

- Length and weights of random samples of hatchery smolts.

Derived Variables:

- Coefficient of Variation: $cv = (1 + 1/4n) \times (s/x)$ (where s = standard deviation, x = estimated mean, n = sample size)
- Appendix 5: Rearing targets

Spatial/Temporal Scale:

- Calculate annually.
- Time series.

Possible Statistical Analysis:

- Use graphic analysis and descriptive statistics to compare the estimated CV of size of hatchery fish released with the program goal.

Analytical Rules:

- This is a monitoring indicator that will be used to support management decisions.

Condition Factor (K) of Hatchery Fish Released

Monitoring Questions:

Q9.3.1: Is the K of hatchery fish released equal to the program target identified in Appendix 5?

Target Species/Populations:

- Q9.3.1 applies to all hatchery stocks.

Statistical Hypothesis 9.3.1:

- $Ho_{9.3.1.1}$: Hatchery fish $K_{\text{at release}}$ = Programmed K identified in Appendix 5

Measured Variables:

- Monthly individual lengths and weights of random samples of hatchery juveniles.

Derived Variables:

- Condition Factor: $K = W/L^3 \times 10^5$

Spatial/Temporal Scale:

- Calculate annually.
- Time series.

Possible Statistical Analysis:

- Use graphic analysis and descriptive statistics to compare the estimated K of released hatchery fish with the program goal.

Analytical Rules:

- This is a monitoring indicator that will be used to support management decisions.
- Type I Error of 0.05.

Number of Hatchery Fish Released

Monitoring Questions:

Q9.4.1: Is the number of hatchery fish released equal to the program goal identified in Appendix 5?

Target Species/Populations:

- Q9.4.1 applies to all hatchery stocks.

Statistical Hypothesis 9.4.1:

- $Ho_{9.4.1.1}$: Hatchery Fish Number = Programmed Number identified in Appendix 5

Measured Variables:

- Numbers of smolts released from the hatchery.

Derived Variables:

- Appendix 5: Rearing targets

Spatial/Temporal Scale:

- Calculate annually.

- Time series.

Possible Statistical Analysis:

- Use graphic analysis and one-sample quantile tests to compare the estimated number of hatchery fish released with the program goal.

Analytical Rules:

- This is a monitoring indicator that will be used to support management decisions.
- Type I Error of 0.05.

SECTION 6: HARVEST MONITORING INDICATORS

6.1 Harvest Rates

Objective 10: Determine if appropriate harvest rates have been applied to conservation, safety-net, and segregated harvest programs to meet the HCP/SSSA goal of providing harvest opportunities while also contributing to population management and minimizing risk to natural populations.

Harvest will be applied to different types of programs in an effort to achieve the management objectives of those programs. Programs designed to augment harvest should routinely contribute to harvest at a rate that greatly reduces the incidence of straying to natural spawning grounds, but also allows the program to be sustained. Safety-net programs may be harvested as part of an adult management strategy to minimize excessive escapement of hatchery-origin fish to spawning grounds. Similarly, conservation programs may undergo harvest to manage returning adults, but the emphasis for these programs should be to achieve escapement goals. In all cases, harvest effort should not have the unintended consequence of removing excessive numbers of conservation or natural-origin fish. In years when the expected returns of hatchery adults are above the level required to meet program goals (i.e., supplementation of spawning populations and/or brood stock requirements), surplus fish may be available for harvest. The M&E Plan specifically addresses harvest and harvest opportunities upstream of Priest Rapids Dam. Harvest or removal of surplus hatchery fish from the spawning grounds may assist in reducing potential adverse ecological and genetic impacts to natural populations (e.g., loss of genetic variation within and between populations, loss of fitness, reduced effective population size, and density-dependent effects).

Monitoring Questions:

Q10.1.1: Conservation Programs: Is the harvest on conservation hatchery fish at an appropriate level to manage natural spawning of conservation hatchery fish but low enough to sustain the hatchery program?

Q10.1.2: Safety-Net Programs: Is the harvest on conservation hatchery fish at an appropriate level to manage natural spawning of safety-net hatchery fish but low enough to sustain the hatchery program?

Q10.1.3: Is the harvest on hatchery fish produced from harvest-augmentation programs high enough to manage natural spawning but low enough to sustain the hatchery program?

Q10.1.4: Is the escapement of fish from conservation and safety-net programs in excess of broodstock and natural production[12] needs to provide opportunities for terminal harvest?

Target Species/Populations:

- Q10.1.1 applies to conservation programs.
- Q10.1.2 applies to safety-net programs.

[12] The current best estimates of carrying capacity (maximum recruits) will be used, as available.

- Q10.1.3 applies harvest augmentation programs.
- Q10.1.4 applies to conservation and safety-net programs.

Statistical Hypothesis 10.1.1:

- $Ho_{10.1.1.1}$: Harvest rate ≤ Maximum level to meet program goals

Statistical Hypothesis 10.1.2:

- $Ho_{10.1.2.1}$: Harvest rate ≤ Maximum level to meet program goals

Statistical Hypothesis 10.1.3:

- $Ho_{10.1.3.1}$: Escapement ≤ Maximum level to meet supplementation goals

Statistical Hypothesis 10.1.4:

- $Ho_{10.1.4.1}$: Harvest rate ≤ Maximum level to meet program goals

Measured Variables:

- Numbers of hatchery fish taken in harvest.
- Numbers of natural-origin fish taken in harvest.

Derived Variables:

- Total harvest by fishery estimated from expansion analysis.

Spatial/Temporal Scale:

- Calculated annually.
- Time series.

Possible Statistical Analysis:

- Use graphic analysis and one-sample quantile tests to compare the estimated harvest of hatchery fish with the program goal.

Analytical Rules:

- This is a monitoring indicator that will be used to support management decisions.
- Type I Error of 0.05.

SECTION 7: REGIONAL OBJECTIVES

Hatchery programs have the potential to increase diseases that typically occur at low levels in the natural environment (Objective 9). In addition, hatchery fish can reduce the abundance, size, or distribution of non-target taxa through ecological interactions (Objective 10). In this section, we address incidence of disease and non-target taxa of concern.

7.1 Incidence of Disease

Objective 11: Determine if the incidence of disease has increased in the natural and hatchery populations.

The hatchery environment has the potential to amplify diseases that are typically found at low levels in the natural environment. Amplification could occur within the hatchery population (i.e., vertical and horizontal transmission) or indirectly from the hatchery effluent or commingling between infected and non-infected fish (i.e., horizontal transmission). Potential impacts to natural populations have not been extensively studied, but should be considered for programs in which the hatchery fish are expected to commingle with natural fish. This is particularly important for supplementation type programs. Specifically, the causative agent of bacterial kidney disease (BKD), *Renibacterium salmoninarum* (Rs), could be monitored at selected acclimation ponds, both in the water and fish, in which the risk and potential for transmission from the hatchery is highest. Although it is technologically possible to measure the amount of Rs in water or Rs DNA in smolts and adults non-lethally sampled, the biological meaning of these data are uncertain. Currently, the only metric available for M & E purposes is measuring the antigen level from kidney/spleen samples (i.e., ELISA, PCR). When available, non-lethal sampling may replace or be used in concert with lethal sampling.

Implementation of this objective will be conducted in a coordinated approach within the hatchery and natural environment. BKD management within the hatchery population (e.g., broodstock or juveniles) has the potential to reduce the prevalence of disease through various actions (e.g., culling or reduced rearing densities). BKD management must also take into account and support other relevant objectives of the M & E program (e.g., Hatchery Return Rate [HRR], number of smolts released). Hence, the goal of BKD management is to decrease the prevalence of disease and maintain hatchery production objectives (i.e., number and HRR).

As previously discussed, disease transmission from hatchery to naturally produced fish may occur at various life stages and locations. Of these, horizontal transmission from hatchery effluent, vertical transmission on the spawning grounds, and horizontal transmission in the migration corridor have been identified as disease interactions that could be examined under this objective, although others may also be relevant. Experimental designs addressing this objective may require technology not yet available, although in some instances samples may be collected, but not analyzed until a link can be established between bacteria levels in samples and disease prevalence.

Developing a complete set of questions and hypotheses statements for this objective may not be practical at this time, because there is currently no BKD Management Plan. However, while developing experimental designs for this objective, it may be feasible to incorporate both hatchery and natural environment monitoring under a single study design. Integration of the different

aspects of the objective would likely result in a more robust approach into understanding the effectiveness of disease management strategies.

Proposed Tasks:

T1: Assemble fish health data for fish used as brood (e.g., ELISA results).

T2: Conduct data exploration exercise to identify potential relationships between pathogen profiles and likely causative variables (e.g., rearing conditions and management actions).

T3: Develop hypotheses for potential testing to meet objective.

7.2 Non-Target Taxa of Concern (NTTOC)

Objective 12: Determine if the release of hatchery fish affects non-target taxa of concern (NTTOC) within acceptable limits.

Commented [TH1]: The text below is new.

Hatchery programs have the potential to affect non-target taxa through various types of interactions (e.g., competition and predation). These interactions can reduce the distribution, size, and abundance of non-target species. The non-target taxa of concern (NTTOC) ecological risk assessment was developed as a regional objective that would addressed ecological interactions on non-target taxa.

In 2008, the Wells HCP, Rocky Reach HCP, Rock Island HCP Hatchery Committees, and the Priest Rapids Hatchery Sub-Committee agreed to an approach to evaluate the potential effects of hatchery programs on NTTOC. The committees originally planned to convene a panel of experts to conduct a preliminary evaluation of the potential effects of Plan supplemented species on NTTOC. At the 15 October 2008 Hatchery Committees meeting, the members agreed to convene an expert panel to conduct a preliminary evaluation of potential effects of supplemented Plan Species on non-target taxa using an approach similar to that used in the Yakima Basin (Pearsons and Hopley 1999; Ham and Pearsons, 2001). The Committees agreed to convene the panel in spring or early summer 2009, and focus this initial effort on HCP Plan Species and the two non-Plan Species, westslope cutthroat trout and lamprey. The Committees identified species interactions, containment objectives for non-target species, and fisheries professionals who possessed the expertise to contribute as panel members. However, this expert panel was never assembled. Instead, the Committees directed the Hatchery Evaluation Technical Team (HETT) to pursue assessment of the hatchery programs potential effects on NTTOC.

The HETT evaluated methods to conduct a risk assessment on NTTOC, and proposed using a combined modeling and a Delphi panel approach, whereby the modeling results would be compared and correlated with the Delphi panel results. The HETT identified the PCD Risk 1 model (Busack et al., 2005; Pearsons and Busack, 2012) to conduct the modeling evaluation. The PCD Risk 1 model is a data intensive, individual-based stochastic model. The HETT determined that the assembled data to be used as inputs for the PCD Risk 1 model would also serve to provide expert panelists the necessary data for them to conduct risk assessments. Hence, the HETT embarked on an extensive effort to gather, organize, and extract the required data from existing datasets, literature, and biologists familiar with the programs and/or particular NTTOC. Ultimately the input data were assembled in a relational database that allowed the data to be output in user-friendly formats for modeling or Delphi panel use. The database also served to hold the modeling results, which could be extracted and summarized as needed.

A report titled *Ecological Risk Assessment of Upper-Columbia Hatchery Programs on Non-Target Taxa of Concern* was drafted in 2013 and finalized in 2014, which included the modeling results to date. The results in the report represent a very extensive effort to model the risk of all the upper Columbia hatchery programs for the identified NTTOC for which data and model runs were available. Should new information become available, the Committees agreed to assess the suitability of the data as it relates to conducting future NTTOC evaluations as a regional objective.

SECTION 8: ADAPTIVE MANAGEMENT

Commented [TH2]: The text below is new.

One of the challenges of evaluating PUD hatchery programs is that hatchery programs are modified resulting in hatchery treatments that are uneven throughout the duration of the hatchery program. Modifications occur as a result of recalculating hatchery release numbers every 10 years and also through adaptive management. To solve this evaluation challenge, we propose to conduct two scales of analysis. First, the entire duration of the program will be analyzed using the entire data set. This evaluation will analyze whether the overall adaptively managed program achieved objectives. Second, where appropriate, analyses will be compared across periods or programs to determine if major program changes have resulted in hypothesized changes to key response variables. We acknowledged that partitioning data into shorter periods will likely result in reduced statistical power so only the biggest changes will be evaluated. In the future, the hatchery committees will develop a table or figure that identifies major program changes in fish culture or M&E.

In the past, hatchery programs have been evaluated at the hatchery program scale (e.g., Nason Creek, Carlton summer Chinook). In some cases, it may be worthwhile to evaluate supplementation programs at different spatial scales. For example, the Nason Creek spring Chinook salmon program can be evaluated at the scale of Nason Creek, the combined effects of spring Chinook hatchery programs in the Wenatchee basin at the Wenatchee basin scale, and then all of the spring Chinook programs in the upper Columbia at the upper Columbia basin scale.

Comparisons of supplemented populations (treatments) to in-basin reference populations are the best way to evaluate whether treatments have caused changes to variables such as natural-origin recruits or productivity. Many suitable out-of-basin references are available (see Appendix 6), but these references do not control for unique factors that may be happening in the upper Columbia or areas outside the upper Columbia. For example, large fires that occur in the Upper Columbia may not occur at similar times in areas outside of this area. Candidate in-basin reference populations are not ideal for spring Chinook salmon because they are small and are above a lake (e.g., Little Wenatchee River) or they have had a long history of hatchery stocking (e.g., Entiat River). Every population of upper Columbia summer and fall Chinook is supplemented so in-basin references are not currently available. Without a suitable number of in-basin reference populations that are similar in size and distribution to treated populations, it will be difficult to unambiguously assess hatchery effects on certain variables. Although not ideal, the only way to increase in-basin reference comparisons is to strategically reduce the number of places where hatchery fish are released such as was done for the Entiat River.

Previous stocking history will lessen the value of reference populations; however, they can still be of value. For instance, the Committees can still test whether NORs are increased under supplementation compared to periods when other populations are not supplemented (i.e., a reverse BACI analysis).

SECTION 9: REFERENCES

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SECTION 10: GLOSSARY

Adult-to-Adult survival (Ratio)	The number of parent broodstock relative to the number of returning adults.
Age at maturity	The age of fish at the time of spawning (hatchery or naturally).
Augmentation	A hatchery strategy where fish are released for the sole purpose of providing harvest opportunities.
Broodstock	Adult salmon and steelhead collected for hatchery fish egg harvest and fertilization.
Donor population	The source population for supplementation programs before hatchery fish spawned naturally.
Effective population size (Ne)	The number of reproducing individuals in an ideal population (i.e., Ne = N) that would lose genetic variation due to genetic drift or inbreeding at the same rate as the number of reproducing adults in the real population under consideration (Hallerman 2003).
ESA	Endangered Species Act passed in 1973. The ESA-listed species refers to fish species added to the ESA list of endangered or threatened species and are covered by the ESA.
Expected value	The number of smolts or adults derived from survival rates agreed to in the Biological Assessment and Management Plan (BAMP 1998).
Extraction rate	The proportion of the spawning population collected for broodstock.
Genetic diversity	All the genetic variation within a species of interest, including both within and between population components.
Genetic stock structure	A type of assortative mating, in which the gene pool of a species is composed of a group of subpopulations, or stocks, that mate panmictically within themselves.
Genetic variation	All the variation due to different alleles and genes in an individual, population, or species.
HCP	Habitat Conservation Plan is a plan that enables an individual or organization to obtain a Section 10 Permit which outlines what will be done to “minimize and mitigate” the impact of the permitted take on a listed species.

HCP-HC	Habitat Conservation Plan Hatchery Committee is the committee that directs actions under the hatchery program section of the HCP's for Chelan and Douglas PUDs.
HRR	Hatchery Replacement Rate is the ratio of the number of returning hatchery adults relative to the number of adults taken as broodstock, both hatchery and naturally produced fish (i.e., adult-to-adult replacement rate).
Long-term fitness	Long-term fitness is the ability of a population to self-perpetuate over successive generation.
Naturally produced	Progeny of fish that spawned in the natural environment, regardless of the origin of the parents.
Mean Ratio	The ratio between a treatment and control population, with the mean taken across a time period, such as years. Used in analysis in Before-After-Control-Impact studies.
Ne	Effective population size.
Non-target taxa of concern (NTTOC)	Species, stocks, or components of a stock with high value (e.g., stewardship or utilization) that may suffer negative effects because of a hatchery program.
NRR	Natural replacement rate is the ratio of the number of returning naturally produced adults relative to the number of adults that naturally spawned, both hatchery and naturally produced.
NTTOC	Non-target taxa of concern.
pHOS	Proportion of Hatchery Origin Spawners.
PNI	Proportionate Natural Influence.
pNOB	Proportion of Natural Origin Broodstock.
PRCC HSC	Priest Rapids Coordinating Committee Hatchery Subcommittee.
Productivity	The capacity in which juvenile fish or adults can be produced.
Reference population	A population in which no directed artificial propagation is currently directed, although may have occurred in the past. Reference populations are used to monitor the natural variability in survival rates and out of basin impacts on survival.
Smolt-to-adult survival rate (SAR)	Smolt-to-adult survival rate is a measure of the number of adults that return from a given smolt population.
Segregated	A type of hatchery program in which returning adults are spatially or temporally isolated from other populations.

Size at maturity	The length or weight of a fish at a point in time during the year in which spawning will occur.
Smolts per redd	The total number of smolts produced from a stream divided by the total number of redds from which they were produced.
SNP or single-nucleotide polymorphism	A single-nucleotide polymorphism is a variation in a single nucleotide that occurs at a specific position in the genome, where each variation is present to some appreciable degree within a population.
Spawning Escapement	The number of adult fish that survive to spawn.
Stray rate	The rate at which fish spawn outside of natal rivers or the stream in which they were released.
Supplementation	A hatchery strategy where the main purpose is to increase the relative abundance of natural spawning fish without reducing the long-term fitness of the population.
Target population	A specific population in which management actions are directed (e.g., artificial propagation, harvest, or conservation).

APPENDIX 1: ESTIMATION OF CARRYING CAPACITY

APPENDIX 2: HATCHERY REPLACEMENT RATES

Based on ideas developed by the HETT, in February 2016, the HCP Hatchery Committees and PRCC Hatchery Subcommittee agreed to the following rules and HRR targets:

1. Use the estimated 40% HRR Target during 5-year statistical evaluation periods.
2. Use varying degrees of action depending on the numbers of years that annual HRR deviates from Target.
   a. Green Light (below Target for ≤ 2 years).
   b. Red Light (below Target for > 2 years).
3. Each program will have its own HRR target with the following exceptions.
   a. Nason Creek spring Chinook will use the Chiwawa Target (there are currently no data to calculate a target for Nason Creek spring Chinook).
   b. Methow and Chewuch spring Chinook will use the greater of their two Targets (they are MetComp stock and evaluated similarly).

Table 1. Release numbers and 5-year hatchery replacement rates (HRR) targets for Upper Columbia River Hatchery Programs.

Species	Owner	Program (Hatchery)	Basin (Purpose)	Smolts released[1]	5-Year HRR[2]
Steelhead	CPUD	Eastbank (Chiwawa)	Wenatchee (Conservation)	123,650	6.9
Steelhead	CPUD	Eastbank (Chiwawa)	Wenatchee (Safety Net)	123,650	6.9
Steelhead	DPUD	Wells (Wells)	Columbia (Safety Net)	160,000	26.5
Steelhead	DPUD	Wells (Wells)	Methow (Safety Net)	100,000	26.5
Steelhead	DPUD	Wells (Wells)	Twisp (Conservation)	48,000	26.5
Steelhead	GPUD	Wells (Omak)	Okanogan (Conservation)	100,000	7.3 [3]
SUM Chinook	CPUD	Eastbank (Chelan Falls)	Chelan (Conservation)	176,000	5.7
SUM Chinook	CPUD	Eastbank (Chelan Falls)	Chelan (Harvest)	400,000	5.7
SUM Chinook	CPUD, GPUD	Eastbank (Dryden)	Wenatchee (Conservation)	500,000	5.7
SUM Chinook	DPUD	Wells (Wells)	Columbia (Harvest)	320,000	3.0
SUM Chinook	GPUD	Eastbank (Carlton)	Methow (Conservation)	200,000	3.0
SUM Chinook	CCT	Chief Joseph	Okanogan (Harvest)	1,100,000	8.6
SPR Chinook	CPUD	Eastbank (Chiwawa)	Wenatchee (Conservation)	144,026	6.7
SPR Chinook	CPUD, DPUD, GPUD	Wells (Methow)	Methow (Conservation)	193,765	3.8
SPR Chinook	DPUD, GPUD	Wells (Twisp)	Methow (Conservation)	30,000	2.7
SPR Chinook	GPUD	Eastbank (Nason)	Wenatchee (Conservation)	223,670	6.7

[1] Release goal established by HCPs and adjusted by HC.
[2] Derived from Annual Reports.
[3] Harvest not included.

Attachment E

APPENDIX 3: PNI and pHOS Targets and Sliding Scales

Select CPUD, DPUD, and GPUD funded hatchery mitigation programs have PNI management targets, while others do not. Table 1 summarizes management strategies by species and population. Detailed information can be found in the sections that follow. Descriptions provided in the following sections are taken directly from HGMPs and/or issued and draft permits.

Table 1. Summary of management strategies by species and population.

Species	Population	Management Strategy	Comments
Spring Chinook	Wenatchee	Sliding Scale of PNI management	Details can be found in Section 2.0
	Methow	Two—population sliding scale PNI management	Details can be found in Section 3.0
	Okanogan	None Currently	Details can be found in Section 4.0
Steelhead	Wenatchee	Two-zone management.	Details can be found in 5.0
	Methow	In-development	Details forthcoming; Section 6.0
	Okanogan	None Currently	Details can be found in Section 7.0
Summer Chinook	Wenatchee	None Currently	Details can be found in Section 9.0
	Methow	None Currently	Details can be found in Section 10.0
	Okanogan	0.67; pHOS 0.30	Details can be found in Section 11.0
	Upper Columbia River	None Currently	Details can be found in Section 12.0
Fall Chinook	Hanford Reach	0.67	Details can be found in Section 13.0

2.0 Wenatchee Spring Chinook

Wenatchee spring Chinook will be managed according to the sliding scale identified in the Wenatchee Spring Chinook Management Plan (2010) and Permit Numbers 18118 and 18121. The sliding scale is based upon the estimated number of natural origin spring Chinook over Tumwater Dam. As more information becomes available the sliding scale may be adjusted as a result of gaining a better understanding of the pre-spawn mortality rate and carrying capacity.

Table 2. Sliding scale of PNI goals based on natural origin spring Chinook run size expected to the Wenatchee River basin. Percentiles are based on adult returns observed between 1999 and 2008.

Percentile	NOR Run Size				PNI
	Chiwawa	Nason Creek	White	Wenatchee River (above TWD)	
>75th	>372	>350	>87	>910	≥ 0.80
50% - 75%	278-372	259-349	68-86	631-909	≥ 0.67
25% - 50%	209-277	176-258	41-67	525-630	≥ 0.50
10%-25%	176-208	80-175	20-40	400-524	≥ 0.40
<10th	<175	<80	<20	<400	Any PNI

3.0 Methow/ Chewuch Spring Chinook

The following sliding scale (Table 3) is presented in the April 14, 2016 draft Methow Hatchery Spring Chinook Section 10-Draft. It is anticipated that no further changes will be made to the sliding scale prior to issuance of the final permits.

Table 3. PUD PNI sliding scale calculations for a range of natural run sizes.

Natural Origin Returns	PUD pHOS	WNFH pHOS	PUD pNOB	2-Pop PNI	PUD PNI (equation)
<300	Ensure minimum of 500 total spawners				
300	0.40	0.2	0.75	0.67	0.67
500	0.40	0.2	0.80	0.68	0.76
900	0.30	0.15	1.00	0.78	0.80
1500	0.25	0.1	1.00	0.8	0.80
2000	0.25	0.1	1.00	0.8	0.80
2500	0.25	0.1	1.00	0.8	0.80

4.0 Okanogan Spring Chinook

The Okanogan spring Chinook program is a re-introduction effort implemented as a non-essential experimental population under ESA Section 10j to re-introduce spring Chinook into the Okanogan River. As a non-essential experimental population targeting re-introduction and establishment of a local population of spring Chinook, the Okanogan spring Chinook program will not conduct adult management actions to reduce the proportion of 10j hatchery fish on the spawning grounds or conduct broodstocking efforts in the Okanogan for a 10-year period (2014 – 2023), as such, no PNI or pHOS objectives have been identified for this program in this 10-year period.

CJH Program segregated production released into the mainstem Columbia River are non-listed Leavenworth stock released reared/acclimated/released at CJH. Although no PNI or pHOS targets are identified for the Okanogan 10j population, minimizing strays from the CJH segregated spring Chinook program is a program objective, as such, returning segregated program fish will be subject to directed harvest and aggressive adult surplusing at CJH to minimize straying to the Okanogan River Basin as well as other extant upper Columbia River spring Chinook populations. Stray targets for the segregated program are 5% or less stray rate (i.e. spawning contribution to other upper Columbia River spring Chinook populations).

5.0 Wenatchee Steelhead

Interim escapement goal for Wenatchee River steelhead will be 1,500 spawners with an additional goal of attaining an average PNI of 0.67 for the Wenatchee River basin population as a whole. To achieve the stated goal, the Wenatchee steelhead program will use a two-zone management approach wherein the upper basin (above TWD) will be managed for recovery using an integrated recovery program, a separate spawning escapement goal, and a PNI standard to achieve the overall basin goal of an average PNI over time of 0.67 (Table 4). Areas below TWD will be managed to minimize hatchery supplementation with a pHOS goal of < 0.10.

Steelhead returning upstream of TWD will be managed as an integrated recovery program with a pNOB goal of 1.0. The above TWD escapement goal will be 1,094 spawners. Working within this framework, pNOB will be maximized above TWD while pHOS will be minimized.

Table 4. Wenatchee steelhead two-zone management and PNI targets.

Location	Run Escapement Goal	pNOB Conservation Program	pNOB Safety Net Program	pHOS	PNI
Above TWD	1,094	1.0	0.0	Varies	Varies
Below TWD	406	N/A	N/A	< 0.10	< 0.67
Basin Total	1,500	N/A	N/A	Minimal	Average = 0.67

6.0 Methow Steelhead

Methow steelhead PNI targets are currently in development.

7.0 Okanogan Steelhead

Current program has no PNI goal. CTCR submitted an Okanogan steelhead HGMP to NOAA Fisheries on February 4, 2014. Within the HGMP provisions were included to allow a greater collection of natural-origin broodstock and multiple adult management strategies to address over-escapement of hatchery-origin steelhead to the spawning grounds. The HGMP also identified a near-term (1-4 years) and a long-term PNI objectives of 0.50 and > 0.67, respectively. Once NOAA has completed the consultation and issued a new permit, providing the opportunity to increase the proportion of natural-origin fish in the broodstock and additional adult management strategies, the program will adopt the PNI objectives and this Appendix can be amended accordingly.

8.0 Wells Columbia Mainstem Safety-net Steelhead

The Safety-Net Mainstem Columbia component released below Wells Dam will be managed primarily at the Wells Hatchery volunteer channel. The objective of the adult management of the Safety-Net Mainstem Columbia component is to prevent runs of this component from moving into natural spawning areas. This will be accomplished through in-river harvest and removal of volunteers at the Wells Hatchery outfall. There are no PNI goals for this component.

9.0 Wenatchee Summer Chinook

No PNI goals are established.

10.0 Methow Summer Chinook

No PNI goals are established.

11.0 Okanogan Summer Chinook

Okanogan summer/fall Chinook will be managed to achieve a 5-year rolling average PNI of 0.67 and pHOS of 0.30. Strategies to achieve that PNI target include up to 100% pNOB, aggressive removal of hatchery-origin Chinook in selective fisheries, at the Okanogan weir, and during surplusing at CJH ladder. Reduction in the number of juveniles released in the Okanogan River Basin (integrated program) is also a management option, should adult management actions be unable to control the proportion of hatchery fish on the spawning grounds to achieve that PNI target.

CJH segregated summer/fall Chinook program rears/acclimates/releases smolts into the mainstem Columbia River at CJH. Broodstock are 100% hatchery-origin, as such no PNI target for this production component. Stray rate (i.e. contribution to upper Columbia summer/fall Chinook

populations) is 5% or less. Adult management on returning adults from the segregated program include fisheries, removal at the Okanogan weir, and removal at the CJH ladder.

12.0 Upper Columbia Summer Chinook (Chelan Falls and Wells)

No PNI goals are established. Chelan Falls and Wells FH summer Chinook programs are segregated harvest programs designed to provide opportunity for harvest. Adult returns are not intended to spawn naturally; therefore, there is no escapement goal for natural spawning areas. Adult returns will be managed to meet program objectives. Chelan Falls and Wells Hatchery summer Chinook are available for harvest in the ocean and Columbia River commercial, tribal, and recreational fisheries.

13.0 Priest Rapids Fall Chinook

The Hanford Reach fall Chinook population is intentionally supplemented by Grant PUD at the Priest Rapids Hatchery and the ACOE at the Priest Rapids and Ringold Springs hatcheries. Managers desire to achieve a population level PNI that includes all hatchery programs of ≥0.67. Grant PUD and the HSC do not have control over operation or expansion of the ACOE program and therefore will strive to operate the Priest Rapids Hatchery fall Chinook program in a way that does its fair share of achieving a population level PNI of 0.67.

APPENDIX 4: SPATIAL DISTRIBUTION OF SPAWNERS OR REDDS

Strategies for conservation programs typically intend that hatchery and naturally produced fish spawn together and in similar locations. However, in some cases, strategies may differ from this paradigm. In Table 1, conservation programs that have a spatial distribution management plan that deviates from similar to the natural spawning spatial distributions are presented. Otherwise, conservation programs are intended to have a spawning distribution similar to the natural origin spawning spatial distributions, as described by M&E Objective 5.3.

Table 1. Management targets for the spatial distribution of hatchery-origin redds for conservation programs that deviate from Objective 5.3.

Program	Target	Rational	Source
Carlton Summer Chinook	The observed spawning distribution of hatchery origin Methow summer Chinook from 2005-2010 represents the base-line spawner distribution for evaluating the performance of the hatchery program (i.e., M&E plan check-ins). It is acknowledged that this distribution is lower in the River than the spawning distribution of natural origin summer Chinook salmon.	Based upon an assessment of summer Chinook and ESA-listed spring Chinook abundance and spawner distribution, it was determined that an increase in summer Chinook spawning abundance in the upper most range of natural origin summer Chinook distribution or potentially above the current range may pose an unknown and potentially adverse impact to ESA listed spring Chinook. Due to the concern for spring Chinook, the HSC has endorsed an acclimation site in the Methow Basin that is lower in the basin than may be required to attain exact replication of natural and hatchery origin summer Chinook spawner distribution.	SOA 2011-02 Priest Rapids Coordinating Committee Hatchery Subcommittee Statement of Agreement on Monitoring & Evaluation (M&E) Objective for Spawning Distribution of Hatchery-Origin Summer Chinook
Dryden Summer Chinook	The observed spawning distribution of hatchery origin Wenatchee summer Chinook from 2008-2013 (previous 5 years to the current M&E check-in cycle) represents the base-line spawner distribution for evaluating the performance of the	The primary site endorsed by the HSC for Grant PUD overwinter acclimation of summer Chinook is the Dryden Pond, and is the current acclimation and release site for the existing summer Chinook supplementation program	Adapted from SOA 2011-02 Priest Rapids Coordinating Committee Hatchery Subcommittee Statement of Agreement on Monitoring & Evaluation (M&E) Objective for Spawning Distribution of Hatchery-Origin Summer Chinook

	hatchery program (i.e., M&E plan check-ins).	funded and owned by Chelan PUD. Because current data indicates that spawning distribution of hatchery summer Chinook from the existing program is lower in the Wenatchee River than natural origin spawners, expectations are that acclimation of Grant PUD's summer Chinook at Dryden Pond would continue to return hatchery origin summer Chinook that result in different spawning distributions for hatchery and natural summer Chinook.	

APPENDIX 5: WITHIN HATCHERY REARING TARGETS

Rearing Targets for Upper Columbia River Hatchery Programs. K-factor or fork length targets will be determined based on data from the pending "Five-Year Report."

Table 1. Numbers, fish per pound (fpp), coefficient of variation (CV), and condition factor (K) targets at release of Upper Columbia River Hatchery Programs.

Hatchery	Species	Life Stage	Basin	Release number	FPP	CV	K-factor
Methow	Spring Chinook	Yearling	Methow	193,765[1]	15	<10	TBD
Methow	Spring Chinook	Yearling	Twisp	30,000	15	<10	TBD
Chief Joseph	Spring Chinook	Yearling	Columbia	700,000	15	<10	TBD
Chief Joseph	Spring Chinook	Yearling	Okanogan	200,000	15	<10	TBD
Chiwawa	Spring Chinook	Yearling	Wenatchee	144,026	18	<10	TBD
Nason	Spring Chinook	Yearling	Wenatchee	223,670[3]	18-24	<10	TBD
Winthrop	Spring Chinook	Yearling	Methow	400,000	17	<10	TBD
Leavenworth	Spring Chinook	Yearling	Wenatchee	1.2 M	17	<10	TBD
Wells	Steelhead	Yearling	Columbia	160,000	6	<10	TBD
Wells	Steelhead	Yearling	Methow	100,000	6	<10	TBD
Wells	Steelhead	Yearling	Twisp	48,000	6	<10	TBD
Wells	Steelhead	Yearling	Omak	~100,000[4]	5-8	<10	TBD
Wells	Steelhead	Yearling	Okanogan	~100,000[4]	5-8	<10	TBD
Winthrop	Steelhead	Two year	Methow	200,000	4-6	<10	TBD
Chiwawa	Steelhead	Yearling	Wenatchee	247,300[5]	6	9.0	TBD
Wells	Summer Chinook	Subyearling	Columbia	480,000	50[6]	<7	TBD
Wells	Summer Chinook	Yearling	Columbia	320,000	10	<7	TBD
Chief Joseph	Summer Chinook	Subyearling	Columbia	400,000	50	<7	TBD
Chief Joseph	Summer Chinook	Subyearling	Okanogan	300,000	50	<7	TBD
Chelan Falls	Summer Chinook	Yearling	Chelan	576,000	13	9.0	TBD
Entiat	Summer Chinook	Yearling	Entiat	400,000	17	<10	TBD
Carlton	Summer Chinook	Yearling	Methow	200,000	13-17	<12	TBD
Chief Joseph	Summer Chinook	Yearling	Columbia	500,000	10	<7	TBD
Chief Joseph	Summer Chinook	Yearling	Okanogan	799,998[7]	10	<7	TBD
Dryden	Summer Chinook	Yearling	Wenatchee	500,001	18	9.0	TBD
Priest	Fall Chinook	Subyearling	Columbia	7.3 M[8]	50	<10	TBD
Ringold	Fall Chinook	Subyearling	Columbia	3.5 M	50	<10	TBD

[1] The total release includes the release of 108,249 into the Methow River at the Methow Fish Hatchery, 25,000 into the Methow River at the Goat Wall site, and 60,516 into the Chewuch River at the Chewuch Acclimation Facility.

[2] These fish come from Winthrop National Fish Hatchery (MetComp) eyed eggs.

[3] The total release includes 125,000 conservation fish and 98,670 safety net fish.

[4] The combined Okanogan and Omak steelhead release number is 100,000.

[5] The total release includes 66,771 fish into Nason Creek, 53,170 into the Chiwawa River, 102,359 into the Wenatchee River, and 25,000 into Blackbird Pond.

[6] The Wells subyearling Chinook are not reared to achieve a specific size target. The fish are released on a date to optimize survival and are grown to the largest size possible before release.

[7] The total release is divided equally among the Omak, Riverside, and Similkameen Acclimation Ponds.

[8] The total release consists of 5.6 m fall Chinook for the Grant PUD program and 1.7 M fall Chinook for the Army Corps of Engineers program.

APPENDIX 6: IDENTIFYING AND ANALYZING REFERENCE POPULATIONS

An important goal of supplementation is to increase spawning abundance and natural-origin recruitment of the supplemented population, and not reduce the productivity of the supplemented population. Indeed, a successful supplementation program must increase spawning abundance and natural-origin recruitment to levels above those that would have occurred without supplementation. There are several methods that can be used to test the effects of supplementation programs on these population metrics. One important method is to compare the performance of population metrics (e.g., spawning abundance, natural-origin recruitment, and productivity) in the supplemented population to those in un-supplemented (reference) populations. By comparing supplemented populations to reference populations, one can determine if the supplementation programs benefit, harm, or have no effect on the supplemented populations. These comparisons, however, are only valid if the performance of the reference populations is similar to the performance of the supplemented population prior to the period of supplementation. If the performance of the two populations differs significantly before any supplementation occurs, then any results from comparing the two populations after supplementation will be suspect. It is therefore important to select reference populations that are as similar as possible to the supplemented populations.

One of the goals of the Conceptual Approach to Monitoring and Evaluating the Chelan County PUD Hatchery Programs (Murdoch and Peven 2005) is to use reference populations to analyze the potential effects of hatchery supplementation programs on natural-origin salmon and steelhead spawner abundance and productivity[13]. Murdoch and Peven (2005) identified specific objectives to evaluate the performance of the program. For example, Objective 1 determines if the supplementation programs have increased the number of naturally spawning and naturally produced adults of the target population (supplemented population) relative to a reference population. Objective 7 determines if the proportion of hatchery fish on the spawning grounds affects the freshwater productivity (e.g., number of juveniles per redd) of supplemented streams when compared to reference streams. The relevant questions tested under each objective are as follows:

Objective 1:

- Is the annual change in the number of natural-origin recruits produced from the supplemented populations greater than or equal to the annual change in natural-origin recruits in an un-supplemented population?
- Is the change in natural replacement rates within the supplemented population greater than or equal to the change in natural replacement rates in an un-supplemented population?

Objective 7:

13 Productivity is defined as adult recruits per spawner, where recruits are the number of adults produced from a given brood year (i.e., spawners plus adults harvested).

- Is the change in numbers of juveniles (smolts, parr, or emigrants) per redd in the supplemented population greater than or equal to that in an un-supplemented population?[14]

In this paper, we describe methods used to identify suitable reference streams and statistical techniques that can be used to compare reference populations with supplemented populations. Although we apply the methods described in this paper to Chiwawa spring Chinook salmon (hereafter referred to as Chinook), the methods should also apply to steelhead and other supplemented salmon stocks in the Upper Columbia Basin.

Identification of Reference Populations

Reference populations are an important component of an effectiveness monitoring design because they provide the standard by which treatment conditions are compared (ISRP and ISAB 2005; Murdoch and Peven 2005; Galbreath et al. 2008). Selecting appropriate reference areas and maintaining them over long periods of time is needed to establish the effectiveness of supplementation programs.

We developed a three-step process for identifying suitable reference populations (Figure 1). Each step serves as a filter. That is, potential reference populations are evaluated based on specific criteria under each step. Populations that pass through each step are considered suitable reference populations for a specific supplemented population.

[14] In this paper, we only address adult recruits, not juvenile recruits. This is because we were unable to find suitable reference populations for analysis of juveniles. However, the methods described in this paper would also apply to juveniles.

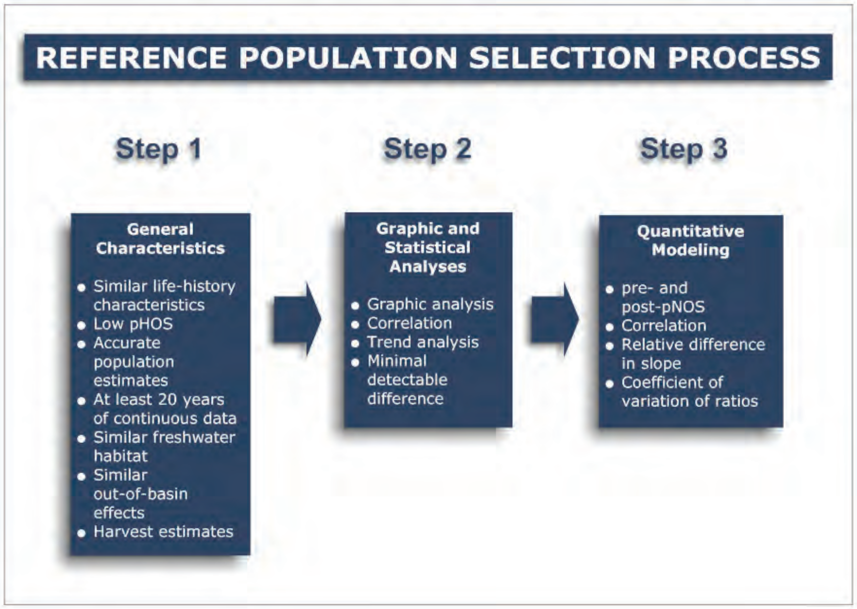

Figure 1. Criteria evaluated during each step in the process of identifying suitable reference populations.

Step 1: General Characteristics

Under step 1, potential reference populations are evaluated based on several general criteria. When compared to the supplemented population, potential reference populations should have:

- Similar life-history characteristics (e.g., run timing, migration characteristics, etc.).
- No or few hatchery fish in the reference area (pHOS < 10%).
- Accurate abundance estimates.
- Long time series of natural-origin abundance and productivity estimates (at least 20 years of continuous data).
- Similar trends in freshwater habitat.
- Similar out-of-basin effects (i.e., similar migration and ocean survivals).
- Harvest estimates for adjusting escapement estimates.

We used these criteria to begin the process of selecting suitable reference populations for the Chiwawa spring Chinook program. We began by identifying stream-type Chinook populations within the Columbia Basin. Galbreath et al. (2008; their Table 1) identified stream-type Chinook populations within the Columbia River Basin that may serve as suitable reference populations for hatchery programs. Supplementing their work with data from the NOAA Fisheries Salmon Population Summary Database, we identified 18 candidate stream-type Chinook populations that may serve as reference populations for the Chiwawa supplementation program (Table 1).

Table 1. Populations of stream-type Chinook salmon and their comparison to Chiwawa spring Chinook.

Population	Similar life-history	No or few hatchery fish	Accurate abundance estimates	Long time series (at least 20 years)	Similar freshwater habitat impairments	Similar out-of-basin effects	Comments
Deschutes River	Yes	Yes	Yes	Yes	No	No	
John Day mainstem	Yes	Yes	Yes	Yes	No	No	
Middle Fk John Day	Yes	Yes	Yes	Yes	No	No	
North Fk John Day	Yes	Yes	Yes	Yes	No	No	
Granite Creek	Yes	Yes	Yes	Yes	No	No	
Wenaha River	Yes	No	Yes	Yes	Yes	No	Hatchery strays (>10%)
Minam River	Yes	No	Yes	Yes	Yes	No	Hatchery strays (>10%)
Slate Creek	Yes	Yes	Yes	No	No	No	
Secesh River	Yes	Yes	Yes	Yes	Yes	No	
Middle Fk Salmon River	Yes	Yes	Yes	No	No	No	Fair productivity est.
Big Creek	Yes	Yes	Yes	Yes	No	No	
Camas Creek	Yes	Yes	Yes	Yes	No	No	Fair productivity est.
Loon Creek	Yes	Yes	Yes	Yes	No	No	Fair productivity est.
Sulphur Creek	Yes	Yes	Yes	Yes	No	No	
Bear Valley Creek	Yes	Yes	Yes	Yes	No	No	
Marsh Creek	Yes	Yes	Yes	Yes	Yes	No	
North Fk Salmon River	Yes	Yes	No	No	Yes	No	
Lemhi River	Yes	Yes	Yes	Yes	No	No	
East Fk Salmon River	Yes	No	Yes	Yes	No	No	Hatchery strays (>10%)
Valley Creek	Yes	No	Yes	Yes	No	No	Hatchery strays (>10%)
Chamberlain Creek	Yes	Yes	Yes	No	Yes	No	
Naches River	Yes	Yes	Yes	Yes	Yes	No	
Little Wenatchee River	Yes	No	Yes	Yes	Yes	Yes	Hatchery strays (>10%)
Entiat River	Yes	No	Yes	Yes	No	No	Hatchery release ending

We then assessed the accuracy and length of the series of abundance estimates. We assumed that abundance estimates generated from expanded redd counts or adjusted weir counts would compare well with estimates in the Chiwawa Basin, which were based on expanded redd counts. In addition, we looked for populations that had an abundance data series that extended from at least 1981 to present. Based on this analysis, we identified 18 populations with abundance estimates that could be compared to those from the Chiwawa Basin (Table 1).

Next, we determined if the potential reference populations came from watersheds with habitat conditions similar to those in the Chiwawa Basin. For this exercise, we searched recovery plans and draft recovery plans to identify tributary factors that limit Chinook abundance, productivity, and survival within the reference populations. We compared these factors with those limiting

Chinook salmon in the Chiwawa Basin. Based on this analysis, we identified eight populations with habitat impairments similar to those in the Chiwawa Basin (Table 1).

Finally, we examined the potential reference populations to see if they experienced out-of-basin effects similar to spring Chinook from the Chiwawa Basin. In this case, we compared the number of mainstem dams that each potential reference population passes during migration. Six of the potential reference populations pass less than six mainstem dams; the other populations pass eight mainstem dams (Table 1). Only the Little Wenatchee population passes seven dams, similar to the Chiwawa population.

In sum, there were no reference populations that matched the Chiwawa spring Chinook population on all the criteria identified above. Differential out-of-basin effects and freshwater habitat conditions prevented most reference populations from matching with Chiwawa spring Chinook. However, some of the potential reference populations were similar to the Chiwawa population on several criteria and warranted further investigation. We selected the following populations for further investigation: Sesech River, Marsh Creek, Naches River, Little Wenatchee, and Entiat River.

We included the Little Wenatchee because it is within the Wenatchee River basin and experiences similar out-of-basin effects and has the same climatic and environmental conditions as the Chiwawa. A confounding effect with the Little Wenatchee is that Chiwawa hatchery fish have strayed into the Little Wenatchee. However, straying of Chiwawa hatchery fish should decrease with the change in source water to the Chiwawa acclimation ponds in 2006. We also included the Entiat River because it is an adjacent basin to the Chiwawa and experiences similar climatic and environmental conditions. The spring Chinook hatchery program that has operated in the Entiat since 1975 has been discontinued. Therefore, this population offers a unique opportunity to compare the Chiwawa population to a population in which the hatchery program has been discontinued.

Step 2: Graphic and Statistical Analysis

Graphic Analysis

Although we were unable to find potential reference populations that matched with the Chiwawa population on all criteria considered under Step 1, spawner abundance, natural-origin recruits (NORs), and productivity of some of the potential reference populations may nevertheless track closely with the Chiwawa population. If the time series of abundance, NORs, and productivity of a potential reference population tracks closely with the abundance, NORs, and productivity of the Chiwawa population, the reference population may provide a reasonable reference condition for testing the effects of supplementation on the Chiwawa population.

Under Step 2, we used graphing techniques to examine the relationship of abundance, NORs, and productivity between the Chiwawa population and the five reference populations (Sesech River, Marsh Creek, Naches River, Little Wenatchee, and Entiat River). We compiled spawner abundance, NORs, and productivity data from local biologists and the NOAA Fisheries Salmon Population Summary Database. We then compared time series plots of spawner abundance, NORs, and productivity data of potential reference populations with the Chiwawa population (Figures 2, 3, and 4; plots on the left side of figures). The time series only included the period 1981 to 1992, which represented the period before supplementation of the Chiwawa population (pre-treatment period). We also plotted the relationship between the abundance, NORs, and productivity of each

potential reference population to the Chiwawa population (Figures 2, 3, and 4; plots on right side of figures). These plots show whether the reference populations closely tracked the Chiwawa population. As a point of reference, data points that fall along the dashed line would represent a perfect relationship between the two populations (i.e., both populations have identical abundance, NORs, and productivity estimates). While a perfect relationship between two independent populations is unrealistic, a strong linear relationship between the two populations indicates populations with similar trends.

Based on analysis of spawner abundance, the Naches River time series tracked more closely with the abundance of Chiwawa spring Chinook than did the other potential reference populations. The poor relationship with the other potential reference streams was largely because of the relatively high abundance of Chiwawa spring Chinook during the mid-1980s. As with spawner abundance, analyses of NORs indicated a close relationship between the Naches and Chiwawa populations. The other potential reference populations tracked poorly with the Chiwawa. The analyses of productivity indicated close relationships between potential reference populations and the Chiwawa population. The Naches, Sesech, and Little Wenatchee populations tracked the closest with the Chiwawa population.

When analyzing the potential effects of a supplementation program on fish performance, it is common to transform the data to meet various assumptions of statistical analysis. The most common transformation used to adjust abundance, NORs, and productivity data is the natural logarithm (LN or $\log_e$). We therefore transformed the spawner abundance, NORs, and productivity data using LN and re-plotted the relationships between the potential reference populations and the Chiwawa population (Figures 5, 6, and 7). We added 1 to each observation before taking its logarithm to avoid taking the logarithm of 0, which is undefined (note that the LN of 1 is 0).

By transforming spawner abundance, NORs, and productivity data, most of the potential reference populations tracked more closely with the Chiwawa population. The Naches, Entiat, and Little Wenatchee abundance data tracked the closest with the Chiwawa abundance data (Figure 5). For NORs, Marsh Creek and the Little Wenatchee populations tracked the closest with the Chiwawa (Figure 6). For productivity, the Naches, Sesech, and Little Wenatchee tracked the closest with the Chiwawa (Figure 7).

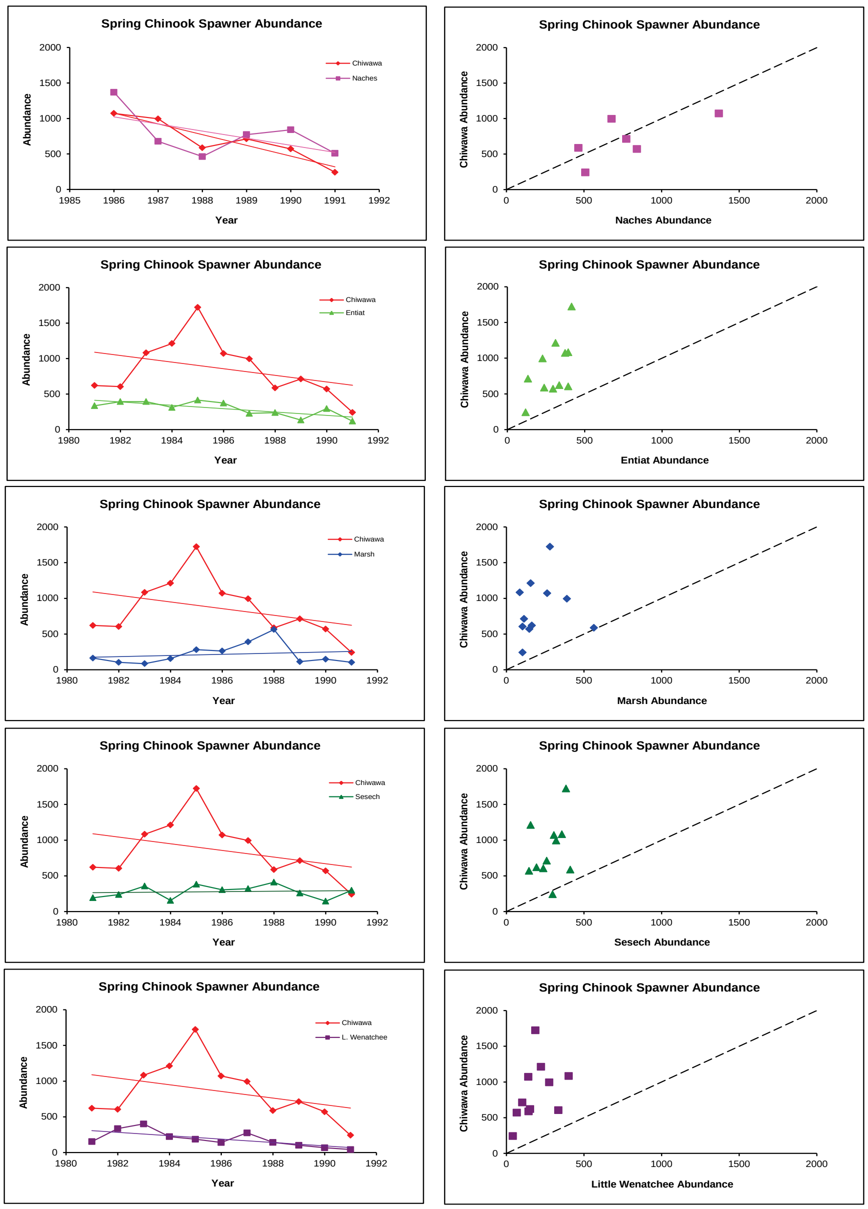

Figure 2. Time series of spawner abundance of potential reference populations and the Chiwawa spring Chinook population before the Chiwawa population was supplemented with hatchery fish.

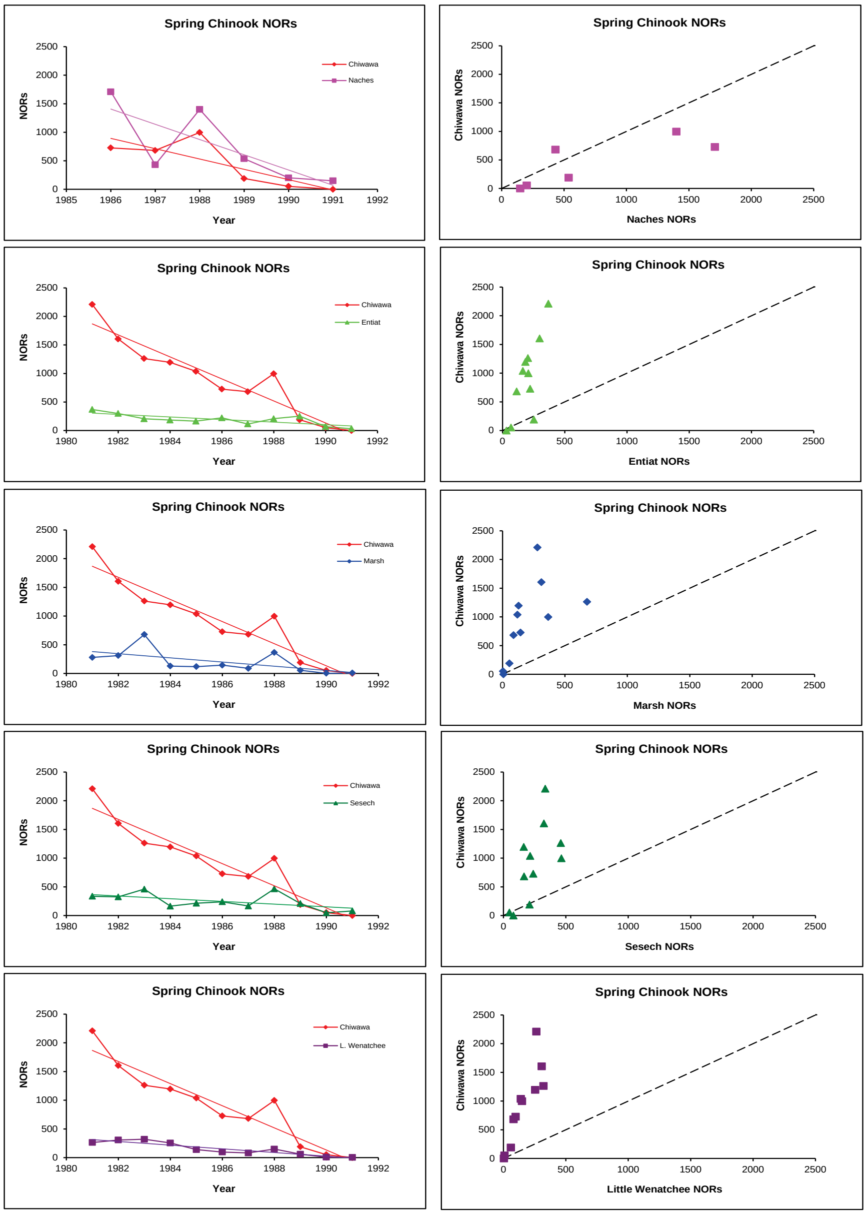

Figure 3. Time series of natural-origin recruits (NORs) of potential reference populations and the Chiwawa spring Chinook population before the Chiwawa population was supplemented with hatchery fish.

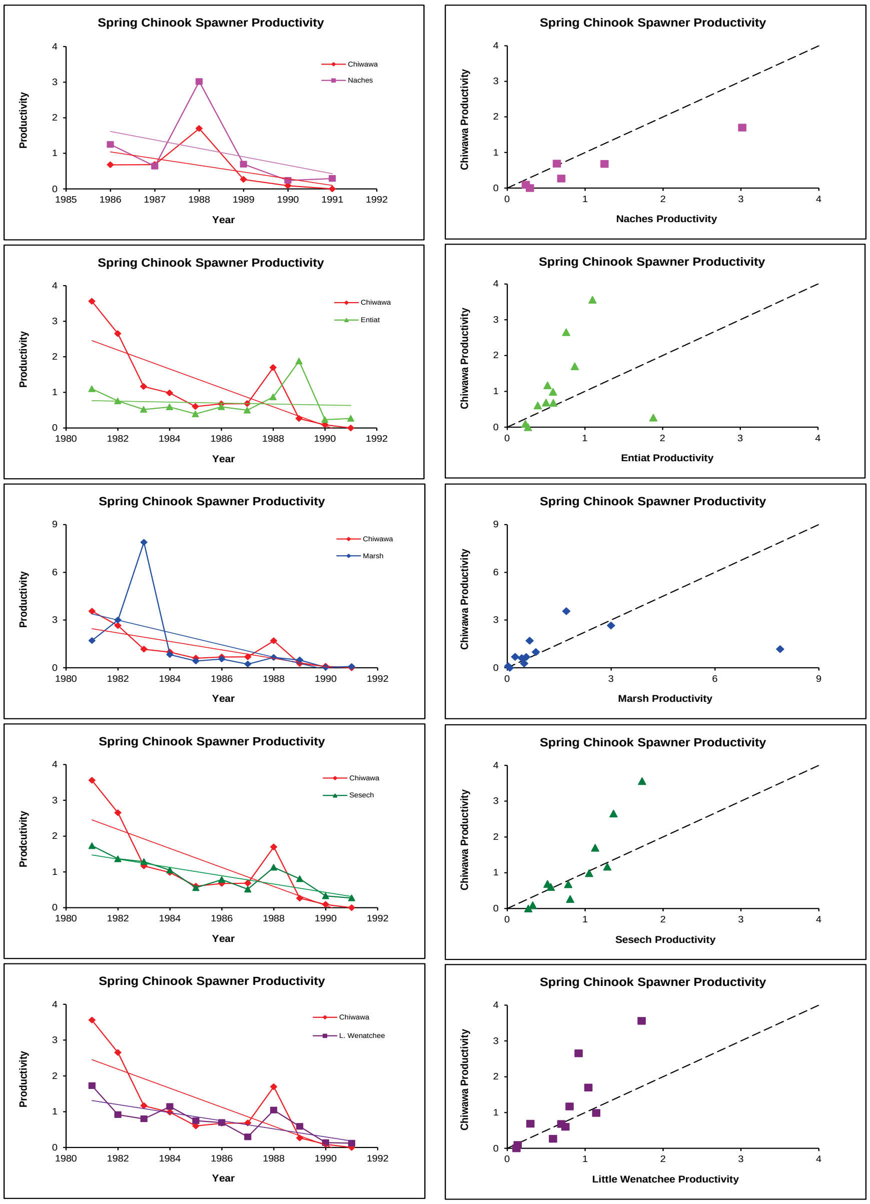

Figure 4. Time series of adult productivity of potential reference populations and the Chiwawa spring Chinook population before the Chiwawa population was supplemented with hatchery fish.

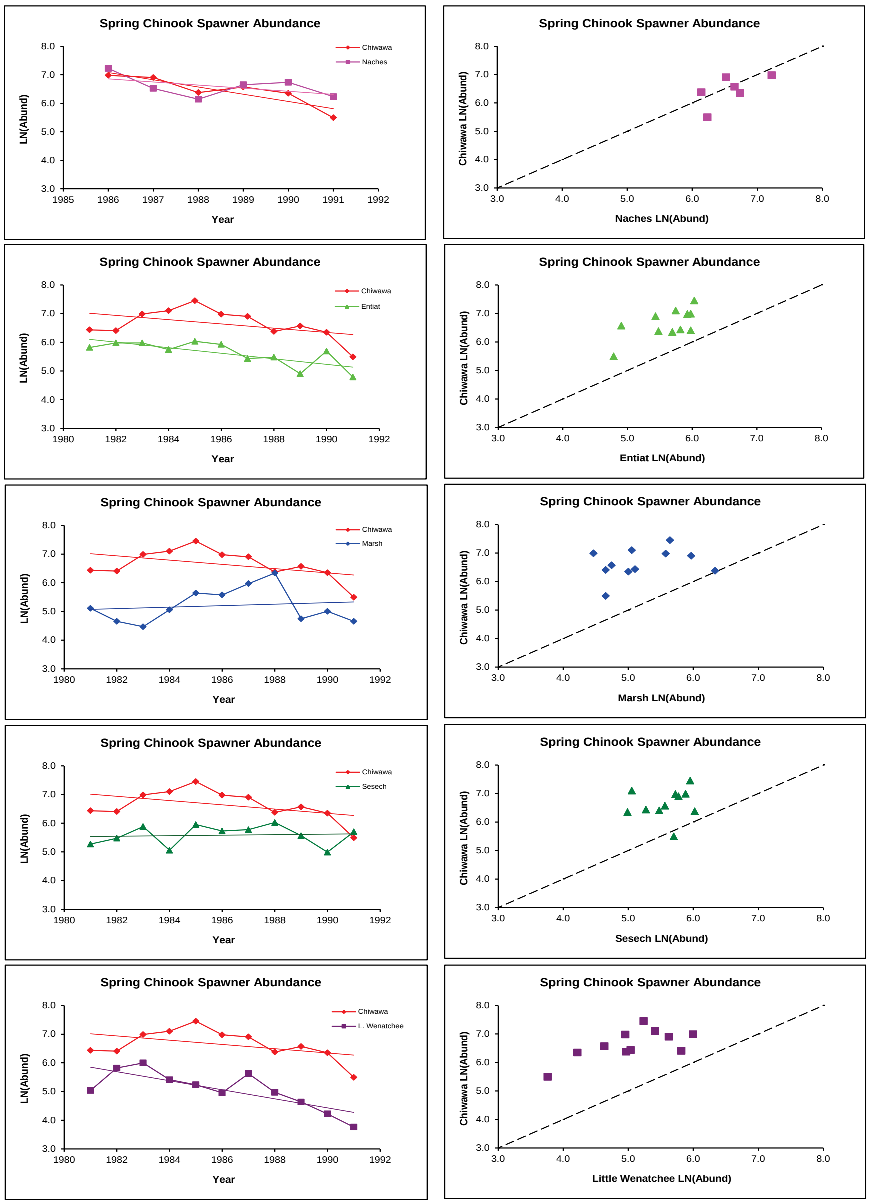

Figure 5. Time series of natural log spawner abundance of potential reference populations and the Chiwawa spring Chinook population before the Chiwawa population was supplemented with hatchery fish.

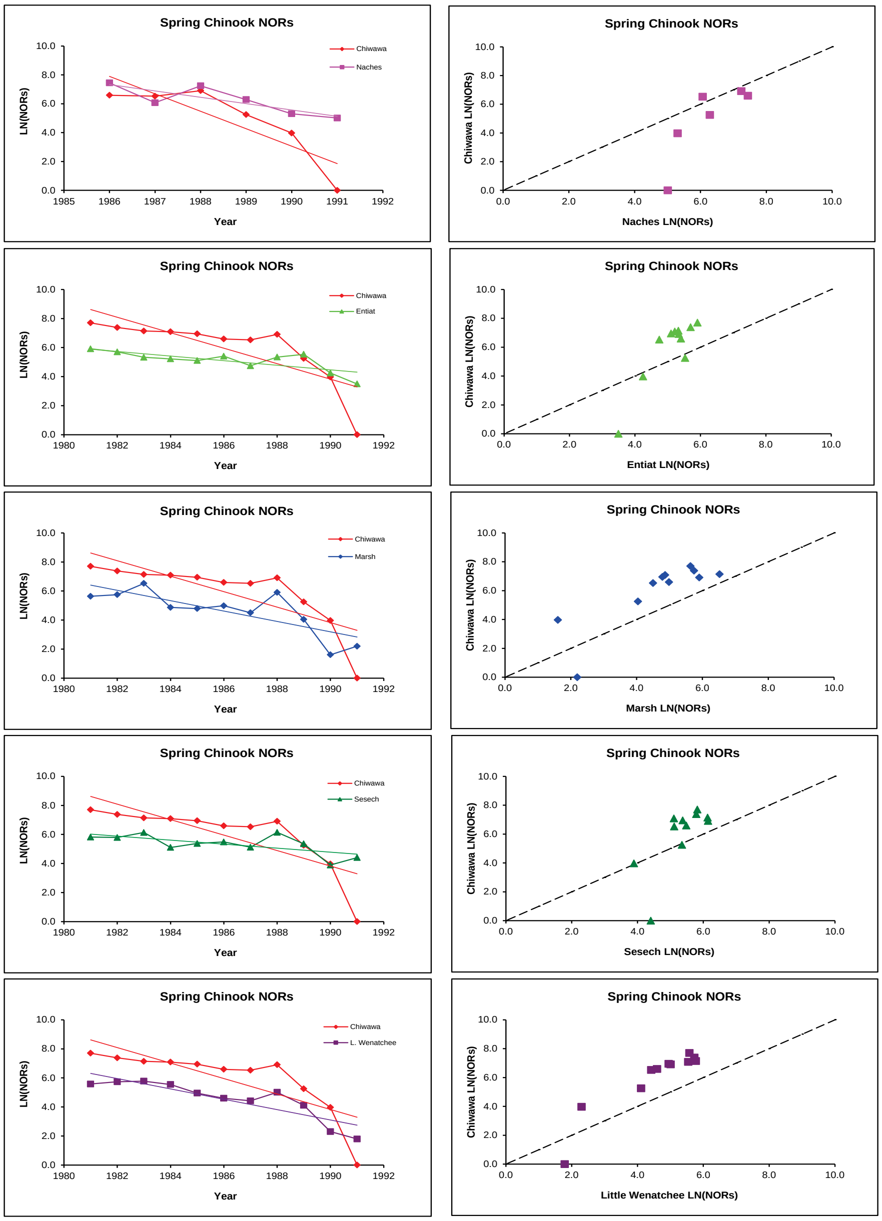

Figure 6. Time series of natural log natural-origin recruits (NORs) of potential reference populations and the Chiwawa spring Chinook population before the Chiwawa population was supplemented with hatchery fish.

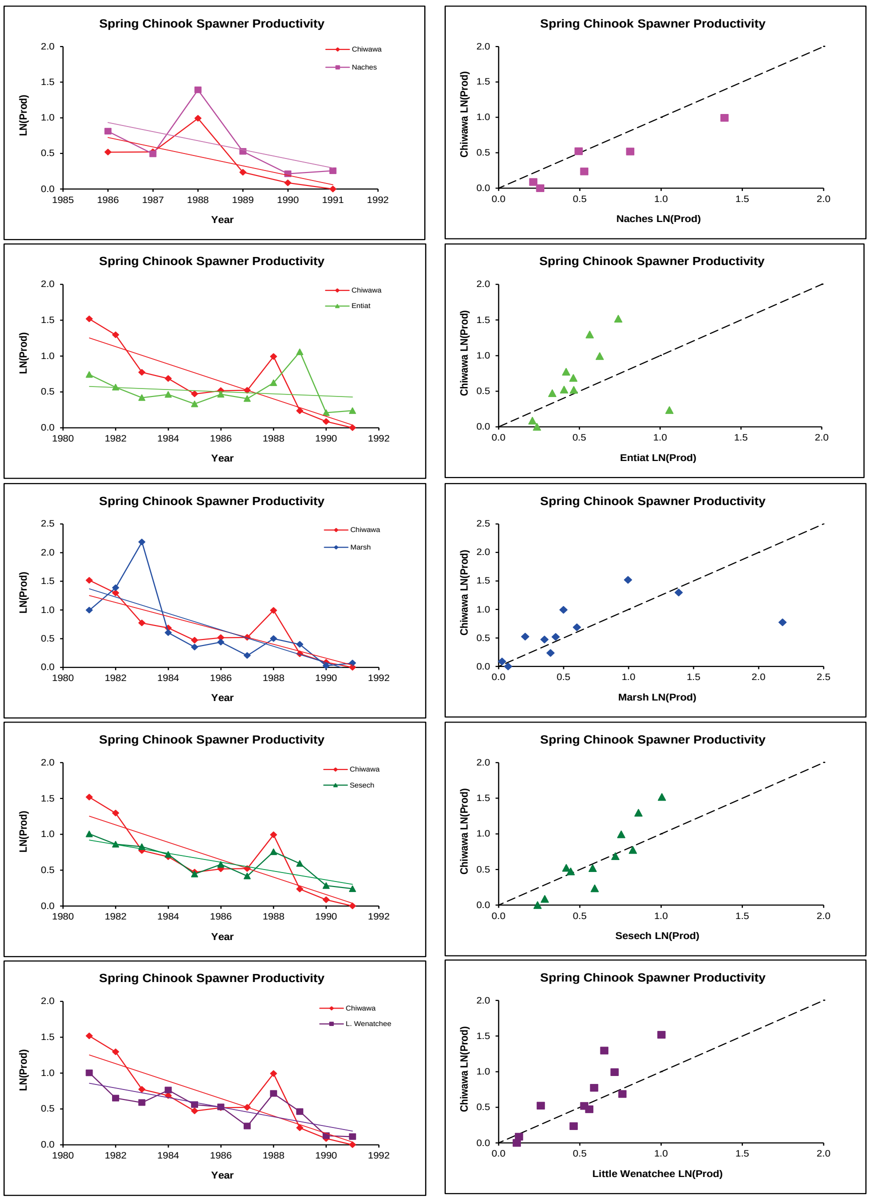

Figure 7. Time series of natural log adult productivity of potential reference populations and the Chiwawa spring Chinook population before the Chiwawa population was supplemented with hatchery fish.

Correlations and Trends

Other methods for evaluating the suitability of potential reference populations under Step 2 include correlation and trend analyses. For correlation analysis, we simply calculated the Pearson correlation coefficient, which is an index of the strength of the association between the potential reference populations and the Chiwawa population. The coefficient ranges from -1 to 1, where a value near 1 or -1 represents that strongest association between the populations. A value of 0 means no association. We used only spawner abundance, NORs, and productivity data during the pre-treatment period (1981-1992). We assumed that populations with coefficients greater than 0.6 represented reasonable reference conditions.

For trend analyses, we used least squares techniques to compute a straight-line trend through the spawner abundance and productivity data for the potential reference populations and the Chiwawa population. Trends were fit to the pre-treatment time series data (1981-1992). We then used t-tests to determine if the slopes of the trends between potential reference populations and the Chiwawa population differed significantly.

It is important to note that time-series trend analyses are susceptible to temporal correlations in the data. Autoregressive integrated moving average (ARIMA) models can be used to describe the correlation structure in temporal data (Gotelli and Ellison 2004). However, these models require a long time series (N > 40) and therefore we could not use them to model the spring Chinook data. As such, we were unable to correct for any temporal correlation that may exist within the time series.

Tests of correlation with spawner abundance data indicated that the Naches River closely correlated with the Chiwawa population (Table 2). There was no difference in abundance trends between the potential reference populations and the Chiwawa population (Table 2; Figure 2). For NORs, all potential reference populations correlated with the Chiwawa population (Table 2). However, trends in NORs of all reference populations, except Naches, differed significantly from the Chiwawa population (Table 2; Figure 3). For productivity, the Naches, Sesech, and Little Wenatchee correlated with the Chiwawa population (Table 2). Only the Entiat productivity trend differed significantly from the Chiwawa population trend (Table 2; Figure 4).

Table 2. Pearson correlation coefficients and t-test results comparing slopes of trends between potential reference populations and the Chiwawa spring Chinook population; d.f. = degrees of freedom and for correlation coefficients, an asterisk (*) indicates significance at P < 0.05.

Reference populations	Pearson correlation coefficient	t-test on slopes		
		t-value	d.f.	P-value
Spawner Abundance Data				
Naches	0.684*	-0.659	8	0.528
Entiat	0.598*	-0.596	18	0.559
Marsh	0.147	-1.341	18	0.197
Sesech	0.274	-1.265	18	0.222
Little Wenatchee	0.399	-0.591	18	0.562
Natural-Origin Recruits				
Naches	0.803*	0.666	8	0.524
Entiat	0.795*	-7.495	18	0.000

Reference populations	Pearson correlation coefficient	t-test on slopes		
		t-value	d.f.	P-value
Marsh	0.605*	-5.786	18	0.000
Sesech	0.648*	-6.874	18	0.000
Little Wenatchee	0.880*	-7.206	18	0.000
Productivity Data				
Naches	0.960*	0.169	8	0.870
Entiat	0.272	-3.057	18	0.007
Marsh	0.320	0.605	18	0.553
Sesech	0.903*	-2.059	18	0.054
Little Wenatchee	0.848*	-2.065	18	0.054

We also ran correlation and trend analyses on natural-log transformed spawner abundance, NORs, and productivity data. These analyses indicated that the Naches, Entiat, and Little Wenatchee abundance data correlated with the Chiwawa population data (Table 3). None of the abundance trends of the potential reference populations differed significantly from the Chiwawa population trend (Table 3; Figure 5). For NORs, all potential reference populations correlated with the Chiwawa population (Table 3). Only trends in NORs of the Entiat and Sesech differed significantly from the Chiwawa population (Table 2; Figure 6). For productivity, the Naches, Marsh, Sesech, and Little Wenatchee correlated with the Chiwawa population data (Table 3). Only the Entiat productivity trend differed significantly from the Chiwawa population trend (Table 3; Figure 7).

Table 3. Pearson correlation coefficients and t-test results comparing slopes of trends between potential reference populations and the Chiwawa spring Chinook population; d.f. = degrees of freedom and for correlation coefficients, an asterisk (*) indicates significance at P < 0.05. Analyses were conducted on natural-log transformed abundance and productivity data.

Reference populations	Pearson correlation coefficient	t-test on slopes		
		t-value	d.f.	P-value
LN Spawner Abundance Data				
Naches	0.642*	-1.323	8	0.222
Entiat	0.652*	0.412	18	0.685
Marsh	0.294	-1.324	18	0.202
Sesech	0.149	-1.431	18	0.170
Little Wenatchee	0.670*	1.325	18	0.202
LN Natural-Origin Recruits				
Naches	0.824*	-1.985	8	0.082
Entiat	0.886*	-2.563	18	0.019
Marsh	0.830*	-1.038	18	0.313
Sesech	0.730*	-2.664	18	0.016
Little Wenatchee	0.927*	-1.150	18	0.265
LN Productivity Data				

Reference populations	Pearson correlation coefficient	t-test on slopes		
		t-value	d.f.	P-value
Naches	0.944*	-0.042	8	0.968
Entiat	0.373	-3.043	18	0.007
Marsh	0.610*	0.428	18	0.674
Sesech	0.913*	-2.050	18	0.055
Little Wenatchee	0.862*	-1.811	18	0.087

In summary, based on correlation, trend, and graphic analyses, the Naches, Entiat, and Little Wenatchee populations appear to be reasonable reference populations for comparing spawner abundance data with Chiwawa data. For NORs, the Naches, Marsh, and Little Wenatchee appear to be reasonable reference populations. For productivity, the Naches, Marsh, Sesech, and Little Wenatchee populations appear to be reasonable reference populations for the Chiwawa population.

Minimal Detectable Differences (MDD)

Given a suite of potential reference populations, it is important to conduct power analyses to determine the minimum differences that can be detected when comparing the reference populations to the supplemented population. As a final exercise under Step 2, we examined potential reference populations for the smallest minimal detectable differences. Before conducting power analyses, several decisions needed to be made, including what statistical procedures will be used to analyze the data, the desired level of statistical power (probability of rejecting a false null hypothesis), the size of the type-I error (the probability of rejecting a true null hypothesis of no difference), and the number of samples (i.e., years) included in the analysis. In this case, the number of samples represents the number of treatment (supplementation) years. The number of pre-treatment years (1981-1992) was based on the number of years of quality data available for Chiwawa spring Chinook and potential reference populations.

We designed the study as a modified BACI (Before-After, Control-Impact) design, which includes replication before and after supplementation in both the treated (T) population and the reference (R) populations. A common approach used to analyze data from BACI designs includes analysis of difference scores (Stewart-Oaten et al. 1992; Smith et al. 1993). Differences are calculated between paired treatment and reference population scores (i.e., T-R). Another approach is to calculate ratios (treatment/reference; T/R) for paired treatment and reference population scores (Skalski and Robson 1992). Finally, differences in annual changes in paired treatment and reference population scores can be calculated (i.e., ΔT-ΔR) (Murdoch and Peven 2005; Hays et al. 2006).[15] These derived difference and ratio scores are then analyzed for a before-after treatment effect with a two-sample t-test, Aspin-Welch modification of the t-test, or a randomization test. For power analyses, we calculated minimal detectable differences assuming the use of an independent two-sample t-test with a type-I error rate of 0.05, power of 0.80 (beta or type-II error rate of 0.20), and sample sizes (treatment years) of 5, 10, 15, 20, 25, and 50 years.

15 The difference of annual difference scores was estimated by first subtracting the population parameter (e.g., spawner abundance) in year 2 from year 1. This continues for all years in the data series for both treatment ($T_{t+1} – T_t$) and reference populations ($R_{t+1} – R_t$). We then calculated differences between paired treatment and reference annual difference scores [($T_{t+1} – T_t$) - ($R_{t+1} – R_t$) = ΔT-ΔR].

The power analysis calculated the minimal detectable difference between mean difference or ratio scores before and during supplementation. We used existing data to calculate variances for the pre-supplementation and supplementation periods. Thus, variances were known and unequal. For both spawner abundance and NORs, the null hypothesis tested was that the mean difference or ratio before supplementation equaled the mean difference or ratio during supplementation. The alternative hypothesis was that the mean difference or ratio before supplementation was less than the mean difference during supplementation (one-tail test; Difference < 0). For productivity, the null hypothesis tested was that the mean difference or ratio before supplementation equaled the mean difference or ratio during supplementation. The alternative hypothesis was that the mean difference or ratio before supplementation was greater than the mean difference during supplementation (one-tail test; Difference > 0).

Based on spawner abundance data, power analysis indicated that the Sesech-Chiwawa pairing consistently produced the smallest detectable differences (Table 4). However, when the abundance data were transformed using natural logs, the Entiat-Chiwawa pairing produced the smallest detectable difference (Table 5). Minimal detectable differences, based on mean difference scores on untransformed data and a treatment period of 20 years, ranged from 334 to 394 adult spawners; transformed data ranged from 0.479 to 1.010. These analyses indicate that the Naches, Entiat, Sesech, and Little Wenatchee populations appear to be reasonable reference populations for comparing spawner abundance data with Chiwawa data. The Marsh Creek population produced some of the largest detectable differences and based on these analyses may not be a reasonable reference population.

Table 4. Minimal detectable differences between mean difference and ratio scores before and during supplementation. Analyses were conducted on spawner abundance data.

Response variable	Treatment years	Minimal detectable differences by reference population				
		Naches	**Entiat**	**Marsh**	**Sesech**	**Little Wenatchee**
T-R	5	638	604	560	396	652
	10	464	448	444	354	481
	15	405	395	406	341	424
	20	376	368	387	334	394
	25	358	352	376	331	376
	50	322	319	354	323	340
T/R	5	0.600	2.084	39.251	1.569	5.498
	10	0.506	1.548	24.729	1.508	3.828
	15	0.478	1.367	19.646	1.490	3.256
	20	0.465	1.275	16.828	1.481	2.954
	25	0.458	1.219	14.974	1.475	2.765
	50	0.447	1.105	10.573	1.465	2.366
ΔT-ΔR	5	1,049	761	717	518	766
	10	750	542	539	411	547
	15	650	467	480	376	473
	20	598	429	450	359	434

Response variable	Treatment years	Minimal detectable differences by reference population				
		Naches	Entiat	Marsh	Sesech	Little Wenatchee
	25	567	405	431	348	410
	50	506	355	395	329	361

Table 5. Minimal detectable differences between mean difference and ratio scores before and during supplementation. Analyses were conducted on natural-log transformed spawner abundance data.

Response variable	Treatment years	Minimal detectable differences by reference population				
		Naches	Entiat	Marsh	Sesech	Little Wenatchee
T-R	5	0.975	0.871	2.061	0.828	1.013
	10	0.721	0.613	1.375	0.648	0.722
	15	0.637	0.525	1.138	0.588	0.623
	20	0.595	0.479	1.010	0.559	0.571
	25	0.569	0.450	0.928	0.541	0.539
	50	0.521	0.390	0.749	0.505	0.473
T/R	5	0.157	0.162	2.343	0.160	0.368
	10	0.116	0.115	1.474	0.125	0.247
	15	0.102	0.099	1.170	0.114	0.206
	20	0.095	0.090	1.001	0.108	0.183
	25	0.091	0.085	0.890	0.104	0.169
	50	0.082	0.075	0.625	0.098	0.138
ΔT-ΔR	5	1.261	1.288	3.076	1.160	1.467
	10	0.898	0.900	2.020	0.887	1.001
	15	0.776	0.768	1.653	0.797	0.840
	20	0.713	0.698	1.463	0.751	0.755
	25	0.675	0.655	1.325	0.724	0.701
	50	0.600	0.564	1.038	0.670	0.585

Based on NORs, power analysis indicated that the Entiat-Chiwawa, Marsh-Chiwawa, and Little Wenatchee-Chiwawa pairings produced the smallest detectable differences (Table 6). When NORs were transformed using natural logs, the Little Wenatchee-Chiwawa pairing produced the smallest detectable difference (Table 7). Minimal detectable differences, based on mean difference scores on untransformed data and a treatment period of 20 years, ranged from 483 to 640 NORs; transformed data ranged from 0.958 to 2.262. These analyses indicate that the Entiat, Marsh, and Little Wenatchee populations appear to be reasonable reference populations for comparing NORs with Chiwawa data.

Table 6. Minimal detectable differences between mean difference and ratio scores before and during supplementation. Analyses were conducted on natural-origin recruits.

Response variable	Treatment years	Minimal detectable differences by reference population				
		Naches	Entiat	Marsh	Sesech	Little Wenatchee
T-R	5	1,139	541	573	630	546
	10	809	511	515	550	503
	15	698	502	498	526	489
	20	640	497	489	514	483
	25	604	494	484	507	479
	50	534	489	474	493	472
T/R	5	0.469	2.538	5.196	1.976	6.973
	10	0.451	2.183	4.183	1.894	5.118
	15	0.446	2.072	3.854	1.869	4.492
	20	0.445	2.017	3.691	1.857	4.170
	25	0.444	1.986	3.594	1.850	3.973
	50	0.443	1.924	3.405	1.836	3.572
ΔT-ΔR	5	1,639	500	519	609	531
	10	1,239	386	409	433	396
	15	1,109	348	374	372	351
	20	1,046	329	356	341	328
	25	1,009	318	346	321	314
	50	943	295	325	281	285

Table 7. Minimal detectable differences between mean difference and ratio scores before and during supplementation. Analyses were conducted on natural-log transformed natural-origin recruits.

Response variable	Treatment years	Minimal detectable differences by reference population				
		Naches	Entiat	Marsh	Sesech	Little Wenatchee
T-R	5	2.380	1.646	1.967	2.247	1.174
	10	2.291	1.479	1.505	1.835	1.026
	15	2.270	1.428	1.351	1.702	0.980
	20	2.262	1.403	1.273	1.636	0.958
	25	2.258	1.389	1.227	1.597	0.945
	50	2.253	1.361	1.133	1.522	0.920
T/R	5	0.322	0.332	0.739	0.398	0.356
	10	0.301	0.289	0.581	0.334	0.322
	15	0.296	0.275	0.530	0.314	0.312
	20	0.294	0.269	0.504	0.305	0.307
	25	0.293	0.265	0.488	0.299	0.304

Response variable	Treatment years	Minimal detectable differences by reference population				
		Naches	Entiat	Marsh	Sesech	Little Wenatchee
	50	0.291	0.258	0.458	0.288	0.298
ΔT-ΔR	5	2.858	2.400	2.355	3.283	2.109
	10	2.560	1.714	1.881	2.311	1.552
	15	2.485	1.481	1.728	1.979	1.365
	20	2.456	1.360	1.652	1.805	1.269
	25	2.443	1.285	1.607	1.697	1.210
	50	2.430	1.130	1.519	1.471	1.092

Using untransformed productivity data, power analysis indicated that the Little Wenatchee-Chiwawa pairing consistently produced the smallest detectable differences (Table 8). The Marsh-Chiwawa pairings produced the largest detectable differences. When we analyzed natural-log transformed productivity data, the Naches-Chiwawa and Little Wenatchee-Chiwawa pairings produced the smallest detectable differences (Table 9). Minimal detectable differences, based on mean difference scores on untransformed data and a treatment period of 20 years, ranged from 0.754 to 1.839; transformed data ranged from 0.277 to 0.477. These analyses indicate that the Naches, Entiat, Sesech, and Little Wenatchee populations appear to be reasonable reference populations for comparing productivity data with Chiwawa data. The Marsh Creek population produced some of the largest detectable differences and based on these analyses may not be a reasonable reference population.

Table 8. Minimal detectable differences between mean difference and ratio scores before and during supplementation. Analyses were conducted on productivity data.

Response variable	Treatment years	Minimal detectable differences by reference population				
		Naches	Entiat	Marsh	Sesech	Little Wenatchee
T-R	5	2.181	1.382	2.033	3.517	1.192
	10	1.442	1.119	1.900	2.265	0.901
	15	1.186	1.033	1.859	1.828	0.804
	20	1.047	0.991	1.839	1.588	0.754
	25	0.959	0.966	1.828	1.432	0.724
	50	0.764	0.917	1.806	1.074	0.664
T/R	5	1.364	1.773	0.863	0.876	2.167
	10	1.095	1.359	0.831	0.687	1.587
	15	1.011	1.221	0.822	0.625	1.391
	20	0.971	1.152	0.817	0.594	1.290
	25	0.949	1.110	0.814	0.575	1.228
	50	0.910	1.027	0.908	0.538	1.102
ΔT-ΔR	5	3.298	1.864	3.211	4.420	1.942
	10	2.263	1.382	2.968	2.811	1.291

Response variable	Treatment years	Minimal detectable differences by reference population				
		Naches	Entiat	Marsh	Sesech	Little Wenatchee
	15	1.909	1.220	2.894	2.248	1.066
	20	1.723	1.137	2.859	1.938	0.944
	25	1.606	1.087	2.839	1.735	0.866
	50	1.365	0.986	2.800	1.259	0.695

Table 9. Minimal detectable differences between mean difference and ratio scores before and during supplementation. Analyses were conducted on natural-log transformed productivity data.

Response variable	Treatment years	Minimal detectable differences by reference population				
		Naches	Entiat	Marsh	Sesech	Little Wenatchee
T-R	5	0.540	0.551	0.674	0.890	0.585
	10	0.367	0.452	0.542	0.590	0.413
	15	0.308	0.421	0.499	0.486	0.355
	20	0.277	0.405	0.477	0.430	0.324
	25	0.257	0.396	0.465	0.393	0.305
	50	0.215	0.378	0.440	0.314	0.265
T/R	5	0.915	1.286	0.743	0.697	1.685
	10	0.744	0.973	0.704	0.541	1.227
	15	0.691	0.868	0.692	0.489	1.072
	20	0.666	0.815	0.687	0.463	0.993
	25	0.652	0.783	0.683	0.447	0.943
	50	0.628	0.719	0.677	0.416	0.843
ΔT-ΔR	5	0.885	0.810	1.028	1.252	0.971
	10	0.631	0.609	0.822	0.809	0.640
	15	0.546	0.542	0.755	0.655	0.525
	20	0.502	0.508	0.722	0.570	0.463
	25	0.475	0.487	0.702	0.516	0.423
	50	0.423	0.446	0.664	0.391	0.333

Step 3: Quantitative Method for Ranking Selection Criteria

Not surprisingly, different selection criteria produced different results (Table 10). Determining whether a given population is or is not a suitable reference population based on selection criteria such as graphic analysis can be subjective. In addition, treating each selection criterion as equally important may not be appropriate. For example, using the information in Table 10, is it appropriate to select a reference population that has two or three "Yes" entries, or should only populations with four "Yes" entries be selected as suitable reference populations? This approach does not allow certain selection criteria to carry more weight in the overall selection process. That is, correlation may be more important than graphic analysis in the overall selection process. In order to reduce

subjectivity, we developed a method of scoring and weighting each selection criterion. This method allows a more quantitative process for selecting suitable reference populations.

Table 10. Summary of results from graphic analysis, correlations, trend analysis, and power analysis (minimal detectable differences). "Yes" indicates that the population is a suitable reference population for the Chiwawa population; "No" indicates that it may not be a suitable reference population.

Potential reference populations	Graphic analysis	Correlation	Trends	Minimal detectable differences
Spawner Abundance				
Naches	Yes	Yes	Yes	Yes
Entiat	Yes	Yes	Yes	Yes
Marsh	No	No	Yes	No
Sesech	No	No	Yes	Yes
Little Wenatchee	Yes	Yes	Yes	Yes
Natural-Origin Recruits				
Naches	Yes	Yes	Yes	No
Entiat	No	Yes	No	Yes
Marsh	Yes	Yes	Yes	Yes
Sesech	No	Yes	No	No
Little Wenatchee	Yes	Yes	Yes	Yes
Productivity				
Naches	Yes	Yes	Yes	Yes
Entiat	No	No	No	Yes
Marsh	No	Yes	Yes	No
Sesech	Yes	Yes	Yes	Yes
Little Wenatchee	Yes	Yes	Yes	Yes

We developed scoring methods for each of the following five selection criteria:

(1) The proportion of natural-origin spawners (pNOS) in the reference population for the period before supplementation (pre-pNOS);

(2) pNOS in the reference population for the period following supplementation (post-pNOS);

(3) The correlation between the reference and supplemented populations before supplementation;

(4) The relative difference in slopes between the reference and supplemented populations before supplementation; and

(5) The coefficient of variation (CV) of the ratio of supplemented to reference populations before the period of supplementation.

Each selection criteria was scored from 0 to 1, with 0 being the worst possible score and 1 being the best.

The pre- and post-pNOS values were calculated as the average pNOS values before and after supplementation, respectively. Because pNOS values range from 0-1, we did not need to rescale

these values. When using reference populations to evaluate the effects of supplementation programs, it is important that the reference populations maintain high values of pNOS throughout the life of the monitoring program. Therefore, we heavily weighted the mean pNOS scores. We assigned weights of 30 and 40 to the mean pre- and post-pNOS scores, respectively. The relatively larger weight for the post-supplementation period is to reduce the likelihood of retaining a reference population that becomes influenced by hatchery fish during the supplementation period.

We assessed the association between the reference and supplemented populations during the pre-supplementation period by calculating the Pearson correlation coefficient, which ranges from -1 to 1. To scale the coefficient between 0 and 1, we took the absolute value of the coefficient. Thus, a coefficient of -0.92 would be reported as 0.92. For our analyses, we were not concerned with the direction of the relationship, only the strength of the relationship. The correlation coefficient was given a weight of 12.5.

As noted earlier, we used least squares to fit a linear trend to each of the reference populations and the supplemented population during the pre-supplementation period. Using the slope estimates for each trend line, we calculated the relative difference in slopes as the slope of the supplemented population minus the slope of the reference population, divided by the slope of the reference population. To scale this value between 0 and 1, we used absolute values, and depending on the direction of the slopes, we subtracted the relative difference from 1. The latter was needed to make sure a larger relative difference value indicated a small difference in slopes between the supplemented and reference populations. The relative difference score was given a weight of 7.5.

Finally, as a means to score effect size, we calculated the CV of the ratio of supplemented to reference population parameters (i.e., T/R). The CV was calculated as the standard deviation of the ratios divided by the absolute value of the mean ratios. The CV was subtracted from 1. This scaled the value from 0 to 1 with larger values representing the best condition. The CV was given a weight of 10, which is greater than the weight for trend, but less than the weight for correlation.

The total score for a reference population was calculated by multiplying the estimated value, which ranged from 0 to 1, by its weight. The sum of the five weighted values provided a total score, which ranged from 0 to 100. Based on several simulations, we set the cut-off score at 81. That is, if the total score for a given reference population equaled or exceeded 81, the population was included as a suitable reference population. If the total score fell below 81, the population was not considered a suitable reference. Based on the distribution of all scores possible, a score of 81 or greater represented only 3% of the total distribution. Thus, a cut-off of 81 is quite conservative.

Under Step 3, we used this method to select the final suite of suitable reference populations. Table 11 shows results from scoring each of the reference populations using the quantitative method. Using the cut-off criterion of 81, only the Naches, Marsh, and Sesech populations would be considered suitable reference populations for the Chiwawa supplementation program. Both the Entiat and Little Wenatchee populations failed to meet the minimum score, largely because of the influence of hatchery fish within those populations (i.e., relatively low pNOS values).

Table 11. Results from scoring potential reference populations using the selection criteria (pNOS, correlation, trend, and effect size). Populations with scores less than 81 were considered unsuitable as reference populations. Populations with scores equal to or greater than 81 were considered suitable references. These results were based on natural-log transformed data.

Potential reference populations	Population metric		
	Abundance	NORs	Productivity
Naches	85	88	91
Entiat	23	21	16
Marsh	79	91	87
Sesech	84	85	88
Little Wenatchee	51	53	49

An important benefit from scoring the different selection criteria is that the total scores can be used to weight the outcome of differing statistical results. For example, analyses may show that when three suitable reference populations are compared to the supplemented population, two of the reference populations may indicate a significant treatment effect, while the third indicates no effect. Under this scenario it is not clear if the supplementation program has or has not affected the abundance or productivity of the supplemented population. If, however, the two reference populations that produced a significant result had higher total scores than the reference population that did not indicate a significant result, one can place more weight on the results from populations with higher total scores.

Conclusions

The purpose of this exercise was to develop a method for selecting suitable reference populations that could be used to assess the effects of supplementation programs on spawner abundance, NORs, and productivity. The selection process included a three-step process (Figure 8). Step 1 identified populations with similar life-history characteristics, few or no hatchery spawners, a long time series of accurate abundance and productivity estimates, and similar freshwater habitat impairments and out-of-basin effects. Populations that met these criteria were then examined for their graphical and statistical relationship with the supplemented population (Step 2). The statistical analysis under Step 2 were converted to a quantitative model (Step 3) that was used to generate a weighted score for pNOS, correlation, trends, and effect sizes for each potential reference population. Reference populations with total scores of 81 or greater were selected as suitable reference populations.

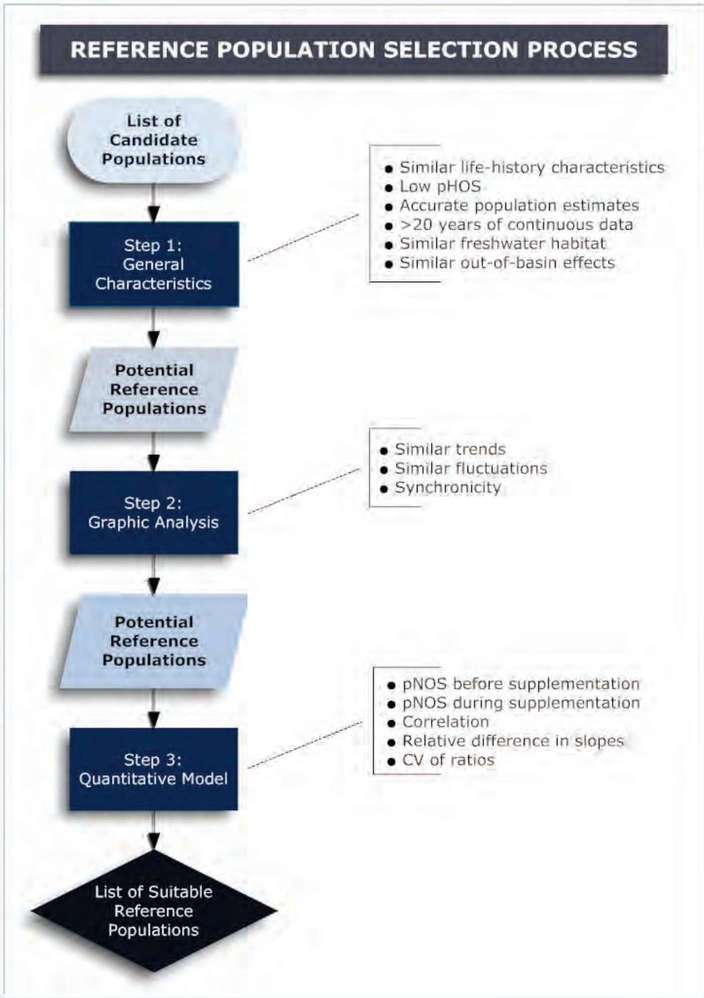

Figure 8. Three-step process for selecting suitable reference populations for supplemented populations.

We used this approach to select suitable reference populations for analyzing the effects of the Chiwawa spring Chinook supplementation program on fish abundance and productivity. The method indicated that the Naches, Marsh, and Sesech populations would serve as suitable reference populations for the Chiwawa spring Chinook supplementation program. Both the Entiat and Little Wenatchee populations failed to meet the minimum score, largely because of the influence of hatchery fish within those populations (i.e., relatively low pNOS values). However, because the presence of hatchery spring Chinook within those populations should decrease, they may serve as unique reference populations in which the comparisons change from all populations receiving

hatchery fish to only the Chiwawa population receiving hatchery fish. Therefore, we will continue to include both the Little Wenatchee and Entiat populations in future analyses.

An important assumption in the use of reference populations is that the supplemented and reference populations that tracked each other before supplementation would continue to track each other in the absence of supplementation. Given that the reference populations did not match the Chiwawa population on all criteria examined (Table 1) and some reference populations tracked the Chiwawa population more poorly than others (Figures 2-7; Tables 2-4), there may be some uncertainty as to whether differences observed between the Chiwawa and reference populations during the supplementation period are associated with the hatchery program, "nuisance" factors[16], or a combination of both. In addition, we have no ability to regulate or control activities in reference areas. Any large-scale change (man-made or natural) in reference areas could affect our ability to assess the effectiveness of the supplementation program.

Because we have no ability to maintain reference areas for long periods of time and may not be able to control all activities even within the supplemented populations, we propose the use of a "causal-comparative" approach to strengthen the certainty of our inferences (Pearsons and Temple 2010). The causal-comparative approach relies on correlative data to try and make a case for causal inference.[17] Correlation is used to rule out alternative hypotheses (note that we make our case as much if not more by disproving plausible alternatives as we do by showing that the data are consistent with a hypothesis). For example, large scale land-use activities or natural events can affect stream flows, fine sediment recruitment, and water temperatures. Changes in these factors can affect the freshwater survival and productivity of fish independently of supplementation programs. If changes in habitat, migratory, and ocean conditions do not affect reference and treatment populations similarly, inferences associated with supplementation programs may be confounded. By measuring and tracking these extraneous factors within reference and treatment areas, we can assess the effects of these state variables on population conditions independent of the supplementation programs. This allows us to more effectively assess the influence of supplementation programs on populations.

To that end, we recommend that the following state variables be measured and tracked within the Chiwawa Basin and each of the reference areas: mean annual precipitation, total and riparian forest cover, road density, impervious surface, and alluvium. These variables can be used to describe differences in water temperatures at different life stages (pre-spawning, egg incubation, and summer rearing) and substrate characteristics, including fine sediments and embeddedness (Jorgensen et al. 2009). They can be used to assess possible changes in spawner abundance, NORs, and productivity that are independent of supplementation.

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[16] A "nuisance" factor is any factor that is outside the control of the experimenter and can affect the response variable (spawner abundance or productivity). In this case, nuisance factors may include differences in freshwater habitat trends and conditions, out-of-basin effects (e.g., migration and ocean survival), and hatchery strays that affect the Chiwawa and reference populations differently.

[17] It is important to point out that correlation does not demonstrate cause-and-effect. It only suggests a relationship between variables. Thus, inferences based on correlation lack the certainty that is associated with a design-based approach.

Analyses with Reference Populations

Once suitable reference populations are selected, methods for analyzing the supplemented and reference populations need to be identified. What follows is a description of different analyses that can be used to assess the effects of supplementation programs on spawner abundance, NORs, and productivity using reference populations. Later in this report we describe methods for assessing supplementation effects when reference populations are not available.

We used some of the reference populations selected for the Chiwawa program to illustrate the different methods for evaluating the effects of the supplementation program on spawner abundance, NORs, and productivity. For abundance, we selected the Naches, Entiat, Little Wenatchee, and Sesech populations as suitable references for the Chiwawa population. For NORs, we selected the Naches, Entiat, Marsh, and Little Wenatchee populations as suitable references. For productivity, we selected the Naches, Sesech, Little Wenatchee, and Marsh Creek as suitable references for the Chiwawa. As noted earlier, we included the Little Wenatchee and Entiat populations, even though they did not meet all the criteria for suitable reference populations.

Analysis of Trends

As a first step, we used trend analyses to assess the effects of the Chiwawa supplementation program on spring Chinook spawner abundance, NORs, and productivity. Here, we compared the slopes of the trends between each treatment/reference pair before and during supplementation using t-tests. If the hatchery program is successfully supplementing the natural spring Chinook population, trends in spawner abundance and NORs should deviate significantly (i.e., the slope of the supplemented population should be greater than the slopes of the reference populations during the supplementation period). For productivity, the slope of the supplemented population, relative to the reference population, should increase or remain the same.

Trend analysis indicated that the relationship of slopes of spawner abundance between the Chiwawa and reference populations did not change significantly after the initiation of supplementation (Figure 9; Table 12). This was true for both transformed and untransformed abundance data. Before supplementation, spawner abundances trended down in both the Chiwawa and reference populations (Figure 9). During the period of supplementation, abundances in both the Chiwawa and reference populations trended upward. Interestingly, in nearly all treatment/reference comparisons, the Pearson correlation coefficient was greater in the supplementation period than in the pre-supplementation period (Table 12). This was most evident in the transformed abundance data (Figure 9).

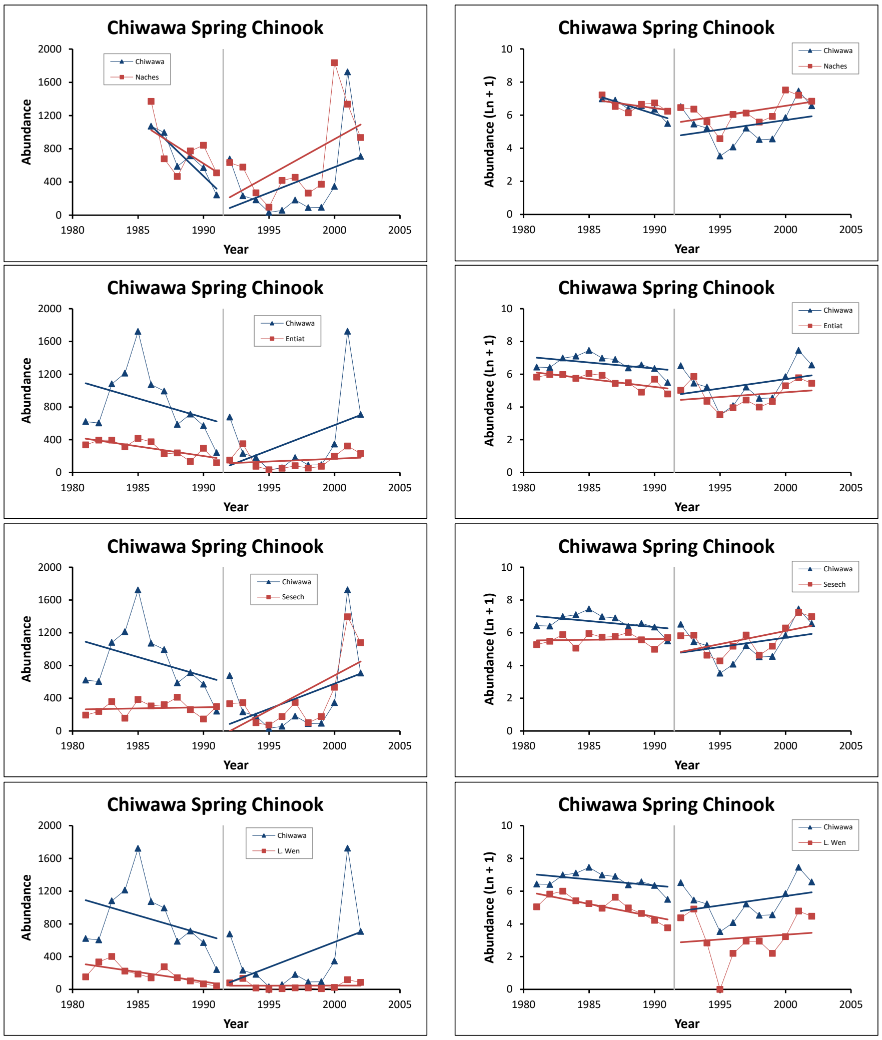

Figure 9. Trends in spring Chinook spawner abundance in the Chiwawa and reference populations. The vertical lines in the figures separate the pre- and post-supplementation periods. Figures on the left include untransformed spawner abundance data; those on the right include natural-log transformed data.

Table 12. Pearson correlation coefficients and t-test results comparing slopes of spawner abundance trends between reference populations and the Chiwawa spring Chinook population before and during the supplementation periods; for correlation coefficients, an asterisk (*) indicates significance at P < 0.05. Analyses include both untransformed and natural-log transformed spawner abundance data.

Reference population	Pearson correlation coefficient		Test on slopes			
			t-value		P-value	
	Before	During	Before	During	Before	During
Spawner Abundance						
Naches	0.684*	0.595	-0.659	-0.414	0.528	0.684
Entiat	0.598*	0.672*	-0.596	1.162	0.559	0.260
Sesech	0.274	0.904*	-1.265	-0.418	0.222	0.681
Little Wenatchee	0.399	0.685*	-0.591	1.330	0.562	0.200
LN Spawner Abundance						
Naches	0.642*	0.813*	-1.323	-0.047	0.222	0.963
Entiat	0.652*	0.860*	0.412	0.422	0.685	0.678
Sesech	0.149	0.878*	-1.431	-0.333	0.170	0.743
Little Wenatchee	0.670*	0.861*	1.325	0.316	0.202	0.756

Trend analysis indicated that the relationship of slopes of NORs between the Chiwawa and reference populations did not change significantly after the initiation of supplementation (Figure 10; Table 13). Before supplementation, Chiwawa NORs trended downward more strongly than the reference populations (Figure 10). However, during the supplementation period, both the Chiwawa and reference population NORs trended upward in parallel. In nearly all treatment/reference comparisons, the Pearson correlation coefficient was greater in the pre-supplementation period than in the supplementation period (Table 13).

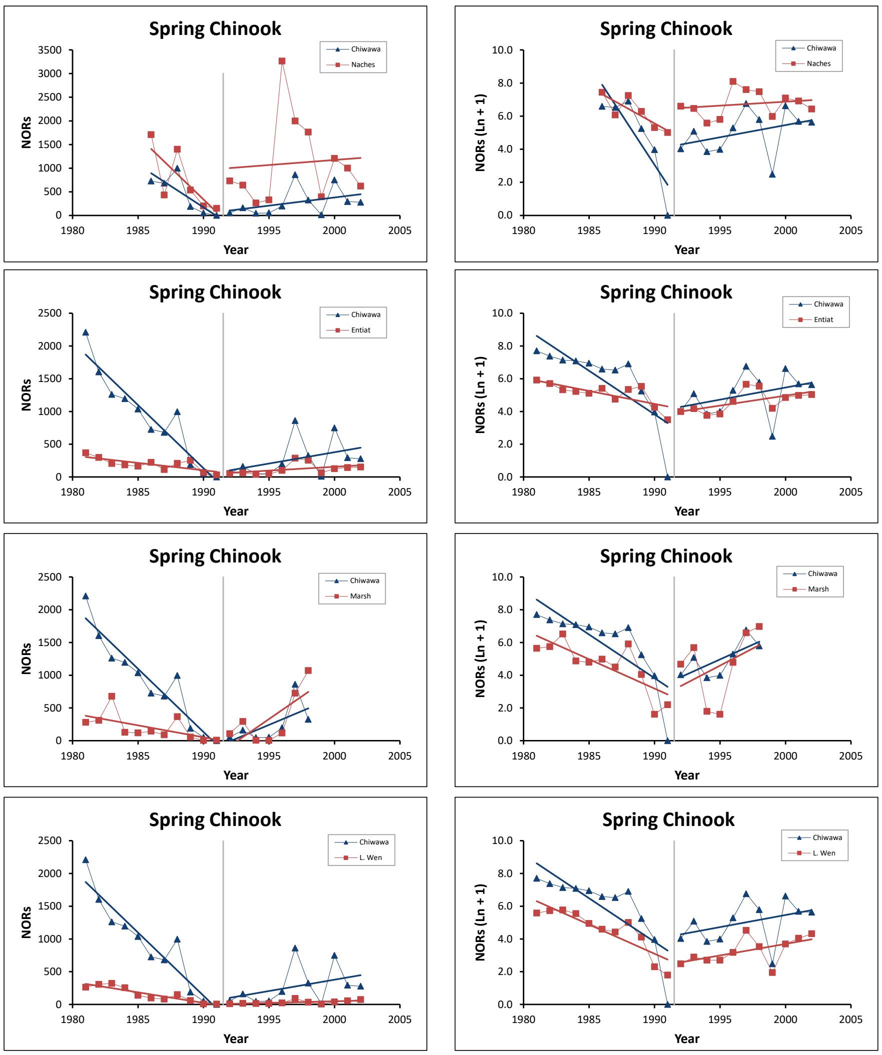

Figure 10. Trends in spring Chinook natural-origin recruits (NORs) in the Chiwawa and reference populations. The vertical lines in the figures separate the pre- and post-supplementation periods. Figures on the left include untransformed NORs; those on the right include natural-log transformed data.

Table 13. Pearson correlation coefficients and t-test results comparing slopes of natural-origin recruits trends between reference populations and the Chiwawa spring Chinook population before and during the supplementation periods; for correlation coefficients, an asterisk (*) indicates significance at $P < 0.05$. Analyses include both untransformed and natural-log transformed natural-origin recruits.

Reference population	Pearson correlation coefficient		Test on slopes			
			t-value		P-value	
	Before	During	Before	During	Before	During
Natural-Origin Recruits						
Naches	0.803*	0.432	0.666	0.140	0.524	0.890
Entiat	0.795*	0.754*	-7.495	0.847	0.000	0.408
Marsh	0.605*	0.677*	-5.786	-0.718	0.000	0.489
Little Wenatchee	0.880*	0.758*	-7.206	1.128	0.000	0.274
LN Natural-Origin Recruits						
Naches	0.824*	0.710*	-1.985	0.693	0.082	0.497
Entiat	0.886*	0.796*	-2.563	0.202	0.019	0.842
Marsh	0.830*	0.835*	-1.038	-0.134	0.313	0.896
Little Wenatchee	0.927*	0.898*	-1.150	0.046	0.265	0.964

As with NORs and spawner abundance data, trend analysis indicated that the relationship of slopes of productivity (recruits/spawner) between the Chiwawa and reference populations did not change significantly after the initiation of supplementation (Figure 11; Table 14). This was true for both transformed and untransformed productivity data. Before supplementation, productivities trended down in both the Chiwawa and reference populations (Figure 11). During the period of supplementation, productivities fluctuated widely in both the Chiwawa and reference populations. Nevertheless, during the supplementation period, productivities generally increased in both the reference and Chiwawa populations. Unlike with spawner abundance, the Pearson correlation coefficients resulting from analysis of productivity data were generally higher in the pre-supplementation period than during the supplementation period (Table 14).

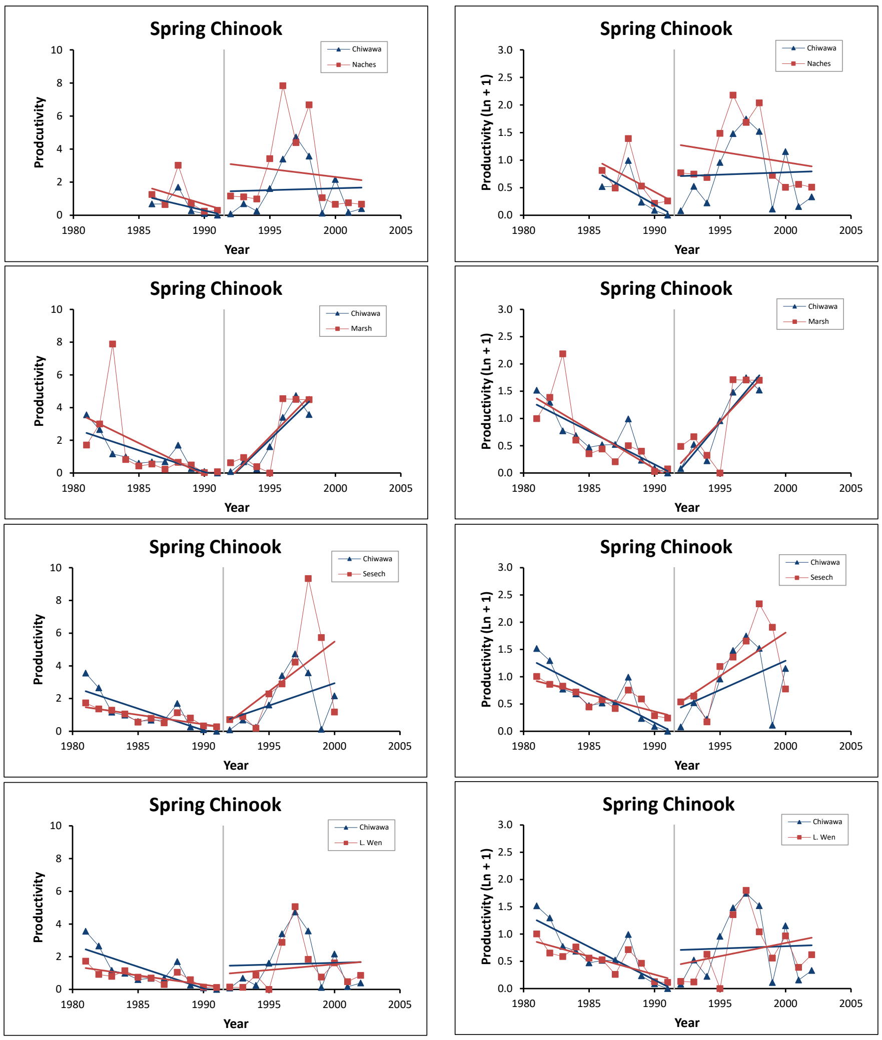

Figure 11. Trends in spring Chinook productivity (recruits/spawner) in the Chiwawa (supplemented) and reference populations. The vertical lines in the figures separate the pre- and post-supplementation periods. Figures on the left include untransformed productivity data; those on the right include natural-log transformed data.

Table 14. Pearson correlation coefficients and t-test results comparing slopes of productivity (recruits/spawner) trends between reference populations and the Chiwawa spring Chinook population before and during the supplementation periods; for correlation coefficients, an asterisk (*) indicates significance at P < 0.05. Analyses include both untransformed and natural-log transformed productivity data.

Reference population	Pearson correlation coefficient		Test on slopes			
			t-value		P-value	
	Before	During	Before	During	Before	During
Productivity						
Naches	0.960*	0.802*	0.169	0.387	0.870	0.703
Marsh	0.320	0.910*	0.605	-0.132	0.553	0.898
Sesech	0.903*	0.491	-2.059	-0.837	0.054	0.417
Little Wenatchee	0.848*	0.864*	-2.065	-0.213	0.054	0.834
LN Productivity						
Naches	0.944*	0.805*	-0.042	0.526	0.968	0.605
Marsh	0.610*	0.804*	0.428	0.281	0.674	0.784
Sesech	0.913*	0.531	-2.050	-0.463	0.055	0.651
Little Wenatchee	0.862*	0.751*	-1.811	-0.480	0.087	0.637

Using trend analysis, we found no evidence that the supplementation program has significantly increased the spawner abundance and NORs of spring Chinook in the Chiwawa Basin. Even though we documented an increasing trend in spawner abundance and NORs during the supplementation period, a similar increase in spawner abundance and NORs was observed in the reference populations. In addition, we found no evidence that the supplementation program has increased the productivity of spring Chinook in the Chiwawa Basin. Importantly, the productivity of spring Chinook in the Chiwawa Basin did not trend downward during the supplementation period. Thus, based on trend analysis, it appears that the supplementation program has not increased or decreased the abundance and productivity of spring Chinook in the Chiwawa Basin.

We note that this exercise only tests the slopes of the trend lines. It does not test for differences in elevations of the trend lines. A supplementation program could increase spawner abundance, NORs, and productivity of the target population without changing the slopes of the trend lines. That is, supplementation could cause the elevation of the trend line to be greater during the supplementation period than during the pre-supplementation period. In the next section we evaluate elevation differences by testing mean differences before and after supplementation.

Analysis of Mean Differences, Ratios, and Rates

For assessing mean differences between supplemented and reference populations, we derived three different response variables using transformed and untransformed spawner abundance, NORs, and productivity data. The first included difference scores, which were calculated as the difference between paired treatment and reference data (T-R). The second included ratios, which were calculated as the ratio of paired treatment and reference data (T/R). Finally, we calculated the differences in annual changes in paired treatment and reference population data (ΔT-ΔR; see footnote #2).

If the hatchery program is successfully supplementing the natural spring Chinook population, the mean difference or ratio score of paired spawner abundance data and NORs during the supplementation period should be greater than the pre-supplementation period. For productivity, the mean difference or ratio score during the supplementation period should be equal to or higher than the pre-supplementation period. We tested the following statistical hypotheses.

Spawner Abundance and NORs:

Ho: Mean Difference (or Ratio) before supplementation ≥ Mean Difference (or Ratio) during supplementation.

Ha: Mean Difference (or Ratio) before supplementation < Mean Difference (or Ratio) during supplementation (i.e., $\mu_{pre} - \mu_{post} < 0$).

Productivity (Recruits/Spawner):

Ho: Mean Difference (or Ratio) before supplementation ≤ Mean Difference (or Ratio) during supplementation.

Ha: Mean Difference (or Ratio) before supplementation > Mean Difference (or Ratio) during supplementation (i.e., $\mu_{pre} - \mu_{post} > 0$).[18]

For each set of response variables, we tested before/after supplementation effects using a one-tailed Aspin-Welch unequal-variance test. We used the Aspin-Welch unequal-variance test instead of Student's t-test, because in nearly every case, the variances of response variables in the pre-treatment and supplementation periods were unequal.[19] This was true even for natural-log transformed variables. We used the modified Levene equal-variance test to assess the equality of variance. In some cases, the distributions of response variables were not normal (based on the Omnibus Normality test and examination of histograms, normal probability plots, and box plots). Therefore, we also used a randomization test, based on 10,000 Monte Carlo simulations, to assess differences in response variables before and during supplementation. The randomization procedure only allowed the testing of two-tailed hypotheses. Therefore, we generated 95% confidence intervals on the mean difference ($\mu_{pre} - \mu_{post}$) using bootstrapping methods to determine the direction of the difference. We generated 5,000 bootstrap samples to calculate confidence intervals.

All these statistical methods assume that the samples of derived difference or ratio scores from the pre-supplementation and supplementation periods were independent. However, BACI designs, like time-series trend analysis, are repeated-measures designs and therefore are susceptible to temporal correlations in the data. This means that the two samples of difference or ratio scores may not be independent. Under this scenario, ARIMA models can be used to describe the correlation structure in temporal data (Gotelli and Ellison 2004). ARIMA models can be fit individually to the reference and supplemented time series data, or to a derived data series created by taking the ratio or difference of the supplemented/reference data at each time step. ARIMA models, however, require a long time series (N > 40) and therefore we could not use them to model

18 Because of the logic of null hypothesis testing, the rejection of the null hypothesis of no difference in productivity would mean that the supplementation program has reduced the productivity of the target population (here rejection of the null indicates "harm"). Notice that the rejection of the null hypothesis of no difference in spawner abundance means that the supplementation program has improved the spawner abundance in the target population (here rejection of the null indicates "benefit").

19 In cases in which the variances were equal, both the Aspin-Welch test and Student's t-test gave the same result.

the spring Chinook data. Thus, we acknowledge that our analyses may be confounded if the samples are not independent.

Difference Scores (T-R)

Analysis of supplementation effects on spawner abundance using difference scores indicated that supplementation did not significantly increase spawning abundance in the Chiwawa Basin (Table 15; Figure 12). Only the Little Wenatchee-Chiwawa pairing using transformed abundance data indicated a significant increase in spawning abundance following supplementation. The randomization test indicated significant differences in several of the treatment-reference pairs; however, the bootstrap CIs indicated that those differences were in the wrong direction (i.e., CIs > 0). That is, compared to the reference populations, spawner abundance decreased in the Chiwawa Basin during the supplementation period (Figure 12).

Table 15. Results of the Aspin-Welch unequal-variance test, randomization test (based on 10,000 Monte Carlo samples), and 95% CI (based on 5,000 bootstrap samples) on transformed and untransformed spawner abundance data. Tests determined if the mean difference scores during the supplementation period were greater than mean difference scores during the pre-supplementation period.

Reference population	Aspin-Welch unequal-variance test			Randomization test P-value	Bootstrap 95% CI
	t-value	P-value	Effect size		
Spawner Abundance					
Naches	1.066	0.848	184	0.322	-162 – 472
Entiat	1.872	0.962	316	0.078	17 – 633
Sesech	4.502	0.999	607	0.000	349 – 851
Little Wenatchee	1.773	0.954	321	0.093	0 – 690
LN Spawner Abundance					
Naches	2.603	0.990	0.701	0.026	0.210 – 1.214
Entiat	1.701	0.946	0.388	0.108	-0.033 – 0.811
Sesech	5.394	0.999	1.327	0.000	0.891 – 1.805
Little Wenatchee	-2.259	0.018	0.609	0.034	-1.125 – -0.097

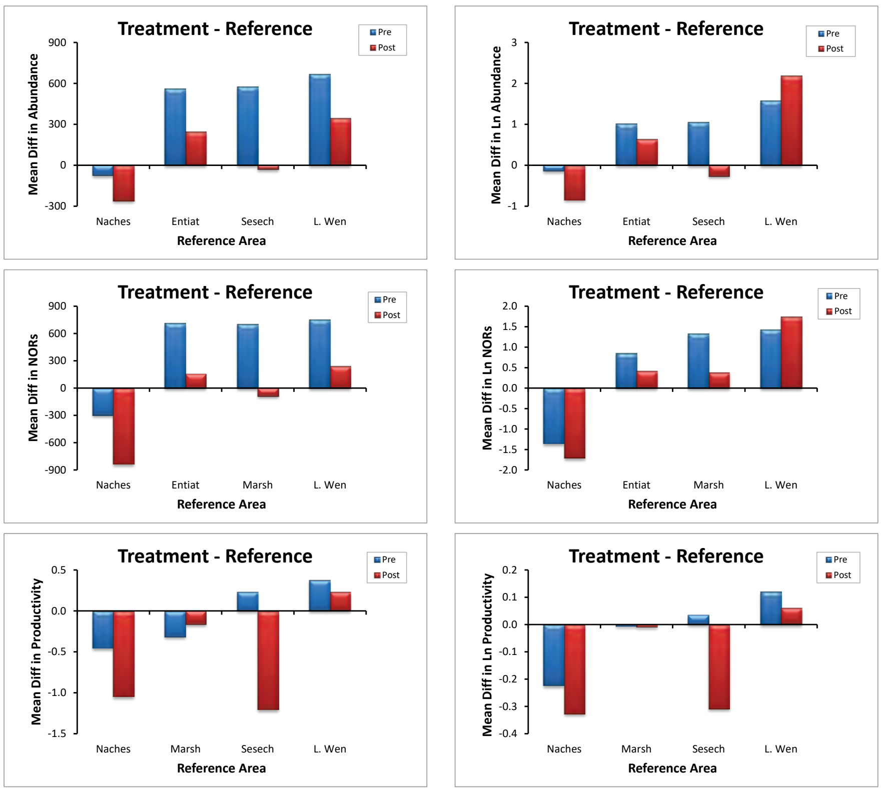

Figure 12. Mean difference (Treatment – Reference) scores of untransformed (figures on the left) and transformed (figures on the right) spawner abundance, natural-origin recruits (NORs), and productivity data before (pre) and after (post) spring Chinook supplementation in the Chiwawa Basin. Positive effects of supplementation on spawner abundance and NORs are indicated when the post-supplementation (red) bars are greater than their corresponding pre-supplementation (blue) bars. Negative effects of supplementation on productivity are indicated when the pre-supplementation (blue) bars are greater than their corresponding post-supplementation (red) bars.

Analysis of supplementation effects on NORs using difference scores indicated that supplementation did not significantly increase NORs in the Chiwawa Basin (Table 16; Figure 12). The randomization test indicated significant differences in several of the treatment-reference pairs; however, the bootstrap CIs indicated that those differences were in the wrong direction. That is, compared to the reference populations, NORs decreased in the Chiwawa Basin during the supplementation period (Figure 12).

Table 16. Results of the Aspin-Welch unequal-variance test, randomization test (based on 10,000 Monte Carlo samples), and 95% CI (based on 5,000 bootstrap samples) on transformed and untransformed natural-origin recruits. Tests determined if the mean difference scores during the supplementation period were greater than mean difference scores during the pre-supplementation period.

Reference population	Aspin-Welch unequal-variance test			Randomization test P-value	Bootstrap 95% CI
	t-value	P-value	Effect size		
Natural-Origin Recruits					
Naches	1.787	0.953	537	0.081	-60 – 1039
Entiat	2.879	0.993	558	0.007	201 – 916
Marsh	3.817	0.999	795	0.001	381 – 1153
Little Wenatchee	2.668	0.991	510	0.013	145 – 863
LN Natural-Origin Recruits					
Naches	0.430	0.659	0.354	0.686	-0.948 – 1.975
Entiat	0.788	0.779	0.445	0.465	-0.504 – 1.583
Marsh	1.45	0.916	0.953	0.168	-0.169 – 2.243
Little Wenatchee	-0.813	0.214	-0.319	0.506	-0.948 – 0.484

Analysis of supplementation effects on productivity (adult recruits/spawner) using difference scores indicated that supplementation did not significantly decrease productivity in the Chiwawa Basin (Table 17; Figure 12). All tests, regardless of treatment-reference pairs, indicated that productivity did not change significantly during the supplementation period. These tests indicate that supplementation has not negatively affected the productivity of spring Chinook salmon in the Chiwawa Basin.

Table 17. Results of the Aspin-Welch unequal-variance test, randomization test (based on 10,000 Monte Carlo samples), and 95% CI (based on 5,000 bootstrap samples) on transformed and untransformed productivity data. Tests determined if the mean difference scores during the supplementation period were less than mean difference scores during the pre-supplementation period.

Reference population	Aspin-Welch unequal-variance test			Randomization test P-value	Bootstrap 95% CI
	t-value	P-value	Effect size		
Productivity					
Naches	1.134	0.139	0.594	0.296	-0.427 – 1.540
Marsh	-0.203	0.579	0.152	0.932	-0.304 – 1.381
Sesech	1.607	0.071	1.435	0.151	-0.403 – 2.917
Little Wenatchee	0.431	0.335	0.147	0.665	-0.498 – 0.762
LN Productivity					
Naches	0.770	0.227	0.104	0.480	-0.125 – 0.378
Marsh	0.012	0.495	0.003	0.992	-0.375 – 0.493
Sesech	1.463	0.087	0.343	0.161	-0.135 – 0.732
Little Wenatchee	0.390	0.351	0.060	0.701	-0.229 – 0.347

Ratio Scores (T/R)

As with difference scores, analysis of supplementation effects on spawner abundance using ratios indicated that supplementation did not significantly increase spawning abundance in the Chiwawa Basin (Table 18; Figure 13). Only the Little Wenatchee-Chiwawa pairing indicated a significant increase in spawning abundance following supplementation. Analysis with both transformed and untransformed Little Wenatchee-Chiwawa data indicated a significant effect. In contrast, only difference scores derived from transformed data indicated a significant effect. The randomization test indicated significant differences in several of the treatment-reference pairs; however, the bootstrap CIs indicated that those differences were in the wrong direction. That is, compared to the reference populations, spawner abundance decreased in the Chiwawa Basin during the supplementation period (Figure 13).

Table 18. Results of the Aspin-Welch unequal-variance test, randomization test (based on 10,000 Monte Carlo samples), and 95% CI (based on 5,000 bootstrap samples) on transformed and untransformed spawner abundance data. Tests determined if the mean ratios during the supplementation period were greater than mean ratios during the pre-supplementation period.

Reference population	Aspin-Welch unequal-variance test			Randomization test P-value	Bootstrap 95% CI
	t-value	P-value	Effect size		
Spawner Abundance					
Naches	2.110	0.970	0.398	0.065	0.056 – 0.737
Entiat	1.254	0.888	0.731	0.223	-0.365 – 1.834
Sesech	4.251	0.999	2.428	0.000	1.278 – 3.435
Little Wenatchee	-2.649	0.009	3.897	0.018	-6.579 – -1.202
LN Spawner Abundance					
Naches	2.783	0.993	0.120	0.021	0.045 – 0.199
Entiat	1.273	0.890	0.055	0.220	-0.026 – 0.135
Sesech	5.143	0.999	0.244	0.000	0.160 – 0.335
Little Wenatchee	-3.462	0.002	0.327	0.003	-0.516 – -0.154

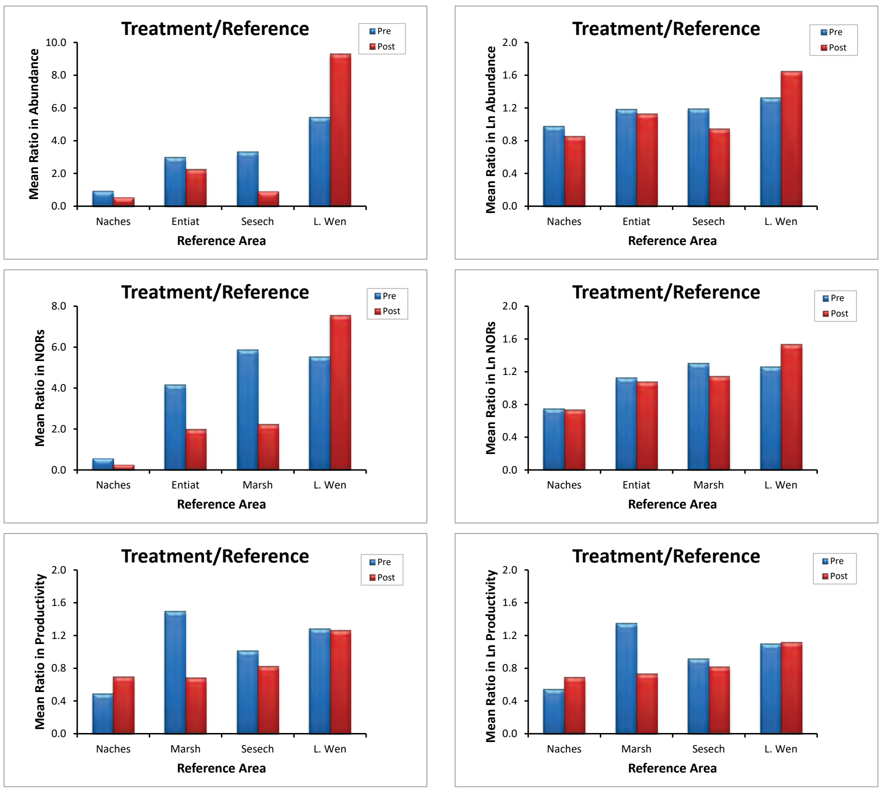

Figure 13. Mean ratios (Treatment/Reference) scores of untransformed (figures on the left) and transformed (figures on the right) spawner abundance, natural-origin recruits (NORs), and productivity data before (pre) and after (post) spring Chinook supplementation in the Chiwawa Basin. Positive effects of supplementation on spawner abundance and NORs are indicated when the post-supplementation (red) bars are greater than their corresponding pre-supplementation (blue) bars. Negative effects of supplementation on productivity are indicated when the pre-supplementation (blue) bars are greater than their corresponding post-supplementation (red) bars.

Analysis of supplementation effects on NORs using ratios indicated that supplementation did not significantly increase NORs in the Chiwawa Basin (Table 19; Figure 13). Only the Little Wenatchee-Chiwawa pairing indicated a significant increase in transformed NORs following supplementation. The randomization test indicated significant differences in several of the treatment-reference pairs; however, the bootstrap CIs indicated that those differences were in the wrong direction. That is, compared to the reference populations, NORs decreased in the Chiwawa Basin during the supplementation period (Figure 13).

Table 19. Results of the Aspin-Welch unequal-variance test, randomization test (based on 10,000 Monte Carlo samples), and 95% CI (based on 5,000 bootstrap samples) on transformed and untransformed natural-origin recruits. Tests determined if the mean ratios during the supplementation period were greater than mean ratios during the pre-supplementation period.

Reference population	Aspin-Welch unequal-variance test			Randomization test P-value	Bootstrap 95% CI
	t-value	P-value	Effect size		
Natural-Origin Recruits					
Naches	1.318	0.881	0.306	0.219	-0.157 – 0.670
Entiat	2.447	0.987	2.172	0.028	0.593 – 3.871
Marsh	2.001	0.965	3.638	0.075	0.532 – 7.201
Little Wenatchee	-1.148	0.136	2.020	0.284	-5.055 – 1.516
LN Natural-Origin Recruits					
Naches	0.057	0.522	0.009	0.967	-0.230 – 0.351
Entiat	0.359	0.638	0.049	0.759	-0.173 – 0.336
Marsh	0.603	0.721	0.161	0.579	-0.272 – 0.681
Little Wenatchee	-1.914	0.038	0.277	0.027	-0.504 – 0.031

Analysis of supplementation effects on productivity (adult recruits/spawner) using ratios indicated that supplementation did not significantly decrease productivity in the Chiwawa Basin (Table 20; Figure 13). Although the Aspin-Welch test indicated a significant effect when comparing the Chiwawa to the Marsh Creek population, both the randomization test and the bootstrap CI did not indicate a significant effect. These tests indicate that supplementation has probably not negatively affected the productivity of spring Chinook salmon in the Chiwawa Basin.

Table 20. Results of the Aspin-Welch unequal-variance test, randomization test (based on 10,000 Monte Carlo samples), and 95% CI (based on 5,000 bootstrap samples) on transformed and untransformed productivity data. Tests determined if the mean ratios during the supplementation period were less than mean ratios during the pre-supplementation period.

Reference population	Aspin-Welch unequal-variance test			Randomization test P-value	Bootstrap 95% CI
	t-value	P-value	Effect size		
Productivity					
Naches	-0.677	0.745	0.209	0.688	-0.700 – 0.425
Marsh	2.236	0.022	0.814	0.054	0.112 – 1.459
Sesech	0.677	0.253	0.191	0.515	-0.356 – 0.718
Little Wenatchee	0.033	0.487	0.018	0.979	-0.879 – 1.162
LN Productivity					
Naches	-0.639	0.734	0.148	0.616	-0.548 – 0.316
Marsh	1.952	0.036	0.613	0.081	-0.003 – 1.170
Sesech	0.447	0.330	0.098	0.663	-0.301 – 0.515
Little Wenatchee	-0.034	0.513	0.015	0.982	-0.692 – 0.861

Difference of Annual Difference Scores (ΔT-ΔR)

Analysis of supplementation effects on spawner abundance using difference scores of annual changes indicated that supplementation did not significantly increase spawning abundance in the Chiwawa Basin (Table 21; Figure 14). None of the statistical analyses detected a significant increase in annual change in the Chiwawa Basin relative to the reference populations.

Table 21. Results of the Aspin-Welch unequal-variance test, randomization test (based on 10,000 Monte Carlo samples), and 95% CI (based on 5,000 bootstrap samples) on transformed and untransformed spawner abundance data. Tests determined if mean difference scores of annual change during the supplementation period were greater than mean difference scores of annual change during the pre-supplementation period.

Reference population	Aspin-Welch unequal-variance test			Randomization test P-value	Bootstrap 95% CI
	t-value	P-value	Effect size		
Spawner Abundance					
Naches	0.009	0.503	2	0.995	-502 – 539
Entiat	-0.239	0.407	48	0.826	-414 – 327
Sesech	-0.126	0.451	20	0.902	-311 – 266
Little Wenatchee	-0.318	0.377	65	0.761	-452 – 311
LN Spawner Abundance					
Naches	-0.425	0.339	0.142	0.698	-0.744 – 0.466
Entiat	-0.084	0.467	0.028	0.933	-0.681 – 0.593
Sesech	-0.349	0.366	0.117	0.740	-0.741 – 0.515
Little Wenatchee	0.001	0.500	0.000	0.999	-0.663 – 0.687

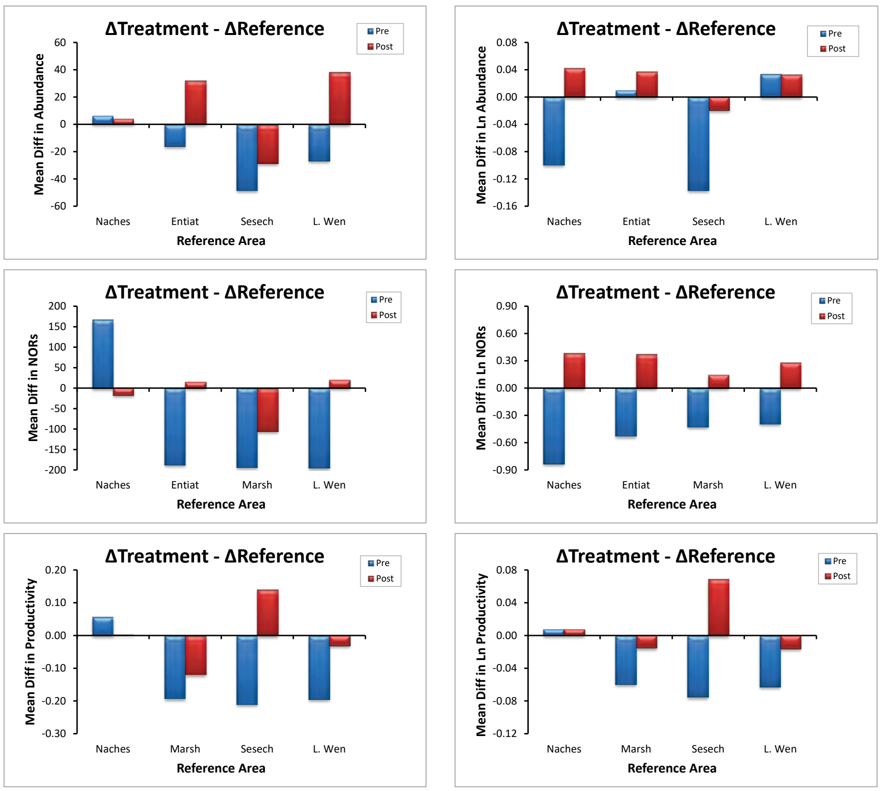

Figure 14. Mean difference scores of annual changes (ΔTreatment – ΔReference) of untransformed (figures on the left) and transformed (figures on the right) spawner abundance and productivity data before (pre) and after (post) spring Chinook supplementation in the Chiwawa Basin.

Analysis of supplementation effects on NORs using difference scores of annual changes indicated that supplementation did not significantly increase NORs in the Chiwawa Basin (Table 22; Figure 14). None of the statistical analyses detected a significant increase in annual change in the Chiwawa Basin relative to the reference populations.

Table 22. Results of the Aspin-Welch unequal-variance test, randomization test (based on 10,000 Monte Carlo samples), and 95% CI (based on 5,000 bootstrap samples) on transformed and untransformed natural-origin recruits. Tests determined if mean difference scores of annual change during the supplementation period were greater than mean difference scores of annual change during the pre-supplementation period.

Reference population	Aspin-Welch unequal-variance test			Randomization test P-value	Bootstrap 95% CI
	t-value	P-value	Effect size		
Natural-Origin Recruits					
Naches	0.399	0.652	184	0.741	-699 – 989
Entiat	-1.381	0.092	202	0.194	-471 – 86
Marsh	-0.505	0.311	88	0.624	-425 – 206
Little Wenatchee	-1.437	0.084	214	0.179	-481 – 64
LN Natural-Origin Recruits					
Naches	-1.301	0.118	1.214	0.224	-2.783 – 0.531
Entiat	-1.408	0.088	0.901	0.188	-1.977 – 0.387
Marsh	-0.712	0.244	0.570	0.517	-1.952 – 0.975
Little Wenatchee	-1.154	0.132	0.674	0.274	-1.706 – 0.497

Analysis of supplementation effects on productivity (adult recruits/spawner) using difference scores of annual changes indicated that supplementation did not significantly decrease productivity in the Chiwawa Basin (Table 23; Figure 14). All tests, regardless of treatment-reference pairs, indicated that productivity did not change significantly during the supplementation period.

Table 23. Results of the Aspin-Welch unequal-variance test, randomization test (based on 10,000 Monte Carlo samples), and 95% CI (based on 5,000 bootstrap samples) on transformed and untransformed productivity data. Tests determined if the mean difference scores of annual change during the supplementation period were less than mean difference scores of annual change during the pre-supplementation period.

Reference population	Aspin-Welch unequal-variance test			Randomization test P-value	Bootstrap 95% CI
	t-value	P-value	Effect size		
Productivity					
Naches	0.002	0.475	0.054	0.952	-1.464 – 1.583
Marsh	-0.063	0.525	0.074	0.948	-2.395 – 2.031
Sesech	-0.317	0.621	0.350	0.628	-2.387 – 1.695
Little Wenatchee	-0.347	0.633	0.163	0.728	-1.023 – 0.725
LN Productivity					
Naches	0.000	0.500	0.000	0.999	-0.408 – 0.445
Marsh	-0.126	0.549	0.044	0.904	-0.715 – 0.595
Sesech	-0.449	0.668	0.144	0.727	-0.685 – 0.509
Little Wenatchee	-0.200	0.578	0.047	0.842	-0.466 – 0.391

We believe results from analysis of mean differences of annual change (ΔT-ΔR) in spawning abundance, NORs, and productivity are difficult to interpret and may be insensitive to treatment effects. A simpler analysis, which is also easier to interpret, is the use of trend analysis. Therefore, we recommend that analyses using differences of annual change be replaced with trend analysis.

Corrections for Density Dependence and Carrying Capacity

The analyses described above assume that the density of spawners or recruits does not affect the survival and productivity of fish. However, it is well known that the density of fish can affect the number of recruits as well as the productivity of the population. This occurs through the relationship between density and mortality. Mortality of fish can be generally classified as density independent and density dependent. In general, when densities are low, the mortality is density independent, but as densities increase, the amount of density-dependent mortality increases. Monitoring programs can make use of this information to derive density-corrected estimates of productivity. In this section, we describe two different methods for deriving density-corrected estimates of productivity.

The first method controlled the effects of density on productivity (adult recruits/spawner; R/S) by partitioning observed productivities into density-independent and density-dependent productivity. When abundance is below the minimum number of spawners (S) needed to produce the maximum number of recruits (K_{sp}), the observed productivity is used in statistical tests. However, when the abundance is equal to or above K_{sp}, the modeled value of productivity (R/K_{sp}) is used in statistical tests.

$$\boldsymbol{Adj\ R/S} = \begin{cases} \boldsymbol{R/S,} & \boldsymbol{if\ S < K_{sp}} \\ \boldsymbol{R/K_{sp},} & \boldsymbol{if\ S \geq K_{sp}} \end{cases}$$

The density-independent and density-dependent productivities were then combined in a single test.

The second method was based on one of the goals of supplementation, which is to fill the capacity of the environment with fish. This method corrects for differences in carrying capacities between the supplemented and reference populations. We did this by calculating the percent saturation of NORs. That is, we calculated the fraction of the habitat (τ) that was filled with NORs by dividing the observed NOR by the modeled maximum number of NORs (K_R) that the habitat could support.

$$\boldsymbol{\tau = \frac{NOR_{obs}}{K_R}}$$

Note that 1-τ represents the unused portion of the carrying capacity and is the term that is multiplied by the exponential growth equation to derive the logistic growth equation. We included τ in the statistical analyses.

These two methods require the estimation of carrying capacity (K_R) and the spawning abundance that produces the maximum number of recruits (K_{sp}). We estimated these parameters for both reference populations and the supplemented population using Ricker, Beverton-Holt, and smooth hockey stick stock-recruitment models. We used only spawner abundance as a predictor of subsequent brood recruitment. We made the following assumptions in proceeding with the analysis:

- *Density-dependent mortality*—For some time period before recruitment, the brood instantaneous mortality rate is proportional to the number of parent spawners (Ricker 1954).
- *Lognormal variation*—At any particular spawning stock size, the variation in recruitment is log-normally distributed about its average, and acts multiplicatively (Quinn and Deriso 1999).
- *Measurement error*—Error in spawning stock size estimates (measurement error) is small relative to the range of spawning stock sizes observed (Hilborn and Walters 1992). Variation in realized recruitment at any particular spawning stock size (process error) dominates recruitment measurement error.
- *Stationarity*—The average stock-recruitment relationship is constant over time (Hilborn and Walters 1992). That is, environmental conditions randomly affect survival independent of stock size or time.

In general, the methods we used to fit the models to the data followed those outlined in Hilborn and Walters (1992) and Froese (2008). The Ricker model, which assumes that the number of recruits increases to a maximum and then declines as the number of spawners increases, takes the form:

$$\boldsymbol{E(R) = \alpha S e^{-\beta S}}$$

where E(R) is the expected recruitment, S is spawner abundance, α is the number of recruits per spawner at low spawning levels, and β describes how quickly the recruits per spawner drop as the number of spawners increases. We estimated K_R as:

$$\boldsymbol{K_R = \left(\frac{\alpha}{\beta}\right) e^{-1}}$$

and K_{sp} as:

$$\boldsymbol{K_{sp} = \frac{1}{\beta}}$$

The Beverton-Holt model assumes that the number of recruits increases constantly toward an asymptote as the number of spawners increases. After the asymptote is reached, the number of recruits neither increases nor decreases. The asymptote represents the maximum number of recruits the system can support (i.e., carrying capacity for the system; K_R). The Beverton-Holt curve takes the form:

$$\boldsymbol{E(R) = \frac{(\alpha S)}{(\beta + S)}}$$

where E(R) and S are as above, α is the maximum number of recruits produced (K_R), and β is the number of spawners needed to produce (on average) recruits equal to one-half the maximum number of recruits. Because $K_{sp} = \infty$ in the Beverton-Holt model, we estimated K_{sp} as the number of spawners needed to produce 0.99(K_R).

Like the Beverton-Holt model, the smooth hockey stick model assumes that the number of recruits increases toward an asymptote (carrying capacity; K_R) as the number of spawners increases. After the carrying capacity is reached, the number of recruits neither increases nor decreases. The carrying capacity represents the maximum number of recruits the system can support. This curve

takes the form (Froese 2008):

$$\boldsymbol{E(R) = R_\infty\left(1 - e^{-\left(\frac{\alpha}{R\infty}\right)S}\right)}$$

where E(R) and S are as above, α is the slope at the origin of the spawner-recruitment curve, and R_∞ is the carrying capacity of recruits (note that $R_\infty = K_R$). As with the Beverton-Holt model, we estimated K_{sp} as the number of spawners needed to produce $0.99(K_R)$.

We used non-linear regression to fit the three models to spawner-recruitment data. Before fitting the models, we transformed recruitment data using natural logs. We estimated bias and uncertainty measures (95% CI) for the model parameters using bootstrap procedures, which assumed that the {R, S} sample represented or approximated the population. The number of bootstrap samples was 3,000. We computed and stored the non-linear regression results for each bootstrap sample. We then calculated the bootstrap 95% CI by arranging the 3,000 bootstrap parameter values in sorted order and selected the 2.5 and 97.5 percentiles from the list.

We used Akaike's Information Criterion for small sample size (AIC_c) to determine which model(s) best explained the relationship between spawners and recruitment in the supplemented and reference populations. AIC_c was estimated as:

$$\boldsymbol{AIC_c = -2log\big(£(\theta|data)\big) + 2K + \left(\frac{2K(K+1)}{n-K-1}\right)}$$

where *log(£(θ|data))* is the maximum likelihood estimate, *K* is the number of estimable parameters (structural parameters plus the residual variance parameter), and *n* is the sample size (Burnham and Anderson 2002). We used least-squares methods to estimate *log(£(θ|data))*, which was calculated as $log(\sigma^2)$, where σ^2 = residual sum of squares divided by the sample size ($\sigma^2 = RSS/n$). AIC_c assessed model fit in relation to model complexity (number of parameters). The model with the smallest AIC_c value represented the "best approximating" model within the model set. Remaining models were ranked relative to the best model using AIC_c difference scores (ΔAIC_c), Akaike weights (w_i), and evidence ratios. Models with ΔAIC_c values less than 2 indicated that there is substantial support for these models as being the best-fitting models within the set (Burnham and Anderson 2002). Models with values greater than 2 had less support. Akaike weights are probabilities estimating the strength of the evidence supporting a particular model as being the best model within the model set. Models with small w_i values are less plausible as competing models (Burnham and Anderson 2002). If no single model could be specified as the best model, a "best subset" of competing models was identified using (1) AIC_c differences to indicate the level of empirical support each model had as being the best model, (2) evidence ratios based on Akaike weights to indicate the relative probability that any model is the best model, and (3) coefficients of determination (R^2) assessing the explanatory power of each model.

Stock-Recruitment Analysis

We successfully fit stock-recruitment models to the Chiwawa and reference population data. The span of spawner data for the Chiwawa and reference populations was greater than 14 times the minimum observed spawners, which should provide sufficient contrast for estimation of model parameters. In addition, the span of recruitment data was greater than 12 times the minimum observed recruitment, again providing sufficient contrast for estimation of parameters. The relationship between natural log R/S and spawners indicated that some of the highest productivities occurred at the lower spawner levels and the lowest productivities generally occurred at the highest spawner levels (Figure 15). This is consistent with the assumption of density-dependent mortality.

Although model fits were generally poor, explaining less than 40% of the residual variation in natural-log recruitment data, we were able to estimate average maximum recruitment levels (K_R) and the spawning levels needed to produce maximum recruitment (K_{sp}) (Table 24; Figure 15). For all populations examined, Akaike information criterion was unable to identify a best approximating model (i.e., ΔAIC_c values were less than 2, indicating support for all three models). However, evaluation of 95% CIs and the asymptotic correlation coefficients indicated that the smooth hockey stick model may be the best approximating model for each population. Therefore, we used estimates of K_R and K_{sp} derived from the smooth hockey stick model to correct for density dependence and different carrying capacities in treatment-reference comparisons.

As part of the regression diagnostics, we examined the dependence of the model residuals on time and found a significant ($P < 0.05$), positive, one-year-lag autocorrelation for the Entiat (0.562), Marsh (0.551), Sesech (0.564), and Little Wenatchee (0.629) populations. For the purposes of our work here, we did not attempt to correct for this one-year-lag correlation in the residuals. Future analyses will explore the use of autoregressive models (e.g., AR1; Noakes et al. 1987) to correct for autocorrelation.

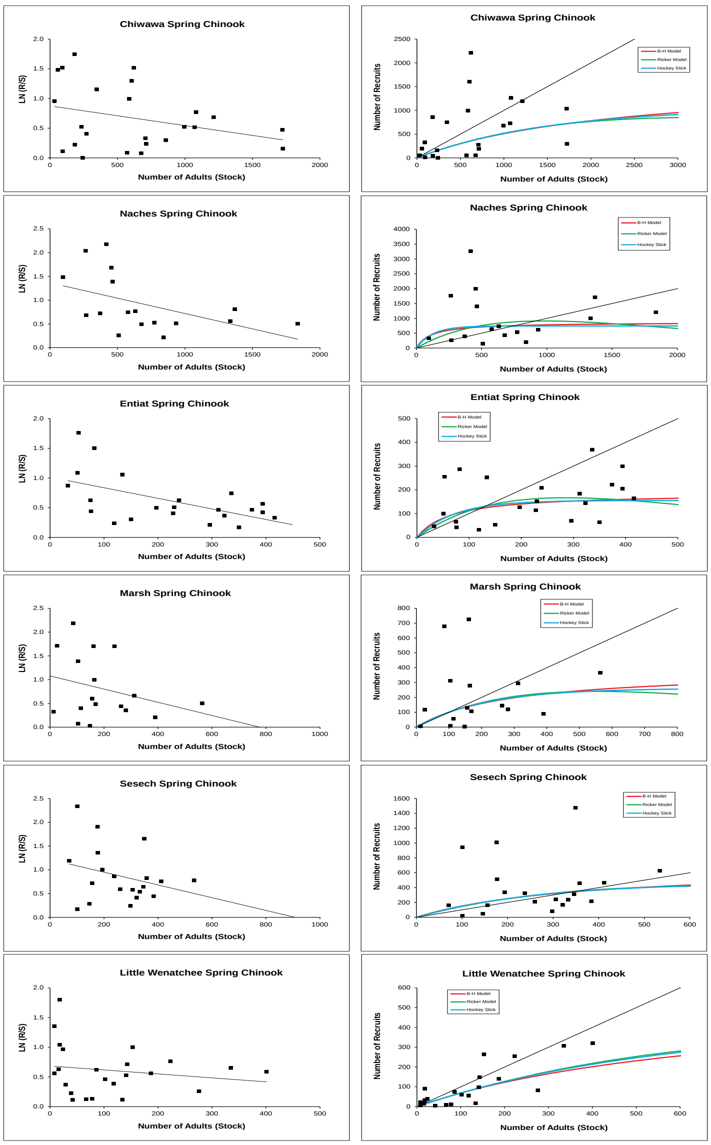

Figure 15. Relationships between natural log recruits/spawner (LN R/S) and spawners (Stock) in the Chiwawa and reference populations (figures on the left) and relationships between numbers of untransformed recruits and spawners in the Chiwawa and reference populations (figures on the right). Figures on the right also show the fit of the Ricker, Beverton-Holt, and the smooth hockey stick models to the data (black straight line represents R=S).

Table 24. Results from fitting Ricker, Beverton-Holt, and smooth hockey stick models to stock-recruitment data from the Chiwawa and reference populations. 95% CI on parameter estimates are based on 3,000 bootstrap trials; Corr coef = asymptotic correlation of the parameter estimates; K_R = maximum natural origin recruits (recruits at carrying capacity); K_{sp} = number of spawners needed to produce K_R; AICc = Akaike's Information Criterion for small sample size; Adj R^2 = coefficient of determination that is adjusted for the number of parameters in the model.

Model	Parameter	Parameter value	Bootstrap 95% CI	Corr coef	K_R	K_{sp}	AICc	Adj R^2
			Chiwawa Population					
Ricker	α	0.7048	-0.6197 1.1055	0.791	852	3,285	-47.949	0.125
	β	0.000304	-0.000668 0.000609					
Beverton-Holt	α	1687.4	-65654539 3062.1	0.989	1,687	43,760	-47.962	0.125
	β	2308.5	-99999538 4526.1					
Smooth hockey stick	α	6.956	-41.313 8.2270	-0.708	1,049	6,847	-47.949	0.125
	β	0.7118	-2.397 1.122					
			Naches Population					
Ricker	α	2.5223	-2.0003 3.9672	0.844	912	983	-45.063	-0.143
	β	0.001018	-0.000752 0.001717					
Beverton-Holt	α	869.4	97.4 1641.4	0.858	869	11,455	-46.801	-0.097
	β	111.8	-346.2 569.8					
Smooth hockey stick	α	6.612	5.9223 7.006	-0.399	744	565	-46.831	-0.095
	β	6.013	-89.071 12.026					
			Entiat Population					
Ricker	α	1.5843	0.1609 2.4178	0.867	167	286	-68.365	-0.049
	β	0.003496	0.001141 0.005906					
Beverton-Holt	α	186.1	67.9 304.3	0.880	186	1,277	-69.895	0.029
	β	65.0	-59.1 189.2					
Smooth hockey stick	α	5.045	4.381 5.378	-0.450	155	344	-69.379	0.003
	β	2.180	-89.369 3.704					
			Marsh Creek Population					
Ricker	α	1.1852	-1.8268 1.9269	0.823	241	552	-32.237	0.218

Model	Parameter	Parameter value	Bootstrap 95% CI	Corr coef	K_R	K_{sp}	AICc	Adj R^2
	β	0.001810	-0.003063 0.003625					
Beverton-Holt	α	383.3	-85109314 665.4	0.970	383	5,310	-32.291	0.234
	β	282.4	-99999944 564.9					
Smooth hockey stick	α	5.565	-22.631 6.584	-0.694	261	984	-32.264	0.227
	β	1.265	-108.574 2.531					
Sesech Population								
Ricker	α	1.6835	-2.9253 2.5951	0.912	421	680	-54.589	-0.005
	β	0.001470	-0.002951 0.002941					
Beverton-Holt	α	689.9	-986.8 2366.7	0.981	690	6,591	-54.678	0.000
	β	351.7	-1059.0 1762.5					
Smooth hockey stick	α	6.1528	-22.851 6.815	-0.821	470	1,185	-54.633	-0.002
	β	0.8000	-119.370 2.909					
Little Wenatchee Population								
Ricker	α	0.7447	0.0828 1.0280	0.735	356	1,298	-66.978	0.357
	β	0.000770	-0.003052 0.001541					
Beverton-Holt	α	564.7	-74423355 1067.6	0.994	565	13,400	-67.055	0.358
	β	719.7	-99999856 1413.4					
Smooth hockey stick	α	6.0181	-49.5620 8.1122	-0.683	411	2,544	-67.000	0.357
	β	0.7550	-0.9539 1.0452					

Method 1: Productivity Data Adjusted for Density Dependence

Analysis of supplementation effects on productivity (adult recruits/spawner adjusted for density-dependent effects based on the smooth hockey stick model) using difference scores indicated that supplementation did not significantly decrease productivity in the Chiwawa Basin (Table 25; Figure 16). All tests, regardless of treatment-reference pairs, indicated that productivity did not change significantly during the supplementation period, even though productivity did decrease during the supplementation period (Figure 16). These results are consistent with those based on unadjusted productivity data (Table 17). This is because most abundance estimates were below the level of assumed density dependence.

Table 25. Results of the Aspin-Welch unequal-variance test, randomization test (based on 10,000 Monte Carlo samples), and 95% CI (based on 5,000 bootstrap samples) on transformed and untransformed productivity data corrected for density dependence. Tests determined if the mean difference scores during the supplementation period were greater than mean difference scores during the pre-supplementation period.

Reference population	Aspin-Welch unequal-variance test			Randomization test P-value	Bootstrap 95% CI
	t-value	P-value	Effect size		
Productivity					
Naches	0.904	0.190	0.496	0.412	-0.511 – 1.497
Marsh	-0.203	0.579	0.152	0.927	-1.298 – 1.372
Sesech	1.607	0.071	1.435	0.146	-0.359 – 2.911
Little Wenatchee	0.431	0.335	0.147	0.668	-0.487 – 0.781
LN Productivity					
Naches	0.570	0.290	0.083	0.568	-0.168 – 0.362
Marsh	0.012	0.495	0.003	0.991	-0.373 – 0.480
Sesech	1.463	0.087	0.343	0.171	-0.125 – 0.732
Little Wenatchee	0.390	0.351	0.060	0.709	-0.218 – 0.365

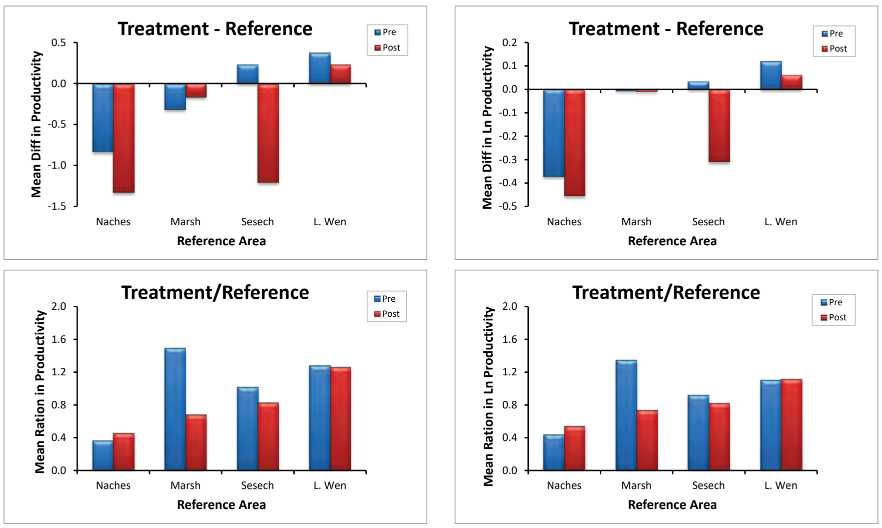

Figure 16. Mean differences (Treatment – Reference; figures on the top) and mean ratios (Treatment/Reference; figures on the bottom) of transformed and untransformed productivity data (adjusted for density dependence) before (pre) and after (post) spring Chinook supplementation in the Chiwawa Basin. Negative effects of supplementation on productivity are indicated when the pre-supplementation (blue) bars are greater than their corresponding post-supplementation (red) bars.

Analysis of supplementation effects on productivity (adult recruits/spawner adjusted for density-dependent effects) using ratios indicated that supplementation did not significantly decrease productivity in the Chiwawa Basin (Table 26; Figure 16). The Aspin-Welch test and the 95% CIs did indicate a significant effect when comparing the Chiwawa to the Marsh Creek population. These results are consistent with those using unadjusted productivity data (Table 20). Again, this is because most abundance estimates were below the level of assumed density dependence.

Table 26. Results of the Aspin-Welch unequal-variance test, randomization test (based on 10,000 Monte Carlo samples), and 95% CI (based on 5,000 bootstrap samples) on transformed and untransformed productivity data corrected for density dependence. Tests determined if the mean ratios during the supplementation period were less than mean ratios during the pre-supplementation period.

Reference population	Aspin-Welch unequal-variance test			Randomization test P-value	Bootstrap 95% CI
	t-value	P-value	Effect size		
Productivity					
Naches	-0.529	0.696	0.087	0.597	-0.394 – 0.214
Marsh	2.236	0.022	0.814	0.056	0.140 – 1.470
Sesech	0.677	0.253	0.191	0.496	-0.343 – 0.727
Little Wenatchee	0.033	0.487	0.018	0.978	-0.902 – 1.181
LN Productivity					
Naches	-0.621	0.726	0.104	0.536	-0.406 – 0.191

Reference population	Aspin-Welch unequal-variance test			Randomization test P-value	Bootstrap 95% CI
	t-value	P-value	Effect size		
Marsh	1.952	0.036	0.613	0.076	0.005 – 1.163
Sesech	0.447	0.330	0.098	0.649	-0.312 – 0.498
Little Wenatchee	-0.034	0.513	0.015	0.980	-0.697 – 0.852

Our analyses assume that there is a spawner abundance (K_{sp}) at which density-independent effects end and density-dependent effects begin. In reality, density-dependent effects occur at low spawning abundance and intensify as spawning abundance increases (evident in the changing slope of the three stock-recruitment curves used in our analyses). We did not account for these increasing density-dependent effects at spawner abundances less than K_{sp}. If we accounted for the increasing effects of density dependence at spawning abundances less than K_{sp}, the analysis with and without productivity adjustments may give different results.

Method 2: Fraction of Carrying Capacity Filled with NORs

We analyzed the effects of supplementation on filling the capacity of the habitat with natural-origin recruits. The smooth hockey stick model derived the carrying capacity (K_R) estimates for the Chiwawa and reference populations. The fraction of the carrying capacity filled with Chinook recruits before and during supplementation for the Chiwawa and reference populations is provided in Table 27. These data indicate that for the Chiwawa population, the mean fraction of the K_R filled with fish decreased significantly from the pre-supplementation period through the supplementation period (Table 27). Likewise, the Entiat and Little Wenatchee populations showed a significant decline in the mean fraction of K_R filled with adult recruits. In contrast, the mean fraction of K_R in the Naches and Marsh Creek populations increased during the same period (Table 27).[20] Interestingly, the fraction of K_R filled with adult recruits for all populations trended downward during the pre-supplementation period (Figure 17). During the supplementation period, however, the fraction of K_R filled with adult recruits trended upward for all populations. These results suggest that agents of mortality outside the Chiwawa and reference populations were reducing recruitment to the populations.

20 Although we do not show the results here, statistical analysis of the mean fraction of carrying capacity filled by adult recruits using natural-log transformed data produced the same result as using untransformed data. This was true for all populations.

Table 27. Fraction of the carrying capacity that was filled with Chinook salmon adult recruits in the Chiwawa and reference populations before (pre) and during (post) supplementation in Chiwawa Basin. The smooth hockey stick model estimated carrying capacity for each population. Statistical results from comparing the pre and post mean scores using the Aspin-Welch unequal-variance test are provided at the bottom of the table.

Supplementation period	Chiwawa	Reference populations			
		Naches	Entiat	Marsh	L. Wenatchee
Pre-supplementation period (1981-1992)	2.11		2.38	1.07	0.64
	1.53		1.93	1.20	0.75
	1.20		1.32	2.60	0.78
	1.14		1.19	0.49	0.62
	0.99		1.06	0.46	0.34
	0.70	2.30	1.43	0.56	0.24
	0.65	0.58	0.74	0.34	0.20
	0.95	1.88	1.34	1.40	0.36
	0.18	0.72	1.63	0.22	0.15
	0.05	0.27	0.45	0.02	0.02
	0.00	0.20	0.21	0.03	0.01
Pre-Mean:	0.86	0.99	1.24	0.76	0.37
Pre-Range:	0.00 – 2.11	0.20 – 2.30	0.21 – 2.38	0.02 – 2.60	0.01 – 0.78
Post-supplementation period (1992-2002)	0.05	0.98	0.34	0.41	0.03
	0.15	0.86	0.41	1.13	0.04
	0.04	0.35	0.27	0.02	0.03
	0.05	0.44	0.30	0.02	0.03
	0.19	4.39	0.65	0.45	0.06
	0.82	2.68	1.85	2.78	0.22
	0.31	2.37	1.65	4.10	0.08
	0.01	0.53	0.42		0.02
	0.71	1.62	0.82		0.10
	0.28	1.35	0.93		0.14
	0.27	0.83	0.98		0.18
Post-Mean:	0.26	1.49	0.78	1.27	0.08
Post-Range:	0.04 – 0.82	0.35 – 4.39	0.30 – 1.85	0.02 – 4.10	0.02 – 0.22
One-sided Aspin-Welch t-test of pre and post means	t = 2.846; P = 0.007	t = -0.967; P = 0.825	t = 1.833; P = 0.041	t = -0.799; P = 0.776	t = 3.321; P = 0.003

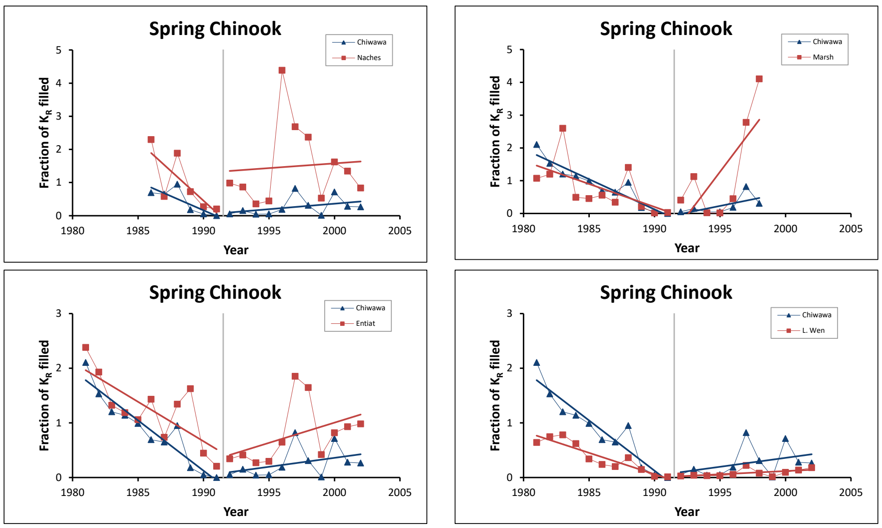

Figure 17. Trends in the fraction of the carrying capacity that was filled with Chinook salmon adult recruits in the Chiwawa and reference populations before (pre) and during (post) supplementation in Chiwawa Basin. The vertical lines in the figures separate the pre- and post-supplementation periods. The smooth hockey stick model estimated carrying capacity for each population.

We then compared the mean difference scores and ratios between the Chiwawa and reference populations before and during supplementation using data representing the fraction of K_R filled with adult recruits. In most of the Chiwawa-reference population comparisons, the absolute value of the mean difference between the fraction of K_R filled with recruits was greater in the supplementation period than during the pre-supplementation period; two of the four pairings were significant (Table 28; Figure 18). Analysis of difference scores using natural-log transformed data indicated that three of the four pairings were significant (Table 28).

Results from analyses using ratios were similar to results using difference scores. Mean ratio scores were generally smaller during the supplementation period than during the pre-supplementation period (Figure 18). This indicated that the mean fraction of K_R filled by adult recruits in most reference populations was greater during the supplementation period than during the pre-supplementation period (i.e., the denominator in the ratio increased between the pre- and post-supplementation periods). In contrast, the fraction of K_R filled by adult recruits in the Chiwawa decreased from the pre- to post-supplementation period (i.e., the numerator in the ratio decreased between the pre- and post-supplementation periods). Thus, unlike the Chiwawa population, the capacity of most reference populations was becoming more saturated during the period when the Chiwawa was being supplemented. Statistical analysis with mean ratios indicated that two of the four pairings were significant (Table 29).

Analyses comparing the Little Wenatchee with the Chiwawa indicate that adult recruits to the Little Wenatchee have been well below its carrying capacity. During the pre-supplementation period, the capacity of the Little Wenatchee was on average 37% saturated with adult recruits. During the supplementation period, the capacity of the Little Wenatchee declined to 8% saturation

with adult recruits (a 22% decline). The Chiwawa, during the pre-supplementation period, was on average 86% saturated. During the supplementation period, percent saturation in the Chiwawa decreased to 26% (a 30% decrease). During the same time periods, the capacity of the Entiat population, which until recently has been supplemented, declined from 124% to 78% saturation (a 63% decline).

Table 28. Results of the Aspin-Welch unequal-variance test, randomization test (based on 10,000 Monte Carlo samples), and 95% CI (based on 5,000 bootstrap samples) on the fraction of the habitat capacity (K_R) that is filled with natural origin recruits. Analyses include both transformed and untransformed data. Tests determined if the mean difference scores during the supplementation period were greater than mean difference scores during the pre-supplementation period.

Reference population	Aspin-Welch unequal-variance test			Randomization test P-value	Bootstrap 95% CI
	t-value	P-value	Effect size		
Fraction of Capacity Filled					
Naches	1.550	0.071	0.657	0.145	-0.173 – 1.378
Entiat	0.835	0.207	0.141	0.422	-0.167 – 0.475
Marsh	2.026	0.040	1.141	0.055	0.064 – 2.054
Little Wenatchee	2.166	0.023	0.310	0.031	0.035 – 0.569
LN Fraction of Capacity Filled					
Naches	2.123	0.026	0.311	0.039	0.031 – 0.575
Entiat	1.405	0.087	0.122	0.176	-0.034 – 0.289
Marsh	2.547	0.017	0.519	0.017	0.125 – 0.864
Little Wenatchee	1.744	0.049	0.130	0.100	-0.004 – 0.273

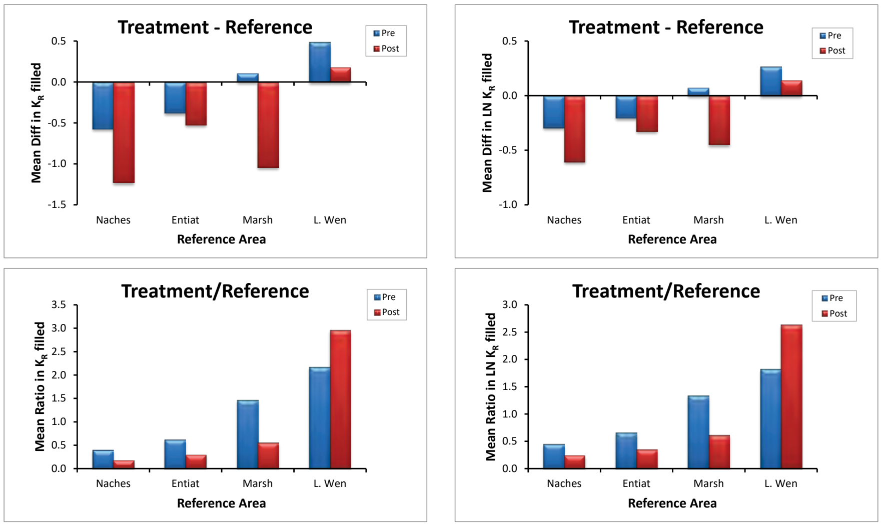

Figure 18. Mean differences (Treatment – Reference; figures on the top) and mean ratios (Treatment/Reference; figures on the bottom) of transformed and untransformed fractions of carrying capacity filled with adult recruits before (pre) and after (post) spring Chinook supplementation in the Chiwawa Basin.

Table 29. Results of the Aspin-Welch unequal-variance test, randomization test (based on 10,000 Monte Carlo samples), and 95% CI (based on 5,000 bootstrap samples) on the fraction of the habitat capacity (K_R) that is filled with natural origin recruits. Analyses include both transformed and untransformed data. Tests determined if the mean ratios during the supplementation period were less than mean ratios during the pre-supplementation period.

Reference population	Aspin-Welch unequal-variance test			Randomization test	Bootstrap 95% CI
	t-value	P-value	Effect size	P-value	
Fraction of Capacity Filled					
Naches	1.317	0.119	0.217	0.219	-0.103 – 0.482
Entiat	2.449	0.013	0.321	0.028	0.085 – 0.577
Marsh	2.001	0.035	0.905	0.070	0.138 – 1.788
Little Wenatchee	-1.148	0.864	0.791	0.278	-1.979 – 0.578
LN Fraction of Capacity Filled					
Naches	1.257	0.127	0.207	0.249	-0.099 – 0.484
Entiat	2.346	0.016	0.313	0.031	0.072 – 0.583
Marsh	1.737	0.056	0.729	0.111	0.028 – 1.531
Little Wenatchee	-1.525	0.924	0.815	0.142	-1.751 – 0.195

Comparing Stock-Recruitment Curves

As a final set of treatment and reference population comparisons, we compared the stock-recruitment curves of the Chiwawa population (using {R, S} data only from the supplementation period) to the reference populations (using all available {R, S} data). Specifically, we tested whether the regression parameters were equal between the Chiwawa population and the reference populations, and whether the fitted curves coincided between populations. Earlier in this report we described the data, methods, and results of fitting the Ricker, Beverton-Holt, and smooth hockey stick curves to the data. Because AIC_c was unable to identify a best approximating model, here we included all three models in our analyses. We tested the following hypotheses.

Parameter equivalence:

Ho: Stock-recruitment parameters (α and β) of the Chiwawa population = Stock-recruitment parameters of the reference populations.

Ha: Stock-recruitment parameters (α and β) of the Chiwawa population ≠ Stock-recruitment parameters of the reference populations.

Curve equivalence:

Ho: Modeled stock-recruitment curves of the Chiwawa population = Modeled stock-recruitment curves of the reference populations.

Ha: Modeled stock-recruitment curves of the Chiwawa population ≠ Modeled stock-recruitment curves of the reference populations.

We used two-sided randomization tests to test the null hypotheses of equal model parameters and that fitted curves coincided. Because the total number of permutations was in the millions, we used a Monte Carlo approach to randomly select 10,000 permutations. The test statistic for comparing the model parameters was formed by summing the difference between the population parameter estimates for each pair of populations. The test statistic for comparing the whole curve was formed by summing the difference between the estimated predicted values for each pair of populations at 500 equally spaced points along the curve.

Ricker Relationships

Ricker curves differed significantly between the Chiwawa and reference populations (Figure 19; Table 30). Interestingly, however, the parameters in the Ricker model did not differ significantly among most populations (Table 30). Only the β parameter differed significantly between the Chiwawa and Entiat populations.

In the Ricker model, the α parameter represents intrinsic productivity (i.e., recruits per spawner at low spawner densities). In this analysis, there was not enough evidence in the stock-recruitment data to reject the hypothesis of inequality in intrinsic productivity. Thus, this test was unable to demonstrate that supplementation, based on the Ricker curve, affected productivity in the Chiwawa population.

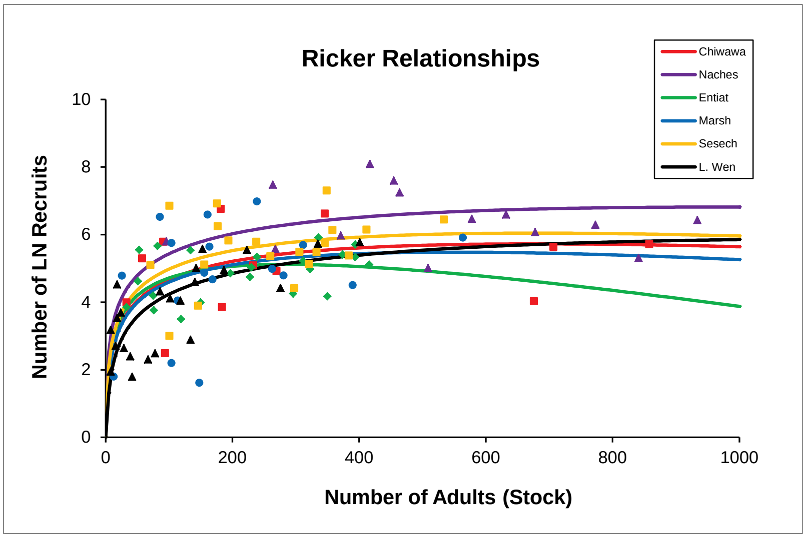

Figure 19. Scatter plot of the number of spawners and natural log adult recruits and fitted Ricker curves to the Chiwawa (supplemented population) and reference (un-supplemented) populations.

Table 30. Randomization test results comparing the equality of Ricker curves and equality of parameter values (α and β). Randomization tests were based on 10,000 Monte Carlo samples. Equality or curves was based on 500 points along the x-axis (spawner abundance axis).

Curves tested	Curve inequality randomization P-value	Parameter inequality		
		Model Parameter		Randomization P-value
		Chiwawa	Reference	
Chiwawa v. Naches	0.008	α = 1.2247	α = 2.5267	0.236
		β = 0.0015	β = 0.0010	0.600
Chiwawa v. Entiat	0.004	α = 1.2247	α = 1.5836	0.978
		β = 0.0015	β = 0.0035	0.025
Chiwawa v. Marsh	0.034	α = 1.2247	α = 1.1855	0.997
		β = 0.0015	β = 0.0018	0.688
Chiwawa v. Sesech	0.036	α = 1.2247	α = 1.6818	0.972
		β = 0.0015	β = 0.0015	0.997
Chiwawa v. L. Wenatchee	0.034	α = 1.2247	α = 0.7439	0.969
		β = 0.0015	β = 0.0008	0.203

Beverton-Holt Relationships

Beverton-Holt curves differed significantly only between the Chiwawa and Naches populations (Figure 20; Table 31). There was no significant difference in curves between the Chiwawa and the other reference populations. The parameters in the Beverton-Holt model did not differ significantly among any of the populations (Table 31). This was true even for the Chiwawa and Naches populations.

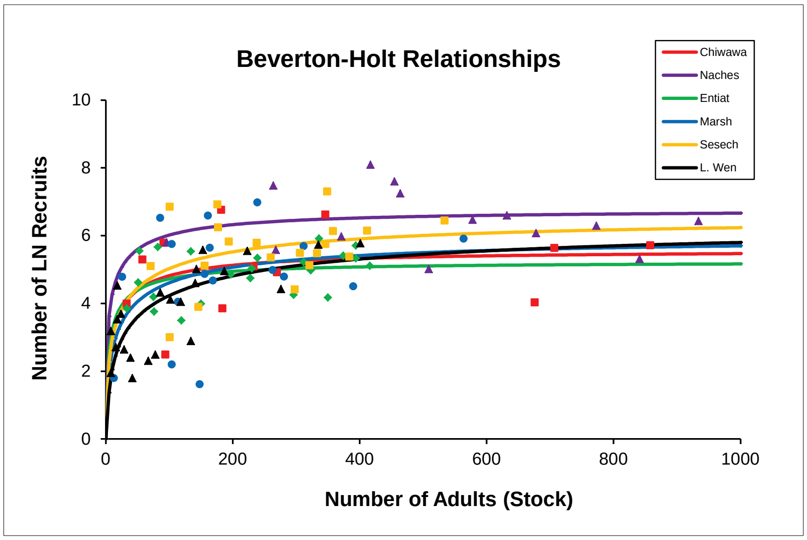

Figure 20. Scatter plot of the number of spawners and natural log adult recruits and fitted Beverton-Holt curves to the Chiwawa (supplemented population) and reference (un-supplemented) populations.

Table 31. Randomization test results comparing the equality of Beverton-Holt curves and equality of parameter values (α and β). Randomization tests were based on 10,000 Monte Carlo samples. Equality or curves was based on 500 points along the x-axis (spawner abundance axis).

Curves tested	Curve inequality randomization P-value	Parameter inequality		
		Model Parameter		Randomization P-value
		Chiwawa	Reference	
Chiwawa v. Naches	0.036	α = 264.25	α = 870.62	0.777
		β = 113.79	β = 112.24	0.963
Chiwawa v. Entiat	0.746	α = 264.25	α = 186.34	0.960
		β = 113.79	β = 65.33	0.954
Chiwawa v. Marsh	0.850	α = 264.25	α = 381.79	0.944
		β = 113.79	β = 281.04	0.891

Curves tested	Curve inequality randomization P-value	Parameter inequality		
		Model Parameter		Randomization P-value
		Chiwawa	Reference	
Chiwawa v. Sesech	0.272	α = 264.25	α = 689.31	0.821
		β = 113.79	β = 351.59	0.869
Chiwawa v. L. Wenatchee	0.654	α = 264.25	α = 568.69	0.864
		β = 113.79	β = 725.87	0.751

Smooth Hockey Stick Relationships

Smooth hockey stick curves differed significantly between the Chiwawa and Naches populations and the Chiwawa and Sesech populations (Figure 21; Table 32). There was no significant difference in curves between the Chiwawa and the other reference populations. Most of the parameters in the smooth hockey stick model did not differ significantly among the populations (Table 32). However, the productivity parameter β did differ significantly between the Chiwawa and the Naches and the Chiwawa and Little Wenatchee populations. The β parameter for the Naches was significantly greater than the Chiwawa, while the β parameter for the Little Wenatchee was significantly less than the Chiwawa.

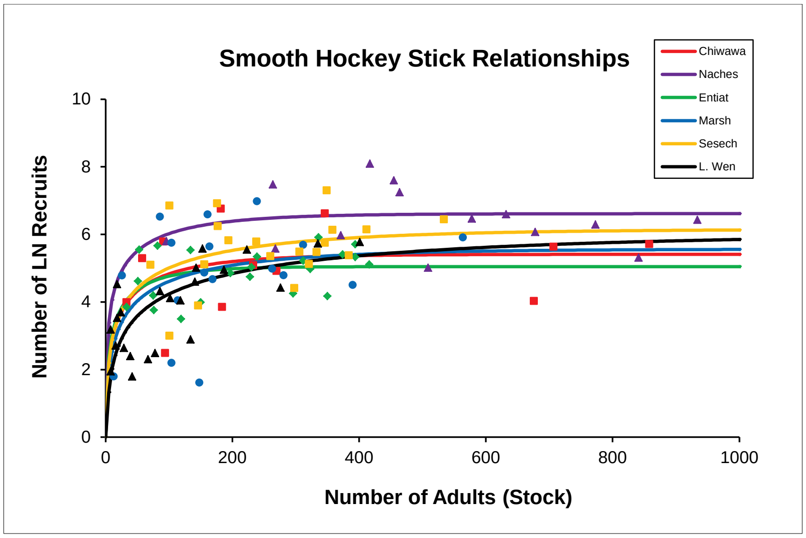

Figure 21. Scatter plot of the number of spawners and natural log adult recruits and fitted smooth hockey stick curves to the Chiwawa (supplemented population) and reference (un-supplemented) populations.

Table 32. Randomization test results comparing the equality of smooth hockey stick curves and equality of parameter values (α and β). Randomization tests were based on 10,000 Monte Carlo samples. Equality or curves was based on 500 points along the x-axis (spawner abundance axis).

Curves tested	Curve inequality randomization P-value	Parameter inequality		
		Model Parameter		Randomization P-value
		Chiwawa	Reference	
Chiwawa v. Naches	0.000	α = 5.41	α = 6.61	0.000
		β = 1.84	β = 5.99	0.000
Chiwawa v. Entiat	0.999	α = 5.41	α = 5.05	0.999
		β = 1.84	β = 2.17	0.999
Chiwawa v. Marsh	0.999	α = 5.41	α = 5.56	0.999
		β = 1.84	β = 1.27	0.999
Chiwawa v. Sesech	0.000	α = 5.41	α = 6.15	0.000
		β = 1.84	β = 1.80	0.999
Chiwawa v. L. Wenatchee	0.990	α = 5.41	α = 6.02	0.999
		β = 1.84	β = 0.75	0.000

Comparing different stock-recruitment curves and their parameters did not provide strong evidence that the supplementation program has negatively affected the productivity of the Chiwawa population.

Analysis without Reference Populations

In some cases, suitable reference populations may not exist to compare with supplemented populations. It is therefore important to have alternative analyses to assess supplementation effects. In this section, we describe methods that can be used to assess supplementation effects when suitable reference populations are not available. We discuss before-after comparisons, correlation analysis, and comparisons to standards as alternatives when reference populations are unavailable.

Before-After Comparisons

Before-after analyses compare population metrics (spawner abundance, NORs, and productivity) before supplementation to those during supplementation. In this case, data collected before supplementation represent the reference condition. The assumption is that population trajectories measured during the pre-supplementation period would continue in the absence of supplementation. We compared trends in abundance and productivity, mean abundance and productivity, and stock-recruitment relationships before and after supplementation.

Trend Analysis

Comparing trends before and after supplementation can be used to assess the effects of supplementation. Here, we compared the slopes of trends of spawner abundance, NORs, and productivity before and during supplementation using t-tests. If the hatchery program is successfully supplementing the natural spring Chinook population, the trend for spawner abundance and NORs during supplementation should be greater than the slope during the pre-supplementation period. For productivity, the slope during the supplementation period should increase or remain the same as that during the pre-supplementation period.

Visual examination of trends of Chiwawa data indicates that spawner abundance, NORs, and productivity decreased during the pre-supplementation period, but increased during the supplementation period (Figure 22). Only the changes in NOR trends were significant (Figure 22). This was true for both transformed and untransformed data.

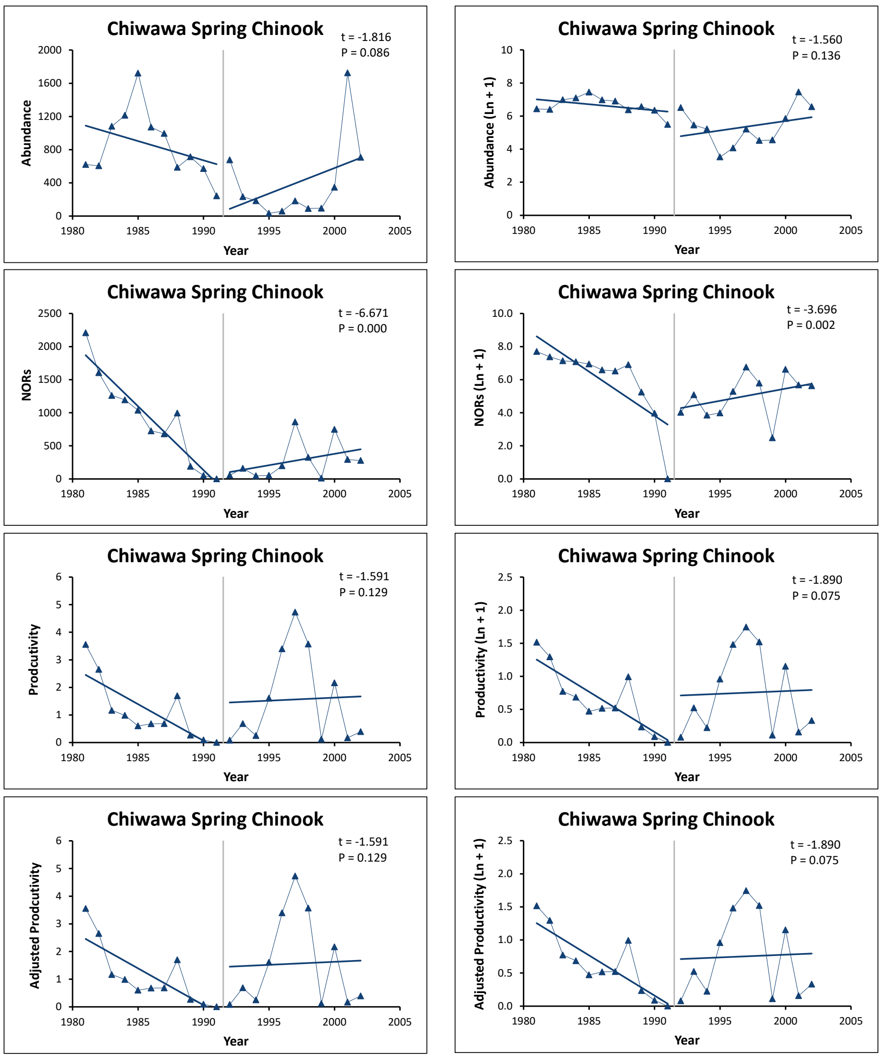

Figure 22. Trends in Chiwawa spring Chinook spawner abundance, natural-origin recruits (NORs), productivity (adults recruits per spawner), and adjusted productivity (adjusted for density dependence) before and during supplementation. The vertical lines in the figures separate the pre- and post-supplementation periods. Figures on the left show untransformed data; figures on the right include natural-log transformed data. Figures include results of t-tests comparing slope of trends before and during supplementation.

Analysis of Mean Scores

We also compared mean spawner abundance, NORs, and productivity data before and after supplementation. If the hatchery program is successfully supplementing the natural spring Chinook population, mean spawner abundance and NORs during the supplementation period should be greater than the pre-supplementation period. For productivity, the mean productivity during the supplementation period should be equal to or higher than the pre-supplementation period. We tested the following statistical hypotheses.

Spawner Abundance and NORs:

Ho: Mean spawner abundance and NORs before supplementation ≥ Mean spawner abundance and NORs during supplementation.

Ha: Mean spawner abundance and NORs before supplementation < Mean spawner abundance and NORs during supplementation.

Productivity (Recruits/Spawner):

Ho: Mean productivity before supplementation ≤ Mean productivity during supplementation.

Ha: Mean productivity before supplementation > Mean productivity during supplementation.

We tested before-after supplementation effects using a one-tailed Aspin-Welch unequal-variance test. We also used a randomization test, based on 10,000 Monte Carlo simulations, to assess differences in spawner abundance and productivity before and during supplementation. The randomization procedure only allowed the testing of two-tailed hypotheses. Therefore, we generated 95% confidence intervals on the mean difference (μ_{pre} - μ_{post}) using bootstrapping methods to determine if the significant result from the randomization test was in the right direction. We generated 5,000 bootstrap samples to calculate confidence intervals.

Mean spawner abundance during the supplementation period was significantly less than the pre-supplementation spawner abundance (Table 33). Mean spawner abundance decreased 46% between the pre- and post-supplementation periods. Likewise, mean NORs decreased significantly between the two periods (Table 33). On the other hand, productivity increased slightly, but not significantly, between the pre- and post-supplementation periods (Table 33). This was true for both adjusted and transformed productivity data.

Table 33. Statistical results comparing mean scores of spawner abundance, natural-origin recruits (NORs), and productivity (using both untransformed and natural-log transformed) before and during supplementation of Chiwawa spring Chinook. Randomization tests were based on 10,000 Monte Carlo samples and 95% CI were based on 5,000 bootstrap samples.

Population metric	Mean scores		Test on means			
			Aspin-Welch test		Random test P-value	Bootstrap 95% CI
	Before	During	t-value	P-value		
Abundance	856	393	2.383	0.986	0.028	112 - 843
LN Abundance	6.6	5.4	3.304	0.997	0.004	0.56 – 1.99
NORs	905	275	2.846	0.993	0.009	214 – 1034
LN NORs	6.0	5.0	1.197	0.876	0.250	-0.40 – 2.54
Productivity	1.13	1.56	-0.721	0.759	0.479	-1.55 – 0.73
LN Productivity	0.64	0.75	-0.450	0.671	0.649	-0.55 – 0.35
Adj Productivity	1.12	1.56	-0.721	0.759	0.477	-1.54 – 0.71
LN Adj Productivity	0.64	0.75	-0.450	0.671	0.652	-0.57 – 0.34

Analysis of Stock-Recruitment Curves

The third method compared stock-recruitment curves of the Chiwawa population during supplementation with those generated before supplementation. Specifically, we tested whether the regression parameters were equal between the pre- and post-supplementation periods, and whether the fitted curves coincided between the two time periods. We used the methods described earlier to fit the Ricker, Beverton-Holt, and smooth hockey stick curves to the two data sets. We tested the following hypotheses.

Parameter equivalence:

Ho: Stock-recruitment parameters (α and β) of the pre-supplementation period = Stock-recruitment parameters of the supplementation period.

Ha: Stock-recruitment parameters (α and β) of the pre-supplementation period ≠ Stock-recruitment parameters of the supplementation period.

Curve equivalence:

Ho: Modeled stock-recruitment curves from the pre-supplementation period = Modeled stock-recruitment curves from the pre-supplementation period.

Ha: Modeled stock-recruitment curves from the pre-supplementation period ≠ Modeled stock-recruitment curves from the pre-supplementation period.

We were only able to fit stock-recruitment curves to the post-supplementation data. Non-linear regression was unable to converge on a solution using only pre-supplementation data. Therefore, we were unable to use this method to test supplementation effects on the Chiwawa spring Chinook population. If we could have fit curves to both the pre- and post-supplementation periods, we would have used two-sided randomization tests to evaluate the null hypotheses of equal model parameters and that fitted curves coincided.

Before describing correlation approaches, it is important to note that comparing before-after data can sometimes be misleading. For example, the spawner abundance, NORs, and productivity data presented in Figure 22 suggest that supplementation is increasing the abundance and productivity of spring Chinook in the Chiwawa Basin. However, when we compared these trends to those from reference populations during the same time periods (Figures 9-11), it becomes clear that supplementation was not responsible for increasing the trends in spawner abundance, NORs, and productivity of the Chiwawa population. Thus, whenever possible, it is wise to compare before-after data with a reference population.

Correlation Analyses

A simple way to see if the supplementation program is increasing or decreasing productivity is to assess the association between the proportion of adult spawners that are made up of hatchery adults (pHOS) and productivity (recruits/spawner). If the supplementation program is working as planned, the increase in hatchery fish spawning naturally should increase the productivity of the population. It should not decrease the productivity of the population.

We tested the association between pHOS and adult productivity[21] using Pearson correlation. During the pre-supplementation period, productivity averaged 1.13 recruits/spawner; during the supplementation period, productivity averaged 1.39 recruits/spawner. This increase in productivity did not appear to be strongly correlated to pHOS (Figure 23). Correlation analysis showed that there was no significant association between pHOS and productivity, even though productivity increased with increasing pHOS.

21 Note that the analysis could also include juvenile productivity (e.g., smolts/spawner).

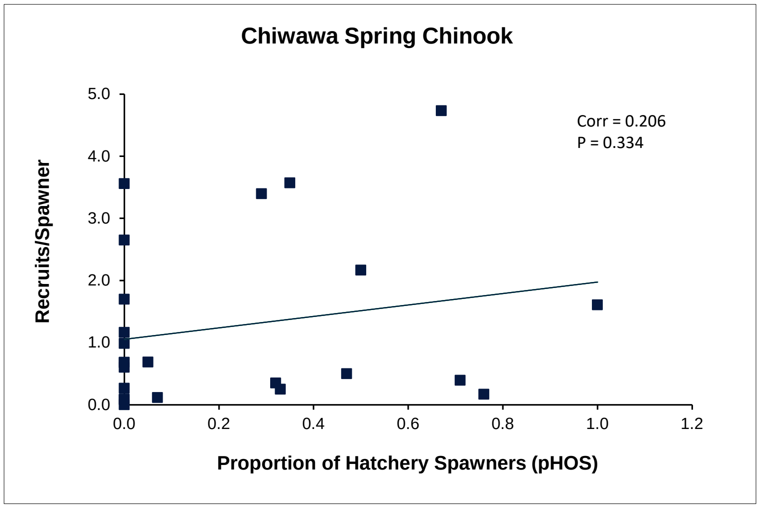

Figure 23. Association between the proportion of spawners that are made up of hatchery adults (pHOS) and the number of natural-origin recruits. The Pearson correlation coefficient (Corr) and its P-value (P) are shown in the figure.

The association between pHOS and productivity can also be assessed by testing the correlation between pHOS and the residuals from stock-recruitment curves fitted to the Chiwawa spawner and natural-origin recruitment data. This approach removes the effects of density dependence on the relationship between pHOS and productivity. A significant negative association provides evidence that hatchery-origin spawners may not be as productive as natural-origin spawners.

The Ricker, Beverton-Holt, and smooth hockey stick models were fit to the Chiwawa stock and recruitment data (including {S, R} data from both the pre- and post-supplementation period, 1981-2004) using methods described earlier. Residuals were calculated by subtracting the predicted recruitment values from the observed (modeled) values. Pearson correlation then tested the association between pHOS and the residuals from each model.

Although there was a negative trend in residuals with increasing pHOS, suggesting that hatchery-origin spawners may not be as productive as natural-origin spawners, the association was not significant (Figure 24). Thus, based on these analyses, there is no strong evidence that the supplementation program has significantly benefited or harmed the natural spring Chinook population.

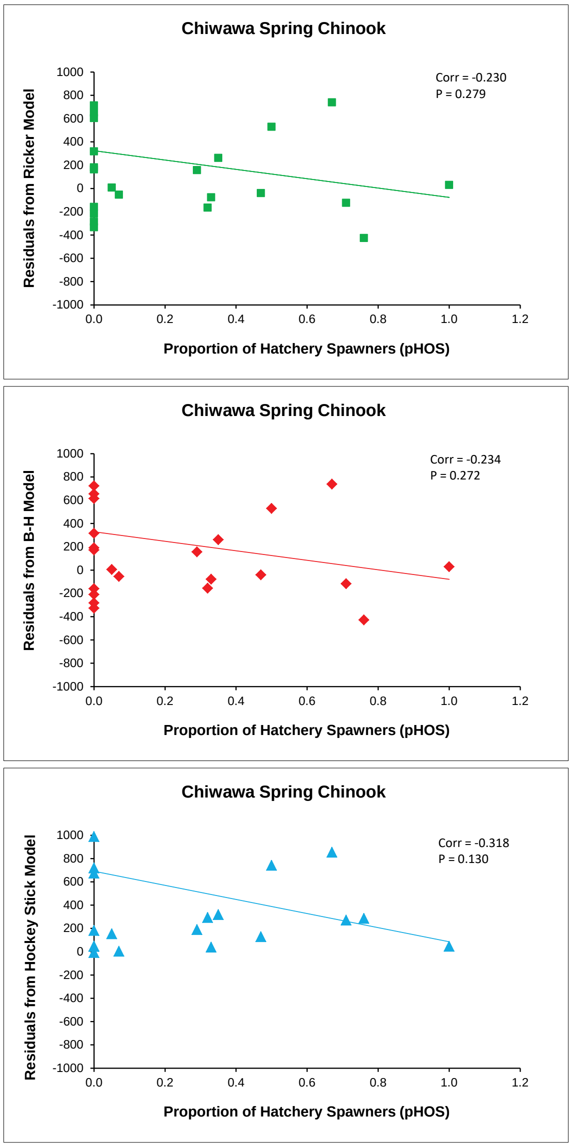

Figure 24. Association between the proportion of spawners that are made up of hatchery adults (pHOS) and the residuals from Ricker, Beverton-Holt (B-H), and smooth hockey stick stock-recruitment models. The Pearson correlation coefficient (Corr) and its P-value (P) are shown in the figures.

Comparison to Standards

In those cases in which suitable reference populations are not available and there are no pre-supplementation data, the investigator is left with comparing population parameters to relevant standards. Standards can include performance of natural-origin fish in similar environments (a type of reference condition), mitigation requirements, quantitative objectives of the program, Biological Assessment and Management Plan (BAMP) values, or other appropriate standards. An example of a statistical hypothesis would be:

Ho: Productivity (Recruits/Spawner) of the supplemented population ≥ standard productivity.

Ha: Productivity (Recruits/Spawner) of the supplemented population < standard productivity.

For these analyses to be useful, the standards must be based on biological reality.

Conclusions and Recommendations

Hatcheries are an important component of fish production within the Upper Columbia Basin. The goal of some of these programs is to supplement natural production in declining populations. The supplementation programs generally use both hatchery and natural (spawned and reared in nature from either wild or hatchery parents) adults for hatchery broodstock. These programs are designed to supplement natural populations by increasing natural reproduction while preventing the establishment of a domesticated hatchery stock. Thus, the programs should increase total spawning escapement and NORs, and not reduce the productivity of the natural population. Measuring the success of these programs is challenging and expensive.

In this paper, we described methods that can be used to determine if supplementation programs are achieving some of their goals. This paper focused on the use of reference populations to determine if the supplementation programs increase total spawning escapement, NORs, and maintain or increase productivities. In some cases, suitable reference populations may not be available (e.g., we found no suitable reference populations for Upper Columbia steelhead and sockeye). In these cases, alternative methods are needed to assess supplementation effects. We also described these alternative methods in this paper.

Identification of Reference Populations

Finding suitable reference populations that match well with supplemented populations is a difficult and time-consuming process. Our three-step selection process included identification of populations with similar life-history characteristics, few or no hatchery spawners, a long time series of accurate abundance and productivity estimates, and similar freshwater habitat impairments and out-of-basin effects. Those populations that met these criteria were then examined for their relationship with the supplemented population (in this case, the Chiwawa spring Chinook population). Several criteria were scored, including pNOS, correlation, trend, and effect size. Reference populations with total weighed scores of 81 or greater were selected as suitable reference populations.

This selection process provided a valuable framework for selecting suitable reference populations for supplemented populations. Interestingly, we found that a given reference population may match well with one parameter of the supplemented population (e.g., spawning escapement), but not for all parameters (e.g., not NORs or productivity). The reason for this may be related to errors

in the estimation of population parameters and/or differential factors limiting population parameters of supplemented and reference populations. Therefore, depending on the parameter analyzed, a different suite of reference populations may be needed.

An important assumption in the use of reference populations is that the supplemented and reference populations that tracked each other before supplementation would continue to track each other in the absence of supplementation. Given that the reference populations did not match the Chiwawa population on all criteria examined, and some reference populations tracked the Chiwawa population more poorly than others, there may be some uncertainty as to whether differences observed between the supplemented and reference populations during the supplementation period are associated with the hatchery program, or other unaccounted factors. For example, any large-scale change (man-made or natural) within the reference or supplemented population could affect our ability to assess the effectiveness of the supplementation program.

To account for some of these uncontrollable factors, we recommend the use of a "causal-comparative" approach to strengthen the certainty of our inferences. This approach relies on correlative data to try and make a case for causal inference. We recommend that the following state variables be measured and tracked within the supplemented and reference populations: mean annual precipitation, total and riparian forest cover, road density, impervious surface, and alluvium. These variables can be used to describe differences in water temperatures at different life stages (pre-spawning, egg incubation, and summer rearing) and substrate characteristics, including fine sediments and embeddedness. These state variables can be used to help explain possible changes in spawner abundance, NORs, and productivity that are independent of supplementation. In addition, the use of multiple reference streams reduces the possibility that man-made changes to a single reference stream will influence the interpretation of the results.

Analyses with Reference Populations

Using reference populations, we evaluated the effects of supplementation on natural-log transformed and untransformed total spawning escapement, NORs, and productivity by comparing trends, analyzing mean differences, ratios, and rates, and comparing stock-recruitment curves and their parameters. For trend analysis, we compared the slopes of the trends between each supplemented/reference pair before and during supplementation. If the hatchery program is successfully supplementing the natural population, trends in spawner abundance and NORs should deviate significantly during the supplementation period (i.e., the slope of the supplemented population should be greater than the slopes of the reference populations during the supplementation period), but not during the pre-supplementation period. For productivity, the slope of the supplemented population, relative to the reference population, should increase or remain the same.

Because trend analysis only tests the slopes of the trend lines, it does not test for differences in elevations of the trend lines, additional analyses were needed to determine if supplementation increased spawner abundance, NORs, and productivity of the target population without changing the slopes of the trend lines. To do this, we derived three different response variables using natural-log transformed and untransformed spawner abundance, NORs, and productivity data. The first derived variable included difference scores, which were calculated as the difference between paired treatment and reference data (T-R). The second included ratios, which were calculated as the ratio of paired treatment and reference data (T/R). Finally, we calculated the differences in annual changes in paired treatment and reference population data (ΔT-ΔR). If the hatchery

program is successfully supplementing the natural population, the mean difference or ratio score of paired spawner abundance data and NORs during the supplementation period should be greater than the pre-supplementation period. For productivity, the mean difference or ratio score during the supplementation period should be equal to or higher than the pre-supplementation period.

As a final set of analyses, we compared the stock-recruitment curves of the supplemented population (using stock and recruitment data only from the supplementation period) to the reference populations (using all available stock and recruitment data). Specifically, we tested whether the regression parameters were equal between the supplemented population and the reference populations, and whether the fitted curves coincided between populations. Here, we were most interested in comparing the productivity parameters in the models.

Surprisingly, these different analyses yielded similar results when they were applied to the Chiwawa spring Chinook and reference population data. Trend analysis was unable to detect a significant difference in trends between the supplemented and reference populations during the supplementation period. Even though we measured an increasing trend in spawner abundance, NORs, and productivity in the supplemented population during the supplementation period, these same parameters trended upward in the reference populations. Likewise, we were unable to detect a significant supplementation effect using difference scores, ratios, and differences in annual changes. However, we found the results from analysis of mean differences of annual change difficult to interpret and they may be insensitive to treatment effects. A simpler analysis, which is also easier to interpret, is to use trend analysis. Finally, comparing stock-recruitment curves and their parameters did not provide strong evidence that supplementation has affected the productivity of the natural population.

Based on these results, we do not recommend using difference scores of annual change (ΔT-ΔR), nor do we recommend comparing stock-recruitment curves and their parameters. As noted above, difference scores of annual change are difficult to interpret and may be redundant with trend analysis. Testing stock-recruitment curves and their parameters appears redundant with testing differences in productivity using difference scores or ratios. In addition, the analyses are computer intensive and do not appear to be very sensitive to changes.

There was little difference in results using difference scores and ratios. It appears that ratios may be more sensitive to change than difference scores (e.g., we found significant differences in some comparisons using ratios but not with difference scores), but ratios can be more difficult to interpret than difference scores. Nevertheless, we recommend the use of ratios in future analyses.

Correcting for Density Dependence and Carrying Capacity

The analyses described so far assumed that the density of spawners or recruits did not affect the survival and productivity of fish. However, without controlling for density effects, productivity of the population would continue to decline with increasing abundance. This scenario could occur in supplementation programs that increase the number of spawners, and could result in lower productivities relative to reference populations. In addition, lower productivities may be caused by differential environmental carrying capacities rather than the capacity of the supplemented fish to produce offspring. Therefore, we described two different methods for deriving density-corrected estimates of productivity. The first controlled the effects of density on productivity by partitioning observed productivities into density-independent and density-dependent productivity. These productivities were then combined in a single test. The second method corrected for differences in carrying capacities between the supplemented and reference populations. This was accomplished

by calculating the percent saturation of NORs, which was estimated as the ratio of observed NORs to the maximum number of NORs that the habitat could support.

We fit Ricker, Beverton-Holt, and smooth hockey stick models to stock and recruitment data to estimate the maximum number of NORs (NORs at carrying capacity) and the maximum number of spawners needed to produce maximum NORs. We fit models to the supplemented and reference populations. Using information-theoretic criterion and evaluating the precision of estimated parameters, we found that the smooth hockey stick model provided the best estimates of maximum NORs and spawners. We used these modeled values to estimate density-independent and density-dependent productivities, and saturation of NORs.

Statistical analyses, using difference scores and ratios of adjusted Chiwawa spring Chinook productivity data, found no significant effects of supplementation on the productivity of the supplemented population. Indeed, the results from correcting for density dependence were similar to those without correcting for density dependence. This is in part because the abundance of the supplemented and reference populations has been below their respective carrying capacities in most years. This was clearly demonstrated in the analyses of NORs corrected for carrying capacity. In the supplemented population, the mean fraction of the carrying capacity filled with NORs decreased significantly during the supplementation period. In other words, the carrying capacity was filled with more NORs during the pre-supplementation period than during the supplementation period, which is contrary to the goal of supplementation. By comparison, two of the reference populations showed a similar decrease in saturation, while the other two reference populations actually increased in saturation. Analyzing the saturation scores using BACI-design analyses indicated that two of the four pairings differed significantly. That is, the percent saturation of the supplemented population decreased significantly relative to two reference populations.

Because productivity can be affected by the abundance of spawners and recruits, we recommend that future analyses comparing supplemented and reference populations adjust for density-dependent effects and differential carrying capacities. Although we detected only slight differences between adjusted and unadjusted results, as supplemented stocks recover, it will become more important to adjust productivities to account for density dependence. Importantly, the analyses using percent saturation placed NORs in the context of the carrying capacity of the environment. This will help managers determine if supplementation programs are filling or over-filling the capacity of the habitat with NORs.

As we noted earlier, analyses using productivities adjusted for density dependence assume that there is a spawner abundance at which density-independent effects end and density-dependent effects begin. In reality, density-dependent effects occur at low spawning abundance and intensify as spawning abundance increases. We did not account for these increasing density-dependent effects at lower spawner abundances. This is an area that needs additional attention.

Analyses without Reference Populations

Because of the rigorous criteria we used to select reference populations, it is likely that reference populations may not exist for making comparisons with supplemented populations. For example, we used the criteria described in this paper to identify reference populations for supplemented steelhead and sockeye populations in the Upper Columbia Basin. We were unsuccessful in identifying any suitable reference populations. Therefore, in the absence of suitable reference populations, it is important to have alternative methods for assessing supplementation effects. We described three different types of analyses one can use to assess supplementation effects in the

absence of reference populations. They include before-after comparisons, correlation analysis, and comparisons to standards.

Before-after analyses compare population metrics before supplementation with those during supplementation. In this case, data collected before supplementation represent the reference condition. The assumption is that population trajectories measured during the pre-supplementation period would continue in the absence of supplementation. We compared trends in spawner abundance, NORs, and productivity before and after supplementation. In addition, we compared mean scores in these three parameters before and after supplementation. Finally, we attempted to compare stock-recruitment parameters before and after supplementation. The hypotheses examined were that the spawner abundance and NORs would be greater during the supplementation period, and that productivities would not decline during the supplementation period.

Trend analysis indicated that the all three Chiwawa spring Chinook population parameters trended downward during the pre-supplementation period, but trended upward during supplementation. On the other hand, mean spawner abundance and NORs were lower during the supplementation period than during the pre-supplementation period. Mean productivities increased, but not significantly, during the supplementation period. We were unable to compare pre- and post-supplementation stock-recruitment curves because we were unable to fit stock-recruitment models to the pre-supplementation data.

We used correlation analyses to determine if the proportion of hatchery-origin fish that spawn naturally on the spawning grounds (pHOS) increased productivity. In addition, we used correlation to assess the association between pHOS and the residuals from stock-recruitment relationships. A significant negative association provides evidence that hatchery-origin spawners may not be as productive as natural-origin spawners. The analysis indicated that the productivity of Chiwawa spring Chinook increased with increasing pHOS, but the association was not significant. In contrast, there was a negative association between pHOS and the stock-recruitment residuals, but again the association was not significant. The latter analysis accounts for density-dependent effects.

In concert, the before-after comparisons and correlation analyses do not provide conclusive evidence that the supplementation program has increased spawner abundance and NORs, or that it has significantly reduced the productivity of the supplemented population. Although increasing the number of hatchery fish on the spawning grounds appears to reduce NORs and productivity, mean productivity actually increased during the supplementation period compared to the pre-supplementation period.

It is important to note that relying on only one set of analysis could result in drawing a wrong conclusion. For example, if we had only conducted trend analysis, we may have concluded wrongly that the Chiwawa spring Chinook supplementation program significantly increased spawner abundance, NORs, and productivity in the supplemented population. The analysis of mean scores and correlations indicates that the supplementation program has not increased spawner abundance or NORs in the supplemented population. Therefore, in the absence of suitable reference populations, we recommend that analyses include the evaluation of trends, means scores, and correlations. By conducting more than one set of analyses, one can use weight-of-evidence to assess the effects of supplementation programs.

Under the scenario that there are no reference populations or pre-supplementation data, one is left with comparing population parameters to relevant standards. These standards could come from mitigation requirements, quantitative objectives, or published or unpublished standards. One could also use correlation to evaluate the association between productivity and pHOS, but this requires a wide range in pHOS values to be most effective. A more extreme approach, which probably would not gain much traction with managers, is to shutoff the supplementation program for some time and then evaluate the effects of the program in a before-after design. The Entiat spring Chinook hatchery program provides a unique opportunity to evaluate this type of management decision.

Some Concerns and Limitations

No matter how hard we try to explain different sources of variation in population data, we are limited by the quality of the data. Teasing out the effects of supplementation requires long time series of population data. Because funding levels and methods change over time, the quality (i.e., accuracy and precision) of the data also changes over time. Importantly, the population parameters examined in this paper (spawner abundance, NORs, and productivity) are rarely measured directly in the field. That is, other population metrics, such as numbers of redds, number of fish counted at weirs or dams, scales, tags, etc., are sampled in the field. These metrics are then used to calculate spawner abundance[22], NORs, and productivity, often based on assumptions about fish/redd, pre-spawning loss, marking rates, and sampling rates. This has a tendency to increase the variability in the data independent of supplementation programs. In our studies, we can only control sampling within the supplemented populations, and even that is limited by available funding. We have no control over the sampling within reference populations. Thus, we have to assume that sampling within the reference populations will continue and that sampling effort will remain comparable to that in the supplemented populations.

In our analyses, we included both the Entiat and Little Wenatchee populations as references for the Chiwawa population. In the analyses, we treated them as equivalent to the other reference populations. That is, the statistical procedures used to compare the supplemented population to each reference population were identical. This is appropriate. However, the interpretation of the results must be different when comparing the Entiat and Little Wenatchee to the supplemented population, because they are populations that were influenced by hatchery fish. As noted earlier, the Entiat spring Chinook hatchery program has been discontinued. Therefore, it provides a unique type of reference where the comparison changes from both populations being supplemented to only one population being supplemented. For the Little Wenatchee, nearly all the strays came from the Chiwawa program. Straying should stop or be greatly reduced with the change in water supply to the Chiwawa Rearing Ponds. In sum, one must be careful in how they interpret these test-reference results.

Finally, it is important to point out that for this paper, we conducted 463 statistical tests. Because we set our Type I error rate at 0.05, by random chance alone, we may have incorrectly rejected about 23 null hypotheses. Inasmuch as this work was designed to evaluate different ways to analyze test-reference data, the number of future analyses will be greatly reduced based on the results from this work. However, if the Type I error rate is a concern to managers, researchers can

[22] The smooth hockey stick model, which we used to estimate density-dependent correction factors for productivity and NORs, is sensitive to errors in spawner escapement estimates. Therefore, it is important to use accurate and precise estimates of spawner escapement.

use a lower error rate, such as α = 0.01. Another option is to analyze test-reference data graphically. Although this is subjective, there are no statistical analyses and therefore no concerns with violating assumptions of statistical tests, including temporal correlation. We believe researchers should use the statistical procedures recommended in this report to support graphic analysis.

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CHELAN AND GRANT PUD HATCHERY PROGRAMS MONITORING AND EVALUATION PROGRESS REPORT AUGUST 2017

August Sampling

Monitoring and evaluation activities during the month of August included monitoring at PIT-tag arrays, juvenile emigration monitoring, juvenile abundance monitoring, fish tagging, spring Chinook spawning surveys, hatchery rearing and spawning activities, broodstock collection, and stock assessments. Monitoring and evaluation activities followed protocols described in Hillman et al. (2013), *Chelan County PUD Hatchery Monitoring and Evaluation Implementation Plan 2016*, and *Grant County PUD Hatchery Monitoring and Evaluation Implementation Plan for Spring and Summer Chinook in the Wenatchee Basin and Summer Chinook in the Methow Basin 2016*.

Juvenile Emigration Monitoring

During the month of August, WDFW operated a rotary smolt trap near the mouth of the Chiwawa River (Chiwawa Trap). WDFW collected biological information including lengths and weights, degree of smoltification, and life-stage characteristics.

Juvenile Abundance Monitoring

During the month of August, BioAnalysts conducted snorkel surveys in the Chiwawa River basin and in sites on Nason Creek and the Little Wenatchee River (reference sites). They counted numbers of all salmonids in randomly selected sites between 31 July and 25 August. All habitat units in the study areas were measured for water surface area and water volume. Results from this work will be presented in a memo to the HCP Hatchery Committees.

PIT-Tagging Activities

WDFW injected PIT tags into juvenile salmon and steelhead captured at the Chiwawa Trap. The goal of the tagging program is to estimate freshwater juvenile productivity, estimate trapping efficiency, better understand the life-history characteristics of salmon and steelhead/rainbow in the Wenatchee River basin, and to estimate SARs.

Spring Chinook Spawning Surveys

During the month of August, Chelan PUD conducted spawning ground surveys for spring Chinook by floating and/or walking streams within the Wenatchee River basin. Surveys were conducted in the

Chiwawa River (including Rock and Chikamin creeks), Nason Creek, Icicle Creek, Upper Wenatchee River (including Chiwaukum Creek), Little Wenatchee River, and the White River (including the Napeequa River and Panther Creek).

Hatchery Rearing and Spawning Activities

WDFW continued to document mortalities, abundance, health, and growth of salmon and steelhead within the hatchery complex. They collected adult summer Chinook and steelhead for the Wenatchee programs, and summer Chinook for the Chelan Falls and Methow programs. They also monitored summer steelhead, summer Chinook, and spring Chinook at Tumwater and Dryden dams as part of stock assessment.

Summary of Information Collected

PIT-Tag Interrogations

Little Wenatchee River PIT-Tag Detection Site—The Little Wenatchee interrogation site operated throughout the month with no interruptions. All antennas are operating at full potential. During August, unique detections included one natural-origin adult spring Chinook, two hatchery-origin adult spring Chinook, three natural-origin juvenile spring Chinook, two hatchery-origin adult sockeye, one unknown-origin adult sockeye, one natural-origin juvenile steelhead, and two bull trout.

White River PIT-Tag Detection Site—The White River interrogation site operated throughout August. WDFW conducted routine maintenance on 29 August to check all system components. They found a malfunction on the downstream row of antennas. Antennas 07-0C remain off until repairs or replacements can be made. Unique detections during August included five natural-origin adult spring Chinook, four hatchery-origin adult spring Chinook, one unknown-origin adult Chinook, one natural-origin adult summer Chinook, one hatchery-origin adult summer Chinook, 24 natural-origin adult sockeye, ten unknown-origin adult sockeye, 19 natural-origin juvenile spring Chinook, one cutthroat trout, three bull trout, and six whitefish.

Juvenile Emigration Monitoring

Chiwawa Trap—The Chiwawa Trap captured 2,027 fish during 31 days of fishing in August (Table 1; Figure 1). Most of the fish captured consisted of spring Chinook (97.2%). Steelhead/rainbow (2.5%) and bull trout (0.3%) made up the remainder of the catch. Based on four trap-efficiency trials, the mean capture efficiency for wild spring Chinook parr was 21.7% (Table 1).

Lower Wenatchee Trap—The Lower Wenatchee Trap was removed at the end of July.

Table 1. Summary of the number of fish trapped, their size (fork length and weight), and trap efficiency for the Chiwawa Trap during 31 days of trapping in August 2017.

Species and life stage	Number of fish collected	Number of fish sampled	Fish Condition		Trap Efficiency			
			Mean length (mm)	Mean weight (g)	Number marked	Number recaptured	Pooled efficiency (%)	Number of trials
Wild Spring Chinook (fry)	4	4	48	1.2				
Wild Spring Chinook (parr)	1,964	1,957	70	3.9	405	88	21.7	4
Wild Spring Chinook (smolt)	0	0						
Wild Spring Chinook (adult)	2	1	560	--				
Hatchery Spring Chinook (smolt)	0	0						
Hatchery Spring Chinook (adult)	0	0						
Wild Steelhead/Rainbow (fry)	7	7	44	1.0				
Wild Steelhead/Rainbow (parr)	26	26	83	9.1				
Wild Steelhead/Rainbow (smolt)	18	18	154	41.1				
Hatchery Steelhead (smolt/trans)	0	0						
Wild Coho (fry)	0	0						
Wild Coho (parr)	0	0						
Wild Coho (smolt)	0	0						
Hatchery Coho (smolt)	0	0						
Wild Sockeye (smolt)	0	0						
Wild Sockeye (adult)	0	0						
Hatchery Sockeye	0	0						
Bull Trout (juvenile)	2	2	276	196.8				
Bull Trout (adult)	4	4	421	381.5				
Pacific Lamprey (ammocoete)	0	0						
Pacific Lamprey (juvenile)	0	0						

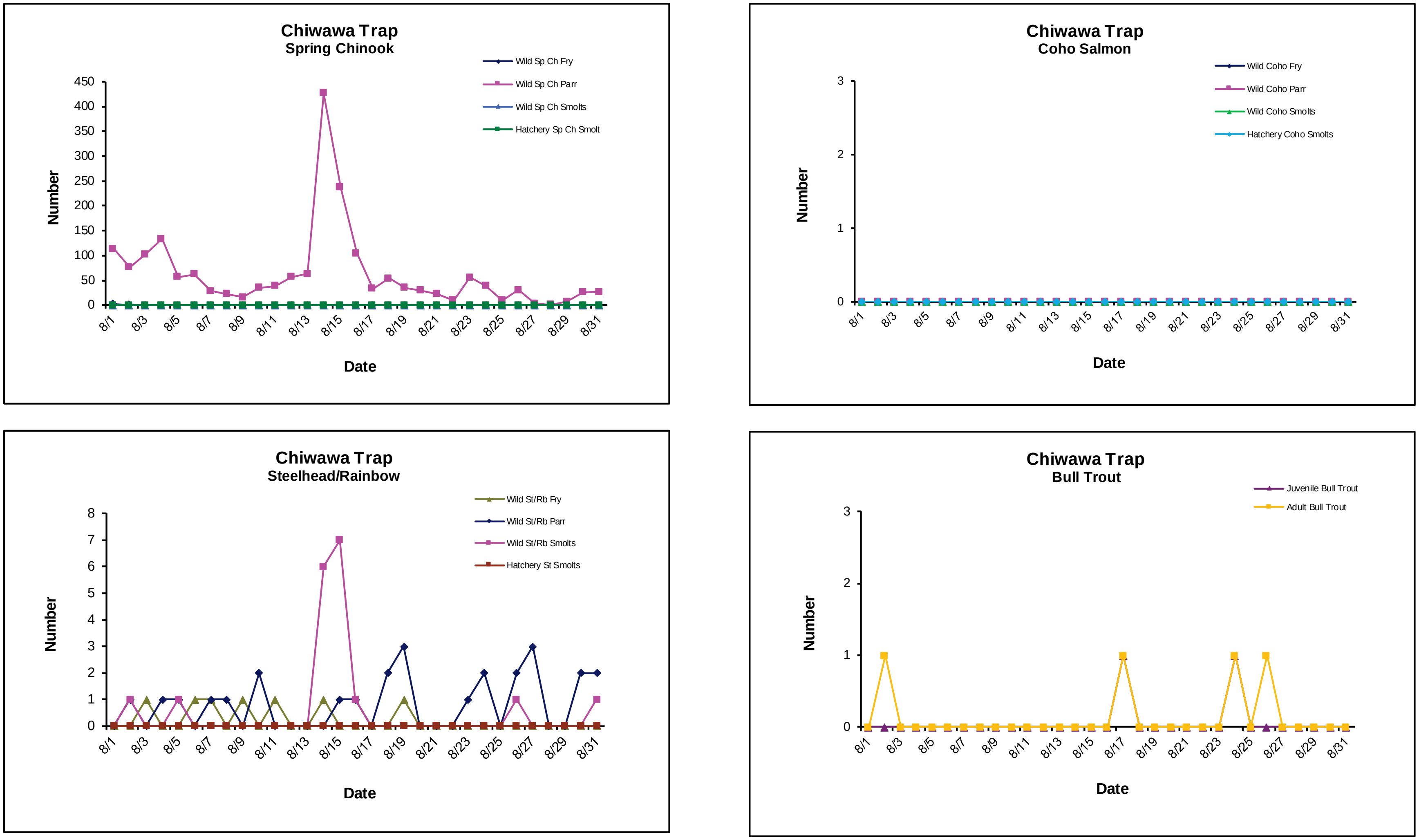

Figure 1. Daily captures of different species and life stages of fish collected in the Chiwawa Trap during August 2017. Note that the scale of the Y-axis differs among graphs.

PIT Tagging Activities

Chiwawa Trap—A total of 1,385 fish were PIT tagged and released at the Chiwawa Trap; 1,350 wild subyearling Chinook, 30 wild steelhead/rainbow, and 5 bull trout (Table 2). Seven wild subyearling Chinook died during trapping. No fish shed their tags during trapping.

Table 2. Summary of the number of fish PIT tagged and released during August 2017.

Sampling Location	Species and Life Stage	Number collected	Number of recaptures	Number tagged	Number died	Shed Tags	Total tagged fish released
Chiwawa Trap	Wild Subyearling Chinook	1,968	120	1,350	7	0	1,350
	Wild Yearling Chinook	0	0	0	0	0	0
	Wild Steelhead/Rainbow	51	1	30	0	0	30
	Hatchery Steelhead/Rainbow	0	0	0	0	0	0
	Wild Coho	0	0	0	0	0	0
	Bull Trout	5	0	5	0	0	5
	Total	**2,024**	**121**	**1,385**	**7**	**0**	**1,385**

The cumulative numbers of fish tagged and released in 2017 are shown in Table 3. In addition, the numbers of fish that died or shed tags are identified in the table. Percent mortality during tagging has been less than 1.5%.

Table 3. Summary of the cumulative number of fish PIT tagged in 2017.

Sampling Location	Species and Life Stage	Number collected	Number of recaptures	Number tagged	Number died	Shed Tags	Total tagged fish released	Percent mortality
Chiwawa Trap	Wild Subyearling Chinook	6,466	222	2,260	16	0	2,260	0.25
	Wild Yearling Chinook	5,823	187	5,711	14	0	5,711	0.24
	Wild Steelhead/Rainbow	801	2	702	1	0	702	0.12
	Hatchery Steelhead/Rainbow	3,840	0	0	1	0	0	0.03
	Wild Coho	0	0	0	0	0	0	0.00
	Total	**16,930**	**411**	**8,673**	**32**	**0**	**8,673**	**0.19**
Lower Wenatchee Trap	Wild Subyearling Chinook	46,806	60	0	360	0	168	0.77
	Wild Yearling Chinook	1,334	9	1,222	7	0	1,222	0.52
	Wild Steelhead/Rainbow	163	0	105	2	0	105	1.23
	Hatchery Steelhead/Rainbow	336	0	0	1	0	0	0.30
	Wild Coho	701	0	0	3	0	0	0.43
	Wild Sockeye	1,045	0	967	4	0	967	0.38
	Total	**50,385**	**69**	**2,294**	**377**	**0**	**2,462**	**0.75**
Total:	**Wild Subyearling Chinook**	53,272	282	2,260	376	0	2,428	0.71

Sampling Location	Species and Life Stage	Number collected	Number of recaptures	Number tagged	Number died	Shed Tags	Total tagged fish released	Percent mortality
	Wild Yearling Chinook	7,157	196	6,933	21	0	6,933	0.29
	Wild Steelhead/Rainbow	964	2	807	3	0	807	0.31
	Hatchery Steelhead/Rainbow	4,176	0	0	2	0	0	0.05
	Wild Coho	701	0	0	3	0	0	0.43
	Wild Sockeye	1,045	0	967	4	0	967	0.38
Grand Total:		**67,315**	**480**	**10,967**	**409**	**0**	**11,135**	**0.61**

Spring Chinook Spawning Surveys

Redd Surveys—Spawning ground surveys for spring Chinook were conducted in the Chiwawa River (including Rock and Chikamin creeks), Nason Creek, Icicle Creek, Upper Wenatchee River, Little Wenatchee River, and the White River (including the Napeequa River and Panther Creek). During the month of August (and the end of July), 191 spring Chinook redds were counted in the Wenatchee River basin. Most of these were observed in the Chiwawa River (127 redds) (Figure 2). Nason Creek had 41 redds (21%), Icicle Creek had 20 redds (10%), the Little Wenatchee had two redds (1%), and the Wenatchee River had one redd. No redds were observed in the White River. Peshastin Creek will be surveyed during the end of the survey period.

Carcass Surveys—A total of 14 spring Chinook carcasses were sampled during spawning surveys in August in the Wenatchee River basin. Most of the carcasses were sampled in Nason Creek (43% or 6 carcasses) and Icicle Creek (36% or 5 carcasses) (Figure 2). Three carcasses were sampled in the Chiwawa River. No carcasses were sampled in the upper Wenatchee, White, or Little Wenatchee rivers in August.

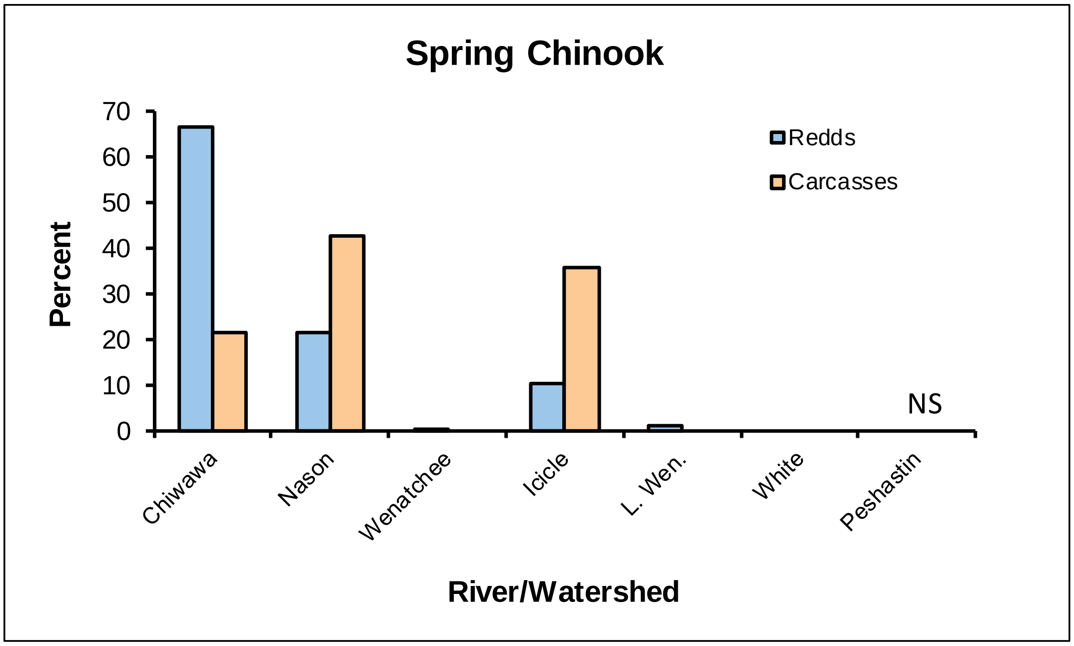

Figure 2. Percent of the total number of spring Chinook redds counted and carcasses sampled in different streams/watersheds within the Wenatchee River basin during August 2017. NS = not sampled.

Hatchery Rearing Activities

2016 Brood Chiwawa Spring Chinook— About 131,176 WxW spring Chinook were present at Eastbank Fish Hatchery at the end of August. A total of 21 fish died during the month. Fish examinations conducted in August indicated no significant health condition. There are no fish health recommendations at this time. Growth information collected during the month is summarized in Table 4.

About 28,317 HxH spring Chinook were present at Eastbank Fish Hatchery at the end of August. A total of 25 fish died during the month. Fish examinations conducted in August indicated no significant health condition. There are no fish health recommendations at this time. Growth information collected during the month is summarized in Table 4.

2016 Brood Nason Spring Chinook—About 158,988 WxW spring Chinook were present at Eastbank Fish Hatchery at the end of August. A total of 65 fish died during the month. Fish examinations conducted in August indicated no significant health condition. There are no fish health recommendations at this time. Growth information collected during the month is summarized in Table 4.

Because of surplus production, 41,263 HxH spring Chinook were released into Banks Lake on 3 August. With a loss of 36 fish during the month, this leaves about 76,135 HxH spring Chinook at Eastbank Fish Hatchery at the end of August.[1] Fish examinations conducted in August indicated no significant health

[1] The production goal for the Nason Spring Chinook program is 125,000 WxW and 98,760 HxH. Because of high fecundity and in-hatchery survival, there was an over production of both WxW and HxH Chinook. To maximize the

condition. There are no fish health recommendations at this time. Growth information collected during the month is summarized in Table 4.

2016 Brood Wenatchee Summer Chinook—About 513,520 summer Chinook were present at Eastbank Fish Hatchery at the end of August. A total of 696 fish died during August. Fish examinations conducted in August indicated no significant health condition. There are no fish health recommendations at this time. Growth information collected during the month is summarized in Table 4.

2016 Brood Methow (Carlton) Summer Chinook—About 215,366 summer Chinook were present at Eastbank Fish Hatchery at the end of August. A total of 425 fish died during August. There was an adjustment of -4,574 after coded-wire tagging. Fish examinations conducted in August indicated no significant health condition. There are no fish health recommendations at this time. Growth information collected during the month is summarized in Table 4.

2016 Brood Chelan Falls Summer Chinook—About 607,465 summer Chinook were present at Eastbank Fish Hatchery at the end of August. A total of 1,160 fish died during August. There was an adjustment of -1,033 after coded-wire tagging. Fish examinations conducted in August indicated no significant health condition. There are no fish health recommendations at this time. Growth information collected during the month is summarized in Table 4.

2017 Brood Wenatchee Summer Steelhead—About 149,561 WxW steelhead were present at the Chelan Fish Hatchery at the end of August. A total of 562 steelhead died during the month. Fish examinations conducted in August indicated no significant health condition. There are no fish health recommendations at this time. Growth information collected during the month is summarized in Table 4.

About 174,174 HxH steelhead were present at Eastbank Fish Hatchery at the end of August. A total of 403 steelhead died during the month. Fish examinations conducted in August indicated no significant health condition. There are no fish health recommendations at this time. Growth information collected during the month is summarized in Table 4.

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use of wild progeny in the program, the WxW fish were marked up to about 105% of the conservation program goal, and the rest of the WxW were retained and marked as though they were HxH (i.e., ad-clip+cwt). The HxH fish were then marked until about 105% of the safety net program goal was achieved (inclusive of the overage of WxW fish). Any remaining HxH progeny were considered surplus and planted into Banks Lake. Thus, there are 27,462 Chinook from WxW parents that are marked as if they are HxH (ad-clip+cwt).

Table 4. Growth data collected from 2016 and 2017 brood salmon and steelhead in August 2017; SD = standard deviation; CV = coefficient of variation.

Program Location - Pond	Sample size	Fork Length (mm)			Weight (g)			Condition Factor (K)	Fish per pound
		Mean	SD	CV	Mean	SD	CV		
2016 Brood									
Chiwawa Spring Chinook- Mixed WxW and HxH									
Eastbank – P12	100	113.1	9.2	8.1	17.5	3.6	20.6	1.20	26
Nason Creek Spring Chinook-WxW									
Eastbank – P2	100	95.6	6.8	7.2	11.4	2.8	24.0	1.29	40
Eastbank – P6	100	92.3	5.8	6.3	10.2	2.5	24.6	1.28	44
Nason Creek Spring Chinook-HxH									
Eastbank – P8	100	94.6	7.2	7.7	11.2	3.1	27.7	1.30	40
Methow Summer Chinook- WxW									
Eastbank – P3	100	85.3	4.9	5.7	7.6	1.3	17.3	1.21	60
Eastbank – P4	100	87.2	4.7	5.4	7.7	1.2	16.1	1.16	59
Eastbank – P5	100	84.9	4.9	5.7	7.7	1.3	16.5	1.25	59
Chelan Falls Summer Chinook- HxH									
Eastbank – P9	100	83.5	4.4	5.3	7.0	1.2	17.4	1.20	65
Eastbank – P10A	100	80.5	4.7	5.8	5.8	1.1	18.1	1.10	78
Eastbank – P10B	100	82.8	4.0	4.9	7.1	1.0	14.6	1.25	64
Wenatchee Summer Chinook- WxW									
Eastbank – R1	100	72.6	3.7	5.2	4.4	0.7	14.9	1.15	103
Eastbank – R2	100	72.5	3.0	4.2	4.4	0.6	14.8	1.14	104
Eastbank – P13	100	70.7	4.2	5.9	4.2	0.8	20.0	1.18	108
2017 Brood									
Wenatchee Summer Steelhead – WxW									
Chelan – RW1	100	89.9	9.4	10.5	9.1	3.0	33.2	1.21	50
Chelan – RW2	100	81.8	7.3	8.9	6.7	1.9	28.1	1.19	68
Chelan – RW3	100	72.7	6.4	8.8	4.6	1.4	30.1	1.16	99
Wenatchee Summer Steelhead – HxH									
Eastbank – P1	100	62.8	5.6	8.8	3.2	0.8	25.5	1.27	144

Hatchery Broodstock Collection and Spawning

2017 Brood Chiwawa Spring Chinook—WDFW began trapping Chiwawa spring Chinook at Tumwater Dam on 5 June and at the Chiwawa Weir on 11 August. Trapping concluded on 2 August. WDFW began spawning Chiwawa spring Chinook on 31 July. A total of 18 females have been spawned resulting in an egg take of 83,106 eggs (56,225 natural-origin eggs and 68,881 hatchery-origin eggs). No adult Chinook have died.

2017 Brood Nason Creek Spring Chinook—WDFW began trapping Nason Creek spring Chinook at Tumwater Dam on 5 June and concluded on 21 July. They began spawning spring Chinook on 31 July. A total of 22 females have been spawned resulting in an egg take of 100,427 eggs (62,901 natural-origin eggs and 37,526 hatchery-origin eggs). Two adult Chinook have died.

2017 Brood Wenatchee Summer Chinook—WDFW began trapping Wenatchee summer Chinook at Dryden Dam on 27 June and they also collected summer Chinook at Tumwater Dam on 18 and 19 August. Trapping concluded on 17 August. A total of 257 natural-origin summer Chinook (128 females and 129 males) were collected and transferred to Eastbank Hatchery. This equates to an estimated egg take of 581,171 eggs. Five adult Chinook have died.

2017 Brood Chelan Falls Summer Chinook—WDFW began trapping Chelan Falls summer Chinook at the Chelan Falls Canal Trap on 21 July. Trapping concluded on 21 August. A total of 327 hatchery-origin summer Chinook (154 females and 173 males) were collected and transferred to Eastbank Hatchery. In addition, eight hatchery-origin summer Chinook were collected at the Entiat National Fish Hatchery on 30 August. In sum, this equates to an estimated egg take of 663,736 eggs. Nine adult Chinook have died.

2018 Brood Wenatchee Summer Steelhead—WDFW began trapping Wenatchee summer steelhead at Dryden and Tumwater dams on 3 July. A total of 14 hatchery-origin steelhead (8 females and 6 males) and 20 natural-origin steelhead (11 females and 9 males) have been collected and transferred to Eastbank Hatchery. This equates to an estimated egg take of 55,481 eggs from natural-origin fish and 36,878 eggs from hatchery-origin fish. No adult steelhead have died.

Trapping Operations at Dams

Tumwater Dam—WDFW began trapping at Tumwater Dam on 4 April. Beginning on 13 July, trapping operations at Tumwater Dam were limited to five days a week (total of 40 hours per week) and the ladder was opened during nights and weekends to minimize delays in sockeye salmon passage. During the month of August, 16 adult spring Chinook were counted at the dam. Of these, eight hatchery-origin jacks were surplused according to adult management protocols. In addition, a total of 88 steelhead were sampled at the dam in August. Of these, 66 steelhead (17 natural-origin, 12 hatchery-origin, and 37 unknown-origin fish) were released upstream and 22 steelhead were collected for broodstock. Lastly, 598 summer Chinook and 1,529 sockeye were observed at the dam.

Dryden Dam—WDFW began trapping at Dryden Dam on 27 June. During August, catch consisted of 325 summer Chinook, 13 spring Chinook, 99 sockeye salmon, and 29 steelhead. Most summer Chinook and steelhead were sampled, PIT tagged, and either retained for broodstock or released back to the river.

Wells Dam—WDFW began trapping summer Chinook at Wells Dam (West Ladder) on 3 July. During August, 25 natural-origin summer Chinook (12 females and 13 males) were collected for broodstock and 115 fish (31 natural-origin and 84 hatchery-origin Chinook) were sampled and released. Most of the fish released were PIT-tagged.

Stock Assessment

Wenatchee Summer Steelhead—WDFW sampled 88 summer steelhead at Tumwater Dam during August; 18 hatchery, 33 wild, and 37 unknown-origin steelhead (Table 5). Six wild and 16 hatchery steelhead were retained for broodstock; the remainder were measured and released back to the river.

In addition, WDFW sampled 29 steelhead at Dryden Dam during August; 11 hatchery and 18 wild steelhead (Table 6). Seven hatchery steelhead were retained for broodstock. The others were measured and released back to the river.

Table 5. Numbers of adult Wenatchee summer steelhead sampled at Tumwater Dam in August 2017 for broodstock collection and stock assessment.

Stock	Location	Date	Broodstock		Sampled & released			Surplused
			Hatchery	Wild	Hatchery	Wild	Unknown	
Wenatchee summer steelhead	Tumwater Dam	8/1	0	0	0	3	1	0
		8/2	0	2	0	0	0	0
		8/3	0	0	0	1	5	0
		8/4	0	0	0	1	0	0
		8/5	0	0	1	0	3	0
		8/6	0	0	0	0	2	0
		8/7	0	0	0	0	3	0
		8/8	0	0	3	2	2	0
		8/9	0	0	1	3	1	0
		8/10	0	0	0	0	0	0
		8/11	1	0	0	0	3	0
		8/12	0	0	0	0	5	0
		8/13	0	0	1	0	4	0
		8/14	0	1	0	0	2	0
		8/15	0	1	0	0	1	0
		8/16	0	0	0	2	0	0
		8/17	0	0	1	0	2	0
		8/18	1	0	0	0	1	0
		8/19	0	0	0	0	0	0
		8/20	0	0	0	0	1	0
		8/21	0	1	0	1	1	0
		8/22	0	1	0	1	0	0
		8/23	0	0	1	2	0	0
		8/24	1	0	0	1	0	0
		8/25	0	2	0	0	0	0
		8/26	0	2	3	0	0	0
		8/27	0	0	1	0	0	0
		8/28	0	2	0	0	0	0
		8/29	3	2	0	0	0	0
		8/30	0	0	0	0	0	0
		8/31	0	2	0	0	0	0
		Total	**6**	**16**	**12**	**17**	**37**	**0**

Table 6. Numbers of adult Wenatchee summer steelhead sampled at Dryden Dam in August 2017 for broodstock collection and stock assessment.

Stock	Location	Date	Broodstock		Sampled & released		Surplused
			Hatchery	Wild	Hatchery	Wild	
Wenatchee summer steelhead	Dryden Dam	8/1	0	0	0	2	0
		8/2	0	0	0	0	0
		8/3	0	0	0	0	0
		8/4	0	0	1	0	0
		8/5					
		8/6					
		8/7	0	0	0	0	0
		8/8	0	0	1	2	0
		8/9	1	0	0	1	0
		8/10	0	0	0	2	0
		8/11	0	0	0	1	0
		8/12					
		8/13					
		8/14	0	0	0	0	0
		8/15	0	0	0	0	0
		8/16	0	0	0	1	0
		8/17	1	0	0	1	0
		8/18	1	0	0	1	0
		8/19					
		8/20					
		8/21	0	0	0	2	0
		8/22	1	0	1	3	0
		8/23	1	0	0	1	0
		8/24	0	0	0	0	0
		8/25	0	0	0	1	0
		8/26					
		8/27					
		8/28	1	0	0	0	0
		8/29	0	0	0	0	0
		8/30	0	0	1	0	0
		8/31	1	0	0	0	0
		Total	**7**	**0**	**4**	**18**	**0**

Summer Chinook—WDFW sampled 598 summer Chinook at Tumwater Dam in August; 11 hatchery and 587 wild summer Chinook (Table 7). All were sampled and released back to the river. In addition, WDFW sampled 197 summer Chinook (77 hatchery and 120 wild Chinook) at Dryden Dam during August (Table 8). A total of 30 wild summer Chinook were retained for broodstock. The remainder were sampled and released back to the river. WDFW also sampled 309 summer Chinook (303 hatchery and 6 wild Chinook) at the Chelan Falls Canal (Table 9). Of these, 214 hatchery fish were retained for broodstock. Finally, WDFW sampled 119 summer Chinook at Wells Dam (72 hatchery and 47 wild fish) (Table 10). Of these, 21 wild fish were retained for broodstock. The remaining fish were sampled and released back to the river.

Table 7. Numbers of adult Wenatchee summer Chinook sampled at Tumwater Dam in August 2017 for broodstock collection and stock assessment.

Stock	Location	Date	Broodstock		Sampled & released	
			Hatchery	Wild	Hatchery	Wild
Wenatchee summer Chinook	Tumwater Dam	8/1	0	0	0	43
		8/2	0	0	0	53
		8/3	0	0	1	22
		8/4	0	0	0	38
		8/5	0	0	2	93
		8/6	0	0	2	30
		8/7	0	0	0	48
		8/8	0	0	1	39
		8/9	0	0	1	41
		8/10	0	0	0	33
		8/11	0	0	1	32
		8/12	0	0	0	21
		8/13	0	0	0	11
		8/14	0	0	0	14
		8/15	0	0	0	2
		8/16	0	0	0	3
		8/17	0	0	0	9
		8/18	0	0	0	5
		8/19	0	0	0	2
		8/20	0	0	0	3
		8/21	0	0	1	1
		8/22	0	0	0	4
		8/23	0	0	0	8
		8/24	0	0	0	11
		8/25	0	0	0	4
		8/26	0	0	0	0
		8/27	0	0	0	3
		8/28	0	0	2	3
		8/29	0	0	0	6
		8/30	0	0	0	2
		8/31	0	0	0	3
		Total	**0**	**0**	**11**	**587**

Table 8. Numbers of adult Wenatchee summer Chinook sampled at Dryden Dam in August 2017 for broodstock collection and stock assessment.

Stock	Location	Date	Broodstock		Sampled & released	
			Hatchery	Wild	Hatchery	Wild
Wenatchee summer Chinook	Dryden Dam (Right and Left Banks)	8/1	0	6	10	7
		8/2	0	6	3	4
		8/3	0	0	6	7
		8/4	0	0	6	9
		8/5				
		8/6				
		8/7	0	5	4	3
		8/8	0	4	3	3
		8/9	0	1	9	5
		8/10	0	0	9	8
		8/11	0	0	4	11
		8/12				
		8/13				
		8/14	0	3	3	0
		8/15	0	4	2	1
		8/16	0	0	0	1
		8/17	0	1	2	7
		8/18	0	0	3	8
		8/19				
		8/20				
		8/21	0	0	3	4
		8/22	0	0	0	3
		8/23	0	0	1	3
		8/24	0	0	1	2
		8/25	0	0	2	1
		8/26				
		8/27				
		8/28	0	0	3	0
		8/29	0	0	0	4
		8/30	0	0	3	1
		8/31	0	0	0	0
		Total	**0**	**30**	**77**	**90**

Table 9. Numbers of adult summer Chinook sampled at the Chelan Falls Canal in August 2017 for broodstock collection and stock assessment.

Stock	Location	Date	Broodstock		Sampled & released	
			Hatchery	Wild	Hatchery	Wild
Summer Chinook	Chelan Falls Canal	8/1				
		8/2	4	0	3	0
		8/3				
		8/4	8	0	1	0
		8/5				
		8/6				
		8/7	123	0	3	0
		8/8	33	0	0	0
		8/9	7	0	10	2
		8/10				
		8/11	9	0	20	0
		8/12				
		8/13				
		8/14	7	0	14	0
		8/15	12	0	10	3
		8/16	5	0	7	0
		8/17	2	0	4	1
		8/18	0	0	5	0
		8/19				
		8/20				
		8/21	4	0	12	0
		8/22				
		8/23				
		8/24				
		8/25				
		8/26				
		8/27				
		8/28				
		8/29				
		8/30				
		8/31				
		Total	**214**	**0**	**89**	**6**

Table 10. Numbers of adult summer Chinook sampled at Wells Dam in August 2017 for broodstock collection and stock assessment.

Stock	Location	Date	Broodstock		Sampled & released	
			Hatchery	Wild	Hatchery	Wild
Summer Chinook	Wells Dam (West Ladder)	8/1	0	0	5	3
		8/2	0	0	6	3
		8/3				
		8/4				
		8/5				
		8/6				
		8/7				
		8/8	0	5	13	3
		8/9	0	3	12	3
		8/10				
		8/11				
		8/12				
		8/13				
		8/14	0	3	12	1
		8/15	0	4	4	2
		8/16				
		8/17				
		8/18				
		8/19				
		8/20				
		8/21	0	2	11	4
		8/22	0	3	7	6
		8/23				
		8/24				
		8/25				
		8/26				
		8/27				
		8/28	0	1	2	1
		8/29	0	1	4	1
		8/30	0	3	8	4
		8/31				
		Total	**0**	**21**	**72**	**26**

Spring Chinook—WDFW sampled six spring Chinook (5 hatchery and 1 wild Chinook) at the Chiwawa Weir in August (Table 11). The wild Chinook was retained for broodstock. The remaining fish were sampled and released back to the river. In addition, WDFW collected 16 spring Chinook at Tumwater Dam during August (Table 12). Of these, eight were surplused (hatchery jacks) and the remaining spring Chinook (3 hatchery, 4 wild, and 1 unknown-origin Chinook) were sampled and released back to the river.

Table 11. Numbers of adult Chiwawa spring Chinook sampled at the Chiwawa Weir in August 2017 for broodstock collection and stock assessment.

Stock	Location	Date	Broodstock		Sampled & released		Surplused
			Hatchery	Wild	Hatchery	Wild	
Spring Chinook	Chiwawa Weir	8/1					
		8/2	0	1	5	0	0
		8/3					
		8/4					
		8/5					
		8/6					
		8/7					
		8/8					
		8/9					
		8/10					
		8/11					
		8/12					
		8/13					
		8/14					
		8/15					
		8/16					
		8/17					
		8/18					
		8/19					
		8/20					
		8/21					
		8/22					
		8/23					
		8/24					
		8/25					
		8/26					
		8/27					
		8/28					
		8/29					
		8/30					
		8/31					
		Total	**0**	**1**	**5**	**0**	**0**

Table 12. Numbers of adult spring Chinook sampled at Tumwater Dam in August 2017 for broodstock collection and stock assessment.

Stock	Location	Date	Broodstock		Sampled & released			Surplused
			Hatchery	Wild	Hatchery	Wild	Unknown	
Spring Chinook	Tumwater Dam	8/1	0	0	0	0	0	0
		8/2	0	0	0	1	0	3
		8/3	0	0	0	2	0	1
		8/4	0	0	0	0	1	0
		8/5	0	0	2	0	0	0
		8/6	0	0	0	0	0	0
		8/7	0	0	0	0	0	1
		8/8	0	0	0	0	0	0
		8/9	0	0	0	1	0	0
		8/10	0	0	0	0	0	0
		8/11	0	0	0	0	0	0
		8/12	0	0	0	0	0	0
		8/13	0	0	0	0	0	0
		8/14	0	0	0	0	0	0
		8/15	0	0	0	0	0	0
		8/16	0	0	1	0	0	2
		8/17	0	0	0	0	0	0
		8/18	0	0	0	0	0	0
		8/19	0	0	0	0	0	0
		8/20	0	0	0	0	0	0
		8/21	0	0	0	0	0	0
		8/22	0	0	0	0	0	0
		8/23	0	0	0	0	0	0
		8/24	0	0	0	0	0	0
		8/25	0	0	0	0	0	1
		8/26	0	0	0	0	0	0
		8/27	0	0	0	0	0	0
		8/28	0	0	0	0	0	0
		8/29	0	0	0	0	0	0
		8/30	0	0	0	0	0	0
		8/31	0	0	0	0	0	0
		Total	**0**	**0**	**3**	**4**	**1**	**8**

FINAL

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ANCHOR QEA

Memorandum

To:	Wells, Rocky Reach, and Rock Island HCP Hatchery Committees	Date: November 16, 2017
From:	Tracy Hillman, HCP Hatchery Committees Chairman	
cc:	Sarah Montgomery, Anchor QEA, LLC	
Re:	**Final Minutes of the October 18, 2017 HCP Hatchery Committees Meeting**	

The Wells, Rocky Reach, and Rock Island Hydroelectric Projects Habitat Conservation Plan (HCP) Hatchery Committees meeting was held at the Grant PUD office in Wenatchee, Washington, on Wednesday, October 18, 2017, from 9:00 a.m. to 12:15 p.m. Attendees are listed in Attachment A to these meeting minutes.

Action Item Summary

- Andrew Murdoch (Washington Department of Fish and Wildlife [WDFW]) will write an overview of proposed expanded sampling at the off-ladder fish trap (OLAFT) at Priest Rapids Dam (Item I-A). *(Note: this item is ongoing.)*
- Mike Tonseth will coordinate with Todd Seamons (WDFW) to produce an outline or recommended approach for genetic monitoring (Item I-A). *(Note: this item is ongoing.)*
- Kirk Truscott will discuss internally and coordinate with Keely Murdoch on potential edits to Chelan PUD's Draft Statement of Agreement (SOA) Regarding District's Coho Obligation (Item I-A). *(Note: this item is ongoing.)*
- Sarah Montgomery and Mike Tonseth will coordinate to revise and finalize the September 20, 2017 Hatchery Committees meeting minutes (Item I-A). *(Note: Tonseth provided revisions and Montgomery distributed the final version on October 19, 2017.)*
- Sarah Montgomery will distribute Barry Berejikian's (Northwest Fisheries Science Center [NWFSC]) presentation, "Potential to improve the conservation benefits of steelhead hatcheries," to the Hatchery Committees (Item II-C). *(Note: Montgomery distributed the presentation on October 19, 2017.)*
- Bill Gale, Matt Cooper, Charlie Snow (WDFW), Tom Kahler, and Greg Mackey will develop management alternatives for the Twisp River and Winthrop National Fish Hatchery (NFH) steelhead programs (Item II-C).
- Sarah Montgomery will notify the Hatchery Committees that the Draft Monitoring and Evaluation Plan for PUD Hatchery Programs (2017 Update) will be a decision item at the Hatchery Committees November 15, 2017 meeting (Item III-C). *(Note: Montgomery notified the*

Hatchery Committees on October 19, 2017, and this item is also described below in "Review Items".)

- Tracy Hillman will distribute the draft timelines for Wenatchee and Methow spring Chinook salmon programs for Hatchery Committees review (Item III-D). *(Note: Hillman sent the timelines to Montgomery, who forwarded them to the Hatchery Committees on October 18, 2017.)*

Decision Summary

- There were no decisions approved during today's meeting.

Agreements

- There were no agreements discussed during today's meeting.

Review Items

- Sarah Montgomery sent an email to the Rocky Reach and Rock Island Hatchery Committees on August 15, 2017, notifying them that the Chelan PUD Draft SOA Regarding District's Coho Obligation is available for a 30-day review, with comments due to Catherine Willard by September 14, 2017. Chelan PUD indicated they will request approval of the SOA at the Hatchery Committees September 20, 2017 meeting. *(Note: this item will be discussed at the November 15, 2017 Hatchery Committees meeting.)*
- Sarah Montgomery sent an email to the Hatchery Committees on October 16, 2017, notifying them that the draft plan, *Implementation of Comprehensive Monitoring and Evaluation of Wells Hatchery Complex Programs in 2018*, is available for review with edits and comments due to Greg Mackey by December 1, 2017.
- Sarah Montgomery sent an email to the Hatchery Committees on October 19, 2017, notifying them that the Draft M&E Plan for PUD Hatchery Programs (2017 Update) is available for review and will be a decision item at the November 15, 2017 Hatchery Committees meeting.

Finalized Documents

- Sarah Montgomery sent an email to the Hatchery Committees on September 15, 2017, notifying them the Chelan PUD and Grant PUD 2016 Final M&E Annual Report and Appendices are now available for download from the Hatchery Committees Extranet site.
- Sarah Montgomery sent an email to the Hatchery Committees on October 24, 2017, notifying them the Chelan PUD 2018 Hatchery Monitoring and Evaluation Implementation Plan

(approved on August 18, 2017) is available for download from the Hatchery Committees Extranet site.

I. Welcome

A. Review Agenda, Review Last Meeting Action Items, and Approve the September 20, 2017 Meeting Minutes (Tracy Hillman)

Tracy Hillman welcomed the Hatchery Committees and asked for any additions or changes to the agenda. None were requested.

The Hatchery Committees representatives reviewed the revised draft September 20, 2017 meeting minutes. Sarah Montgomery said there are a few outstanding comments, and representatives revised the meeting minutes. Hatchery Committees representatives present conditionally approved the draft September 20, 2017 meeting minutes, pending further clarification from Mike Tonseth. (Note: Tonseth revised the minutes, and Montgomery distributed the final approved version on October 19, 2017.)

Action items from the Hatchery Committees meeting on September 20, 2017, and follow-up discussions were addressed *(note: italicized text below corresponds to agenda items from the meeting on September 20, 2017)*:

- *Andrew Murdoch (Washington Department of Fish and Wildlife [WDFW]) will write an overview of proposed expanded sampling at the off-ladder fish trap (OLAFT) at Priest Rapids Dam (Item I-A).*
  This item is ongoing.
- *Mike Tonseth will coordinate with Todd Seamons (WDFW) to produce an outline or recommended approach for genetic monitoring (Item I-A*).
  This item is ongoing.
- *Tracy Hillman will distribute the Upper Columbia Salmon Recovery Board's (UCSRB) discussion draft Hatchery Report to the Hatchery Committees when he receives it (Item I-A).*
  Hillman sent the report to Montgomery, who distributed it to the Hatchery Committees on October 13, 2017.
- *Tracy Hillman will invite Greer Maier (UCSRB) to an upcoming Hatchery Committees meeting to discuss the Hatchery Report (Item I-A).*
  Maier plans to attend the November 15, 2017 Hatchery Committees meeting.
- *Kirk Truscott will discuss internally and coordinate with Keely Murdoch on potential edits to Chelan PUD's Draft Statement of Agreement Regarding the District's Coho Obligation (Item II-A).*

Keely Murdoch said Yakama Nation (YN) and Colville Confederated Tribes (CCT) have met, and Truscott will be discussing this further internally. Mike Tonseth asked when the current agreement expires. Catherine Willard said the agreement expires in October 2017, but a signed agreement is likely not needed until production occurs in 2018.

- *Tom Kahler will send Douglas PUD's Transition Plan Outline to Sarah Montgomery for distribution to the Hatchery Committees (Item III-A).*
  Montgomery distributed the outline following the meeting on September 20, 2017.
- *Douglas PUD will provide their Transition Plan to the Hatchery Committees for review (Item III-A).*
  Tom Kahler sent the plan to Sarah Montgomery, which she forwarded to the Hatchery Committees on October 16, 2017.
- *Hatchery Committees representatives will review the revised Monitoring and Evaluation (M&E) Plan for PUD Hatchery Programs and discuss it during the October 18, 2017 Hatchery Committees meeting (Item IV-D).*
  Sarah Montgomery distributed the latest version of the plan on October 10, 2017, and this item will be discussed today.
- *Tracy Hillman will invite Barry Berejikian (Northwest Fisheries Science Center) to the October 18, 2017 Hatchery Committees meeting to discuss steelhead in the Twisp River (Item V-A).*
  Berejikian is present today for this discussion.

II. Douglas PUD

A. Draft 2018 M&E Implementation Plan (Greg Mackey)

Greg Mackey said the draft plan, *Implementation of Comprehensive Monitoring and Evaluation of Wells Hatchery Complex Programs in 2018*, is available for Hatchery Committees review. Mackey shared the plan (Attachment B), which Sarah Montgomery distributed to the Hatchery Committees on October 16, 2017. Mackey said Douglas PUD requests comments by December 1, 2017, to finalize the contract for M&E by January 1, 2018. He said the plan is nearly identical to the previous year, with the following exceptions:

- The Okanogan Safety-Net and Omak Creek Conservation programs are now reported on by Grant PUD (contracted to BioAnalysts) and therefore will not be reported by Douglas PUD to prevent reporting the same results in two reports.
- Language was changed in various sections to improve clarity.

Greg Mackey said the plan includes pilot studies, such as the Twisp River juvenile population estimate study. He said continued implementation of the pilot studies will be determined based on analysis of the approach and results, which Douglas PUD will be working on this winter.

B. Wells Transition Plan (Tom Kahler)

Greg Mackey shared the document, *Draft Transition Plan for Wells and Methow Fish Hatcheries* (Attachment C), which Sarah Montgomery distributed to the Hatchery Committees on September 16, 2017. He said since the last Hatchery Committees meeting, Douglas PUD has been working with WDFW to develop the plan and has also drafted an internal version of the plan with contractual information, internal strategy, and other details. He said Douglas PUD expects more edits from WDFW, but in the meantime wanted to distribute a version to the Committee for review. Tom Kahler said he was hoping the group could discuss WDFW's edits today, but Douglas PUD has not received them yet. He said Douglas PUD and WDFW are working together and coordinating via point people for the transition.

Mackey said the Transition Plan is available for review and requested comments as soon as possible. He said Douglas PUD has hired managers for the Methow Fish Hatchery and Wells Fish Hatchery, and has interviewed candidates for the remaining jobs with offers being made soon. Bill Gale asked if Douglas PUD will hire a Doctor of Veterinary Medicine, and Mackey said Douglas PUD hopes to, but has not confirmed anyone for that position yet.

Tracy Hillman asked if the transition is still planned to occur within a 90-day period. Mackey said yes, but if some tasks require a longer transition time an extension of time for such tasks may be negotiated with WDFW as needed. He said extensions will occur on a case-by-case basis, but there is no plan to employ a blanket extension for the transition. Kahler said so far Douglas PUD expects the transition to be completed in 90 days, by the end of the contract on November 28, 2017.

Gale said he has two comments regarding the Transition Plan. He said at U.S. Fish and Wildlife Service (USFWS) fish hatcheries, maintenance staff are identified separately from fish culture staff, and hatchery maintenance expectations are detailed for both groups. Gale suggested that Douglas PUD include information about maintenance responsibilities for the staff that will be maintaining the hatcheries so no maintenance tasks are left undone. Mackey said a landscaping company and cleaning staff will perform some of the maintenance duties in addition to hatchery staff, and more information can be included in the plan based on hatchery staff job descriptions.

Gale said the plan also includes some discussion about coordination with USFWS regarding adult management. He suggested that coordination between Methow Fish Hatchery and Winthrop NFH be clearly identified, especially regarding spring Chinook salmon and steelhead broodstocking. Mackey said this information can be added under the hatchery supervisor's job description. Mike Tonseth said those details should also be included in the Broodstock Collection Protocols. Gale added he did not see the Broodstock Collection Protocols mentioned in the Transition Plan. Kahler said the Broodstock Collection Protocols are listed in the Transition Plan. Tonseth said the plan should identify how coordination between the hatcheries is laid out and agreed-to. Gale said the Transition Plan is not intended to be a hatchery operations plan. Rather, it is a guiding document for the transition. Gale said for that reason, the plan should at least include a discussion on coordination and how it will be developed. Mackey thanked Gale for his suggestions and encouraged representatives present to review and provide any comments on the plan as soon as possible.

C. Steelhead Presentation and Discussion of Twisp Steelhead Program (Berejikian/Kahler)

Tracy Hillman welcomed Barry Berejikian and said Berejikian has prepared a presentation about his work on steelhead in Hood Canal and a discussion about the Twisp steelhead program will follow the presentation. Berejikian shared the presentation, "Potential to improve the conservation benefits of steelhead hatcheries" (Attachment D), and said the Hood Canal steelhead project has many willing partners such as non-profits and state, tribal and federal governmental entities including the USFWS and NWFSC. He said he has also worked on a project at Winthrop NFH, and those data will be discussed along with the Twisp program. A summary of the presentation and questions and comments are included in the following sections.

Introduction (slides 1-4)

Berejikian said the presentation will include approaches for egg collection, and rearing and release for small steelhead programs similar to the Twisp program. Effects on abundance and genetic diversity, and alternative rearing strategies to improve smolt performance and reduce domestication selection will also be discussed. Lastly, Berejikian said he will talk about developing practical and flexible rearing strategies for conservation and supplementation programs.

To increase diversity, the Hood Canal steelhead project uses hydraulic sampling to extract eggs from redds, thus natural-origin adults are not handled. This project includes captive rearing and release of age-2 (S2) smolts, and the project monitors effects on abundance and genetic diversity of the natural population.

Hydraulic redd sampling (slides 5-8)

Hydraulic extraction of eggs from redds is an alternative to artificial spawning in hatcheries. It includes identifying redds, marking them, triangulating the redds so they can be found again, then using a hydraulic water pump, cage, and seine to work the redd and collect eggs. Collection goals change as spawning progresses, and this type of sampling allows for sampling the downstream part of a redd and leaving an upstream section undisturbed.

Hydraulic redd sampling produces high proportions of viable eggs (0.93), fish that survive to ponding (0.94), and productive redds (0.76). Berejikian said producing eyed embryos is not a limiting factor. Hydraulic sampling in this study also produced greater genetic diversity among offspring produced than what would be estimated by artificial spawning.

In the Hamma Hamma River, redds were hydraulically sampled and fish were reared and released at age-2. Genetic results of the study show that steelhead mating patterns are complex, females produce on average 1-2 redds, and males service multiple redds.

Keely Murdoch asked if Berejikian has studied the impacts to the remaining eggs in a redd after hydraulic sampling has removed some of the eggs. Berejikian said he does not think there are effects to remaining embryos after hydraulic sampling occurs because a spawning channel study at Manchester Research Station with Chinook salmon measured the egg-to-fry survival of remaining eggs to be about 70%. Greg Mackey asked how many egg pockets on average do steelhead create in one redd. Berejikian said between 6 and 8 on average. Bill Gale asked if female steelhead spawn with different males when they construct a second redd. Berejikian said males can be territorial and follow females to different redds, but it varies and ends up being a combination of the same and different males.

Berejikian said hydraulic sampling works better in rain-driven systems than snow-driven systems (like the Methow basin) due to water-level changes during spring. Todd Pearsons asked about the Chinook salmon spawning channel study—are there significant differences in redd construction that would be affected differently by hydraulic pumping? Berejikian said redd construction for the two species is similar, and Chinook salmon dig deeper redds and cover their redds more entirely.

<u>Hood Canal project, smolting and rearing (slides 9-24)</u>

The Hood Canal steelhead project includes three facilities, which produced varied numbers of smolts and adults for release. Variation between hatcheries was one potential cause of difference in smolt quality. Murdoch asked if the adult release groups were fully grown steelhead, or if they resembled rainbow trout. Berejikian said those fish were about 520 millimeters long, which is smaller than a natural steelhead, but male maturation was not generally observed until age-3. Berejikian said some of the fish were kept in freshwater, and the Skokomish group of fish was transitioned to seawater before being raised to maturity. Size data are not available yet, but the project will look at the effects of early growth history, and differences in water type on growth, maturation, survival, and reproductive success to inform hatchery planning discussions. Pearsons asked what the project did with females that matured at age 3. Berejikian said those females were stripped of eggs and held to age-4 to live-spawn.

The Hamma Hamma and Duckabush groups raised at Lilliwaup Hatchery had downstream and early marine survival rates on par with wild fish, while the Skokomish fish raised at McKernan Hatchery had lower survival rates. Density and vessel shape at the hatchery were likely major contributors to the variation in downstream and early marine survival rates.

Numbers of redds in supplemented rivers (slide 14) increased once supplementation began in 2011. Pearsons asked if redd counts include adult outplants. Berejikian said yes. In the Hamma Hamma River, for example, redd counts increased during supplementation from 2002 to 2009. Genetic diversity improved during and after supplementation in the Hamma Hamma River. Allelic richness did not change, heterozygosity increased slightly, and effective population size increased. Berejikian surmised that the addition of more anadromous steelhead spawners may have attracted more natural spawners. Berejikian summarized that conservation programs can increase natural spawning in the short-term and in the generation after supplementation.

Berejikian said fitness loss in steelhead can be genetically or epigenetically heritable and discussed the potential causes for fitness loss.

Berejikian summarized the effects of rearing steelhead to age-2 smolt. Smolting is a threshold trait in steelhead, and hatchery and wild fish vary in their approximate age of smoltification.

<u>Winthrop NFH (slides 25-29)</u>

Berejikian is also working with Winthrop NFH to study how size and age affect migratory performance of steelhead. He said S2 fish travel faster no matter their size. Body size at release explained most of the differences in downstream survival between S1 and S2 smolts. Volitional releases resulted in faster out-migration rates than forced releases, and volitionally released migrants were larger and had higher survival than forced release migrants.

<u>Heritability and body size (slides 30-36)</u>

Berejikian said one study at Manchester Research Station focused on whether heritable size-selective mortality can be avoided, and the study looked at growth rate and body size at smoltification. S1 fish in this study (with smaller fork lengths) had higher seawater mortality than S2 fish (larger fork lengths). There is more heritability in body size with S1 fish than S2 fish, and heritability has a greater affect while fish are younger. Body size and mass varies among families, and mean family body size is correlated with survival.

Pros and cons of S2 programs (slides 37-49)

Berejikian said one negative effect of S2 programs is greater precocious maturation in males than in S1 smolts. He said not all hatcheries should implement S2 programs, but more flexible strategies can be designed for S2 programs. For example, a size sorting experiment shows that growth rate is determined early in life, and early growth rate influences size at smolting. By sorting steelhead in the fall and splitting fish into two groups, an S1 and S2 group can be produced from the same broodstock. He said this is a more proactive approach than trying to grow an S1 or S2 group, and reacting when fish grow too big or too small. Berejikian said programs can take advantage of the current size of fish and propensity to feed in order to sort fish by size and produce higher quality smolts.

Questions and comments

Mackey said one way to make fish self-sort is to place a rack with bar spacing in the raceways, and only small fish can move to the other side of the rack. He said this allows stocking small fish as parr; however, there are some handling issues with this approach.

Gale asked when Berejikian will have more data on juveniles transferred from Winthrop NFH that are segregated. Berejikian said he will have more information in spring 2018, and he will know how the S1s performed. After that, data on S2s will also be available.

Catherine Willard asked why the study sorts juvenile fish at 8 weeks. Berejikian said with previous sorting efforts, research shows size variation at that stage carries through the rearing process. He said the Hood Canal program had success sorting first in October, and again in March for the S2 program. He said sorting twice might be challenging for a large production hatchery.

Pearsons asked if these study results correspond to relative reproductive success (RRS) results. Berejikian said there is no direct comparison between those types of studies. Pearsons asked if there are results from the Hood Canal studies that support RRS studies. Barry responded that it is difficult to compare studies, but since the program started, the effective size of the wild population has increased almost linearly in Hood River (he referred to Table 3 in Christie et al. 2012). He commented that they (Christie et al.) concluded that there was a large Ryman-Laikre effect, but he thinks the data show the opposite effect. Results need to be evaluated in context with abundance and productivity information.

The Twisp Steelhead Program

Tom Kahler said this discussion will inform the future of the Twisp program, and said the Hatchery Committees should carefully consider a wide range of alternatives. He said Berejikian is knowledgeable about issues affecting the Twisp program, and Kahler asked him to attend today to provide input on the future of the program. Mackey summarized the steelhead programs in the Methow basin and said Douglas PUD operates the Twisp program, which uses wild-by-wild brood collected in the Twisp River. He said fish from this program are released in the Twisp River as S1s, and the Winthrop NFH program releases S2s. He said the Hatchery Committees have been discussing the potential to combine the programs, and need to collectively decide how to rear and release the 248,000 conservation fish available. Gale added that the discussion is about steelhead conservation programs in the Methow basin, not just the Twisp River, and some decisions about the programs will need to be made soon.

Gale said Winthrop NFH has one group of steelhead that could be released in the Twisp River in spring 2018, and a consensus needs to be reached about how, when, and where to release these fish. He said the Hatchery Committees also need to discuss whether and how to composite the programs before broodstock is collected. He said longer-term decisions include how to mix age-at-release groups throughout the basin, and whether to transition to a phase where different release strategies are used.

Kahler said an additional item of concern is that not many families are represented in the Twisp steelhead program, so what is the best way to increase genetic diversity without mining wild stock? Mike Tonseth said the relative reproductive success study in the Twisp River indicated that there may be a Ryman-Laikre effect occurring in this population. Tonseth asked if negative genetic effects are occurring, what is the best way to improve the situation? Tonseth said the Twisp Weir only provides access to about half of the steelhead population in the Twisp River due to its location, limiting genetic diversity in broodstock collected at that location. He said an additional piece to consider is that the relatedness of individuals being collected at the Weir is unknown, and understanding the relatedness may also guide discussions moving forward.

Kahler asked if YN has tried partially live-spawning steelhead. Murdoch said no, but the Columbia River Inter-tribal Fish Commission staff may have information about that from their kelt reconditioning programs. Berejikian said he is not aware of any programs using partial live-spawning, but it was discussed as an option for the Tucannon River. Murdoch said in order to partially live-spawn fish, post-release survival and success would have to be studied. She said after being partially spawned and released, female fish would have to select a site and partner before continuing to spawn. Gale asked if partially spawning male fish would help genetic diversity. Murdoch said she does not think that would increase diversity. Tonseth said it would be similar to using reconditioned kelt. Murdoch agreed and said reconditioned kelt spawn in a subsequent year outside of the hatchery, which increases lifetime fecundity, but does not provide more diversity to the hatchery program.

Gale said there are many possible options for the future of the Twisp and Winthrop NFH programs, and the first decisions should focus on whether to composite broodstock. If the programs are not going to be composited, options are more limited. This first decision will set the stage for future decisions. Murdoch said combining programs should be considered as an option so that there are more overall options available to discuss. She said keeping the Twisp program separate may not be a viable option because there are signs of a Ryman-Laikre effect occurring, which is a concern for the future of natural fish. She said the genetic issues occurring in the Twisp River are exacerbated because it is a subset of the population. She said because it is not a unique spawning aggregate, combining the programs is not necessarily a "composite" approach because they are not genetically distinct. She said implementing hydraulic redd sampling to improve diversity would be difficult in the Twisp River because of spawn timing. Eggs are in the gravel by June, which is also peak runoff for the system, and high water and flow levels would likely prevent access to redds for sampling. She said another concern with using hydraulic sampling for the Twisp program is that it is a mitigation program, not a research program. She said removing eyed eggs from natural-origin fish that are in the wild may not even meet the mitigation requirement. She said with in-gravel mortality, and an eye-up rate likely lower than in hatcheries, it would require much effort for maybe not enough eggs. She said there is also likely less impact on the population overall by collecting adults rather than eggs to meet the mitigation number. She said she favors combining broodstock for the Twisp and Winthrop programs, and releasing fish in the Twisp River and other areas could be part of a comprehensive reworking of steelhead supplementation in the Methow basin.

Tonseth said the hydraulic approach likely will not work in the Methow basin because it is a snow-fed system. Even if it were attempted though, he said there is uncertainty about additional take associated with hydraulically removing eggs from redds, and it may be difficult to permit. He said assessing the permitting feasibility as well as the physical feasibility of different options should be considered as discussions move forward. Gale said one positive aspect of sampling directly from redds is that it allows natural mate choice and redd site selection. He said using spawning channels may be a substitute to redd sampling in the natural environment, and has been successful at Winthrop NFH. He said if, as a group, the Hatchery Committees think that natural mate selection and sorting are important program components, using spawning channels could be a viable way to achieve those priorities. Mackey asked if using spawning channels is a feasible way to achieve the production levels needed for the Twisp program. Gale said more broodstock would probably be needed, and Tonseth said it would require collecting nearly 100% of the eggs produced in the channels.

Gale said he is not opposed to combining the programs, and said he is not too alarmed by the Ryman-Laikre effects occurring in the Twisp River. He said if the Twisp program were kept separate from the Winthrop NFH program, one option would be to take adults from the 48,000 fish Twisp program to Methow Fish Hatchery to spawn, and then remove a percentage of the fish that are smallest and use them in a 2-year program at Methow Fish Hatchery. The other fish would then be sent to Wells Fish Hatchery for release into the Twisp River. Gale said a 2-year program at Methow Fish Hatchery would add an additional brood year each year to the basin.

Tonseth said assessing the relatedness of adults being collected for broodstock in the Twisp River would still be helpful to determine how many families are represented. Murdoch said the Weir might pick up a small proportion of the families in the river. Tonseth said even by adding diversity with factorial mating at the hatchery, there might not be enough diversity to increase the effective population size. Tonseth said hook-and-line broodstock collection might be one way to increase genetic diversity. Mackey said the genetic [relatedness] distance between fish could be used to determine a mating scheme for fish. Gale said another option for increasing diversity is releasing 1- and 2-year old fish in the Twisp River for a few years, then changing the release location and rotating a mixed-smolt-age release group of fish throughout the basin.

Mackey said there are some additional factors to consider when assessing whether to combine broodstock. He said there may be no genetic difference detected between the Twisp River and other areas, but there could be a difference that was not detected. He said there may be selective pressures effecting local adaptation in the Twisp River that, by combining programs, would be precluded. Murdoch said at a larger scale, keeping the Methow population separate from the Okanogan population provides opportunity for local adaptation. Mackey said genetic diversity is not necessarily a step-wise process; if diversity can be increased immediately with local adaptation, it should not be precluded. He said separate spawning aggregates are identified as part of recovery for steelhead. Tonseth said the recovery criteria look at the distinct population segment (DPS) level, and do not identify individual spawning aggregates. He said current actions should focus on DPS-level diversity criteria. Murdoch said local adaptation is important, but in this case, there may be greater concerns for diversity at a higher level. Mackey said a small population with closely related individuals that are more fit for that envorinment could quickly amplify genetic adaptation to the local environment, and local adaptation should be considered as alternatives are developed. He said a do-no-harm approach could include managing the Methow basin as one population, so if severe bottlenecking is occurring in the Twisp River, it could be mitigated by the rest of the population. He said assessing the Twisp River in isolation is not entirely appropriate for determining whether a Ryman-Laikre effect is occurring. He said if there is genetic divergance in the Twisp River it should not be precluded from continuing; homogenizing the population could even be a greater threat to recovery than a perceived Ryman-Laikre effect. Tonseth said he does not necessarily advocate homogenizing the populations. Mackey said he advocates diversification.

Gale said one option is to combine broodstocks and have mixed-age release groups spread into different areas over time. He said that way, after the release into the Twisp River is stopped, for example, the natural population can adapt locally. He said a basin-wide perspective should include a 20-year plan that all parties agree to.

Hillman said that within-population structure and diversity is a requirement for recovery within the Upper Columbia Recovery Plan. He said this is assessed at the population scale, and the Plan requires steelhead spawning within certain spawning areas or tributaries. He asked if the National Marine Fisheries Service (NMFS) has in the past weighed in on whether spawning aggregates can be combined. Murdoch said NMFS previously indicated that this would be okay, and included language for that possibility in the draft Methow steelhead BiOp.

Hillman asked for volunteers to start drafting management alternatives for steelhead in the Methow basin, so it will be easier to discuss this with NMFS and to inform Broodstock Collection Protocols. USFWS and Douglas PUD representatives volunteered to continue this discussion and develop alternatives. Gale said he, Matt Cooper, Charlie Snow, Kahler, and Mackey will develop management alternatives for the Twisp River and Winthrop NFH steelhead programs.

Berejikian said coming up with a list of alternatives is a good plan. Regarding the uncertainty about a Ryman-Laikre effect occurring with Twisp River steelhead, he asked what the trend is, and suggested fully understanding the effects and variables then checking with Craig Busack (NMFS) about intended approaches to address the issues. He said there is an opportunity to consider multiple combined approaches. He said, for example, spawning channels have been mentioned. He said in his own study, the number of fry acquired from one channel (35,000 to 40,000 fry) was nearly equal to the fecundity of the female fish put into the channel, in one out of two channels used in the study. Tonseth suggested testing the spawning channel approach using hatchery fish before putting wild broodstock in it. He also asked what the genetic effects would be if one male fertilizes multiple redds in the spawning channel. Berejikian said he has data he could share with the group on the numbers of males and females placed into the channels in his study, their individual relative reproductive success, and effective population size. Tonseth said those data could help determine if using spawning channels would improve genetic diversity. Berejikian summarized that there are many tradeoffs to consider when thinking about the future of steelhead programs in the Methow basin.

Tonseth asked if a one-year smolt can be produced from a spawning channel. Berejikian said yes, and also suggested working with the WDFW regional office to coordinate on fish health issues. Pearsons asked if there were any fish health issues with using spawning channels in Berejikian's studies. Berejikian said no, because in the Hood Canal study, adults are not handled. The study takes eyed eggs from the natural environment and puts them into a quarantine system. Mackey said in his previous work in the northeast United States, he collected parr by electrofishing natural spawning areas. He said electrofishing has been used in the Twisp River to collect age-0 fish (parr) in September. He said collecting fry could help improve genetic diversity. Tonseth said electrofishing for fry would hopefully result in a mix of families, and Mackey said it can be performed throughout the whole river in contrast to using the Twisp Weir, which only collects a subset of the population. Mackey noted that it would be difficult or impossible to collect an entire program this way. Berejikian said one program in Oregon was collecting juvenile steelhead, and they had skewed sex ratios, disease issues in the hatchery, and eventually switched to an egg collection approach due to successful egg collection in other programs. Representatives present thanked Berejikian for his presentation and input.

III.Joint HCP-HC/PRCC HSC

A. NMFS Consultation Update (Emi Kondo)

Emi Kondo provided an update on consultation for the unlisted programs in the upper Columbia River. She said she requested an initiation of consultation from Chelan PUD, Grant PUD, and WDFW, which would serve as their official request to NMFS to begin consultation. Bill Gale asked if the parties sent a letter initiating consultation when they submitted Hatchery and Genetic Management Plans (HGMPs). Kondo said HGMPs were submitted in 2010, and recalculation for No Net Impact occurred since then, so it is appropriate for the PUDs to submit initiation requests for current programs. She said Chelan PUD and Grant PUD should submit requests, but Douglas PUD should not, as their program has not changed since the HGMPs were submitted. Deanne Pavlik-Kunkle (Grant PUD) said Grant PUD is drafting their request. Kondo said the next step after NMFS receives requests is to respond with a letter of sufficiency. Regarding the Biological Opinion (BiOp) for the unlisted programs, Kondo said the draft will be finished soon and will go to internal review, then comanager review.

B. USFWS Bull Trout Consultation Update (Matt Cooper)

Matt Cooper said Karl Halupka provided him an update on USFWS bull trout consultations, which he summarized as follows:

- Halupka is working to get the BiOp for the batch of Wenatchee subbasin programs signed this week.
- USFWS is continuing regular coordination with NMFS (Emi Kondo and Charlene Hurst) and Mike Tonseth on the Methow steelhead consultation, the consultation for the batch of hatchery programs for unlisted Chinook salmon stocks in the Columbia River, and reinitiation

of Mitchell Act consultation for the Ringold fall Chinook salmon program with the U.S. Army Corps of Engineers. NMFS may initiate consultation on the upper Columbia batch next week.

- USFWS completed expedited consultation on Nason Creek Acclimation Facility intake maintenance and are discussing consultation options for covering future intake maintenance with NMFS and Grant PUD.

Todd Pearsons asked if the signed BiOp for the batch of Wenatchee subbasin programs will be distributed to all Hatchery Committees and PRCC HSC parties. Tonseth said National Oceanic and Atmospheric Administration (NOAA) is the action agency and is consulting with USFWS, so the signed BiOp will be directly transmitted to NOAA and the applicants will likely also be notified. Tonseth said he heard that comments are still being incorporated into the BiOp, and may not be signed this week.

C. M&E Plan for PUD Hatchery Programs 2017 Update (Hillman)

Tracy Hillman said he revised the M&E Plan for PUD Hatchery Programs to reflect changes discussed during the September 20, 2017 Hatchery Committees meeting and distributed it (Attachment E). Hillman reviewed the new information in Section 7.2 (Non-target Taxa of Concern), and Section 8 (Adaptive Management).

He said he also added Appendix 1, Estimation of Carrying Capacity, which Andrew Murdoch (WDFW) is reviewing. Hillman defined two types of carrying capacity as follows:

- Population equilibrium capacity—the maximum number or biomass of a species that can occur based on density dependent mechanisms that reduce population growth rates as population size increases
- Habitat capacity—the maximum number or biomass of a species that habitat can support

He said the appendix includes an example of how carrying capacity is estimated for spring Chinook salmon in the Chiwawa River watershed and the entire Wenatchee River basin. He described methods for assessing density dependence in juvenile spring Chinook salmon and described the importance of having large contrast in spawner abundances in identifying the presence of density dependence and estimating carrying capacity. Keely Murdoch asked if there is a way to discuss the geospatial component to capacity related to the graphs in Appendix 1. She said spring Chinook salmon in the Chiwawa River watershed are a hatchery-driven population, and in years with big escapement, the proportion of hatchery origin spawners is very high. She added that the reproductive success study shows unequal spawner distributions, and a reduction in productivity (parr production) is related to distribution. Hillman agreed and indicated that calculation of habitat capacity, which is based on fish-habitat data and not just fish data, which are used to estimate population equilibrium capacity, should not be affected by hatchery production within the watershed. He said he calculated both habitat and population equilibrium capacities and compared those results in the appendix. Hillman then described the different models used to calculate carrying capacity and their associated assumptions. He said capacity estimates can be standardized by dividing the estimates by watershed area, intrinsic potential, or other watershed-scale metrics. This allows comparisons among different basins or watersheds.

Hillman said for spring Chinook salmon in the Chiwawa River, models produced a range of estimates for parr and smolt capacities. He said the smolt capacity estimates are about half of the parr capacity estimates, and these estimates can be extrapolated to the entire Wenatchee River basin using intrinsic potential. He then compared extrapolated capacity estimates based on intrinsic potential to actual capacity estimates based on data collected at the lower Wenatchee smolt trap. The actual and extrapolated estimates did not differ greatly.

Hillman also reviewed the calculation of habitat capacity using a fish-habitat model (Quantile Regression Forest Model) and using quantile regression to estimate the 90% reference interval for the stock-recruitment functions. He then compared results from all the different models. Todd Pearsons asked why there is a difference in number of spawners needed to reach parr habitat capacity between the Chiwawa River and Wenatchee River. Hillman said the Chiwawa River has higher quality habitat, so one unit of intrinsic potential in the Chiwawa produces more fish than say a unit of intrinsic potential in another area within the Wenatchee.

Hillman suggested that the Hatchery Committees review the recommendations included in Appendix 1. He said one item not included in the appendix is if abundance and productivity data should be normalized using population equilibrium capacity estimates or habitat capacity estimates. Catherine Willard suggested providing the estimate with associated levels of error. Hillman said appendices in annual reports provide error bars for stock-recruitment data, and the Chiwawa River data have less error in their estimates than other areas. Hillman said another item that will need to be decided is how to calculate carrying capacity for summer Chinook salmon.

Pearsons said in order for this document to be useful to the Independent Scientific Advisory Board (ISAB), the Hatchery Committees and PRCC HSC should try to approve it in November 2017. He said the ISAB hopes to finish their assessment by December 2017, but may continue into 2018. Hillman asked representatives present if approving this document in November would be reasonable, and they agreed. Sarah Montgomery said she will distribute the draft again as a decision item for the November 15, 2017 Hatchery Committees meeting.

D. Timeline of Changes in Spring Chinook Salmon Programs (Tracy Hillman)

Tracy Hillman said he drafted timelines for the Wenatchee and Methow spring Chinook salmon programs to determine interruptions for statistical analysis. Hillman shared a document, *Draft Hatchery Program Timelines* (Attachment F), and representatives present reviewed the timelines.

Hillman said he reviewed reports, permitting documents, and other items and picked events or changes he thought might interrupt the time series in a statistically important way. He requested that the Hatchery Committees review the timelines and suggest additions. Catherine Willard said these timelines might also be useful to the ISAB, and suggested adding adult management to the timeline. Keely Murdoch asked if the timelines should just have hatchery program information, or should also include other effects to populations. Hillman said as a minimum, the timelines should include anything that would potentially affect statistical analyses. Todd Pearsons agreed and suggested making a timeline with all suggested events as the first step. Mike Tonseth said the Hatchery Committees should compile one set of timelines with all suggested events, then a subset of timelines including just the major events to be used for statistical analysis. Pearsons suggested checking the timeline included in the UCSRB's Draft Hatchery Report for comparison. Hillman said he did this and found some discrepancies between his version and the draft report. In one example, Matt Cooper explained the difference is due to stating the brood year a hatchery program began, as opposed to the release year. Hillman summarized that the Hatchery Committees will review the timelines, and provide comments and suggestions to him via email. He said he will distribute the draft timelines for review.

IV. HCP Administration

A. Next Meetings

The next Hatchery Committees meetings are on November 15, 2017 (Grant PUD), December 20, 2017 (TBD), and January 17, 2018 (Grant PUD).

V. List of Attachments

Attachment A List of Attendees
Attachment B Implementation of Comprehensive Monitoring and Evaluation of Wells Hatchery Complex Programs in 2018 - Draft
Attachment C Draft Transition Plan for Wells and Methow Fish Hatcheries
Attachment D Potential to improve the conservation benefits of steelhead hatcheries
Attachment E Draft 2017 Update - M&E Plan for PUD Hatchery Programs
Attachment F Draft Hatchery Program Timelines

Attachment A
List of Attendees

Name	Organization
Tracy Hillman	BioAnalysts, Inc.
Sarah Montgomery	Anchor QEA, LLC
Catherine Willard*	Chelan PUD
Greg Mackey*	Douglas PUD
Tom Kahler*	Douglas PUD
Todd Pearsons‡	Grant PUD
Peter Graf‡	Grant PUD
Deanne Pavlik-Kunkel‡	Grant PUD
Mike Tonseth*	Washington Department of Fish and Wildlife
Alf Haukenes†	Washington Department of Fish and Wildlife
Matt Cooper*	U.S. Fish and Wildlife Service
Bill Gale*	U.S. Fish and Wildlife Service
Michael Humling†	U.S. Fish and Wildlife Service
Chris Pasley†	U.S. Fish and Wildlife Service
Emi Kondo†	National Marine Fisheries Service
Barry Berejikian	Northwest Fisheries Science Center
Keely Murdoch*	Yakama Nation

Notes:
* Denotes Hatchery Committees member or alternate
† Joined by phone
‡ Joined for the joint HCP-HC/PRCC HSC discussion

EXHIBIT A

SCOPE OF WORK

IMPLEMENTATION OF COMPREHENSIVE MONITORING AND EVALUATION OF WELLS HATCHERY COMPLEX PROGRAMS IN 2018

Greg Mackey - Douglas County PUD

Todd Pearsons - Grant County PUD

Catherine Willard - Chelan County PUD

Charlie Snow

Alf Haukenes

Methow Research Team

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September 2017

Introduction

The contractor for the M&E Implementation Plan will conduct the field work, data collection, and data management. Reporting will be a collaborative effort between the contractor, Douglas PUD, Grant PUD, and Chelan PUD.

The Douglas County PUD and Grant County PUD Monitoring and Evaluation Plans (M&E Plan; Wells HCP Hatchery Committee 2007) described eight objectives specific to the hatchery programs funded by Douglas County PUD, Grant County PUD, and Chelan County PUD, and two regional objectives that were related to artificial propagation in general. These objectives were designed to address key questions regarding the use of supplementation as mitigation for unavoidable mortality associated with the operation of the Wells Hydroelectric Project (Douglas PUD), the Priest Rapids Hydroelectric Project (Grant PUD), and Rock Island and Rocky Reach hydroelectric projects (Chelan PUD). In 2013, these M&E Plans were reviewed and updated (Hillman et al. 2013) to reflect shifting management paradigms and to incorporate data collection and analysis from the first five years of hatchery program monitoring (Murdoch et al. 2012) conducted under the original M&E Plans. The updated M&E Plan (hereafter referred to as the M&E Plan) contains ten objectives specific to hatchery programs funded by PUDs and two regional objectives. One regional objective has been completed and the other is not planned to be addressed. The primary focus of this plan is assessment of the first ten objectives outlined in the M&E Plan.

Successful implementation of the M&E Plan requires relationships between the PUDs, M&E contractor, and other entities conducting similar field work in the Upper Columbia River Basin. Certain objectives require the collection of data from both target populations and non-target populations, such as reference populations. This proposal does not include field activities conducted by other entities to collect data for reference non-target populations required to implement the M&E Plan.

Addressing all the objectives within the M&E Plan requires multiple years of data collection. This is year five under the 2013 update of the M&E Plan and year thirteen of the plan under the HCP. Objectives 5, 7, 8, and 10 are designed to be addressed after one year or five years (Table 1), and may require only periodic monitoring. Statistical analyses will be conducted consistent with the M&E Plan, revisions thereof, or the 5-year M&E report (Murdoch et al. 2012) as applicable. A revised schedule and definition of M&E reports was recently approved by the hatchery committees. This approved schedule formalizes and supercedes previous schedules. The Implementation Plan is formatted such that species, programs, and the associated M&E Objectives are presented in separate sections that are subdivided into modules to clearly define actions under the M&E Plan and allow flexibility in administering budgets.

Table 1. A potential long-term implementation schedule of objectives outlined in the PUD M&E Plan. The HCP HCs/PRCC HSC may change the M&E plan, its objectives, and implementation in future years. Monitoring and evaluation of hatchery programs in years prior to the 6-9 year period have been completed and are included here for reference only. The work conducted within this proposal would be implementation year thirteen.

Objective	Year of implementation									
	1-4	5	6-9	10	11-14	15	16-19	20	21-24	25
1	X	X	X	X	X	X	X	X	X	X
2	X	X	X	X	X	X	X	X	X	X
3	X	X	X	X	X	X	X	X	X	X
4	X	X	X	X	X	X	X	X	X	X
5	X	X		X		X		X		X
6	X	X	X	X	X	X	X	X	X	X
7	X				X				X	
8	X				X				X	
9	X	X	X	X	X	X	X	X	X	X
10	X	X		X		X		X		X

This plan encompasses one year of work to implement the updated Monitoring and Evaluation Plan for PUD Hatchery Programs operated at the Wells Hatchery and Methow Hatchery, as described in the work plan, below.

2017 M&E Work Plan by Species, Programs, and Activities

Summer Steelhead

Module 1: In-Hatchery Metrics – Steelhead

Required to meet:

Objective 3: Determine if the hatchery adult-to-adult survival (i.e., hatchery replacement rate, HRR) is greater than the natural adult-to-adult survival (i.e., natural replacement rate, NRR) and the target hatchery survival rate.

Objective 8: Determine if hatchery programs have caused changes in phenotypic characteristics of natural populations.

Objective 9: Determine if hatchery fish were released at the programmed size and number.

Biological data for origin, sex, age, size, fecundity, and survival of broodstock will be recorded for all steelhead hatchery programs: Twisp Conservation, Methow Safety-Net, and Columbia Safety-Net. (The Okanogan Safety-Net, Omak Creek Conservation programs are now reported on separately by Grant PUD.) Number of fish, stage-specific survivals, size, coefficient of variation, condition factor, and fish health issues will be recorded. An annual review of size, number and supporting statistics of fish from each program will be compared to those values defined in the M&E Plan Appendix 6, or adjusted values agreed to by the Wells HCP Hatchery Committee. Values within acceptable precision (i.e., +/-10% of HCP defined values) will constitute achievement of program objectives. Failure to achieve release targets will trigger evaluation to determine probable causation and recommendations, when necessary, for improving performance.

Hatchery personnel will assess fecundity of spawned females when fertilized eggs are at the eyed stage, and will provide data to evaluation staff. To assess overall egg mass, we will collect total egg weight samples just after removal from lethally-spawned females, and will record the weight of female fish after egg removal.

Module 2: Steelhead Adult Stock Assessment

Required to meet:

Objective 1: Determine if conservation programs have increased the number of naturally spawning and naturally produced adults of the target population and if the program has reduced the natural replacement rate (NRR) of the supplemented population.

Objective 2: Determine if the proportion of hatchery fish on the spawning grounds affects the freshwater productivity of supplemented stocks.

Objective 3: Determine if the hatchery adult-to-adult survival (i.e., hatchery replacement rate, HRR) is greater than the natural adult-to-adult survival (i.e., natural replacement rate, NRR) and the target hatchery survival rate.

Objective 4: Determine if the proportion of hatchery-origin spawners (pHOS or PNI) is meeting management target.

Objective 5: Determine if the run timing, spawn timing, and spawning distribution of the hatchery component is similar to the natural component of the target population or is meeting program-specific objectives.

Objective 7: Determine if genetic diversity, population structure, and effective population size have changed in natural spawning populations as a result of the hatchery program.

Objective 8: Determine if hatchery programs have caused changes in phenotypic characteristics of natural populations.

The Twisp Weir will be operated for steelhead adult stock assessment between March 1, 2018 (approximate as environmental conditions allow) and June 30, 2018. Activities implemented at the Twisp Weir will include sampling all adult steelhead captured (origin, length, sex, genetic tissue sample, record any marks or tags, Floy tag fish to be released according to color scheme [Table 2]); PIT tagging and releasing adult steelhead (abdomen or pelvic girdle); retain (as necessary) natural origin Twisp returns for broodstock; handle any non-target species captured according to operational protocols and permit conditions; and, perform adult management of hatchery origin returns to achieve a 1:1 hatchery:natural origin ratio of spawners and the removal of non-Twisp hatchery origin adults upstream of the Twisp Weir. Fish sacrificed for adult management may be sampled for fecundity to augment the sample size for hatchery-origin fish. Rainbow trout and cutthroat trout captured at the Twisp Weir will also be sampled and tagged similarly to steelhead.

Table 2. Floy tag colors for adult Twisp steelhead released upstream of the Twisp Weir in 2018.

Sex	Origin	Tag color
Female	Natural	Blue
Female	Hatchery	Red
Male	Natural	Pink
Male	Hatchery	Chartreuse

Floy tag colors will be alternated every other year between hatchery and wild fish to control for any potential color effects on reproductive success.

Wells Dam fish counts will provide data on escapement upstream of Wells Dam. Stock assessment will be used to estimate the composition of the escapement. Wells Dam stock assessment will be performed concurrent with broodstock collection activities at Wells Dam and Wells Hatchery from July 2018 – November 2018. Activities will include sampling all adult steelhead captured (origin, length, sex, genetic tissue sample (broodstock only), record any marks or tags, PIT tags may be applied to released fish [pelvic girdle]), retain hatchery-origin returns for Columbia Safety-Net, Methow Safety-Net, and Okanogan broodstock, handle any non-target species captured according to operational protocols and permit conditions. Management (removal) of excess hatchery origin adult steelhead may also occur at the Wells Hatchery volunteer channel and the Methow Hatchery outfall channel between March and May, 2018.

HRR will be estimated and values that fall below the expected values or the corresponding estimate of NRR (Appendix 2 of the M&E Plan) will be evaluated to determine whether in-hatchery or out-of-hatchery factors contributed to the reduced survival. Smolt to adult returns (SAR) will be estimated for each program and for the natural origin Twisp population. The proportion of hatchery origin spawners (pHOS) and proportion of natural influence (PNI) will be estimated for the Twisp steelhead program and population. Data for pHOS and PNI (for broodstock within Douglas PUD program facilities) will be collected for other parts of the basin. Numbers and proportions of hatchery origin returns removed for adult management for the Twisp, Methow and Columbia programs will be estimated and reported consistent with terms and conditions (Appendix 3 of the M&E Plan) in the pending Wells Complex Summer Steelhead HGMP ESA permit.

Module 3: Report Steelhead Contribution to Harvest

Required to meet:

Objective 10: Determine if appropriate harvest rates have been applied to conservation, safety-net, and segregated harvest programs to meet the HCP/SSSA goal of providing harvest opportunities while also contributing to population management and minimizing risk to natural populations.

In years when the expected returns of hatchery adults exceed the level required to meet program goals of Wells Complex steelhead programs, surplus fish may be available for harvest. The contribution to harvest will be reported for programs that are consistent with harvest. Conservation fishery data derived from creel census (funded and conducted by WDFW) are reported to NMFS annually, and harvest data reported outside the scope of this plan (PTAGIS, etc.) will be summarized.

Module 4: Steelhead Spawning Distribution and Timing

Required to meet:

Objective 5: Determine if the run timing, spawn timing, and spawning distribution of the hatchery component is similar to the natural component of the target population or is meeting program-specific objectives.

Spawner surveys will be conducted at least weekly in the Twisp River using standard spawning ground survey methodology and data analysis as described in Snow et al. (2012). Locations of redds will be recorded using GPS; fish location and origin (identified by Floy tags) will also be recorded. Data collected will provide the number of redds, and timing and spatial distribution of spawning by fish origin. Any carcasses encountered will be sampled for sex, origin, age, egg retention, PIT tag, and other relevant biological data. Spawn timing comparisons of hatchery and natural origin steelhead will be conducted using data from Twisp River reaches T4-T10. The capture efficiency of the Twisp Weir will be estimated by comparing observations of Floy tagged and un-tagged fish in sections upstream of the weir.

Additionally, temporary in-stream PIT tag antenna arrays may be placed in selected tributaries in the Twisp drainage to assist with evaluation of spawning spatial distribution and timing. In conjunction with returning steelhead adults tagged as juveniles and adult steelhead tagging at the Twisp Weir and the Wells and Priest Rapids dams, these arrays are expected to provide a reliable, cost-effective means of corroborating current survey methodologies with observed steelhead use, and detect spawning (if any) in locations where spawning is presumed to not occur, or where surveys are difficult to conduct. Permanent PIT tag arrays located in the Chewuch River, the

Methow River near Winthrop, Washington, and in lower Methow tributaries (i.e., Beaver, Gold, and Libby creeks) will be used to estimate overall steelhead spawner abundance, origin of spawners, and pHOS, for the Chewuch River, and the upper and lower Methow River subbasins. Index redd surveys will be used in the lower Methow reaches in conjunction with PIT tag detection. DCPUD will explore AUC modeling methods to estimate the number of spawners in the lower Methow.

Module 5: Estimation of Steelhead Stray Rates

Required to meet:

Objective 6: Determine if the stray rate of hatchery fish is below the acceptable levels to maintain genetic variation among stocks.

Stray rates of Twisp conservation, Methow Safety-Net, and Columbia Safety-Net steelhead will be estimated by PIT tag detections at in-stream PIT tag detection stations in the Methow Basin and in watersheds outside the Methow Basin (via PTAGIS), and positive identification of recovered or captured steelhead at traps (Twisp Weir, Methow Hatchery, Winthrop NFH, Omak Weir), during spawner surveys, or through creel census.

Collecting stray rate information for steelhead poses a challenge because carcasses are not available for examination. Adult PIT tag monitoring provides the most accurate assessment of stray rates, both within and among populations.

Module 6: Steelhead Juvenile Population Assessment

Required to meet:

Objective 2: Determine if the proportion of hatchery fish on the spawning grounds affects the freshwater productivity of supplemented stocks.

The population abundance of juvenile steelhead will be estimated in the rivers supplemented by Douglas PUD's steelhead hatchery programs. Sampling locations and methods may utilize a combination of the following methods: screw traps, mark-recapture population estimates, electrofishing removal population estimates, snorkel surveys, and PIT tag based survival modeling.

Approach 1: The efficacy of this approach is currently being analyzed and continued implementation of this approach will be determined based on this assessment. Under this approach, rotary screw smolt traps are used in the Twisp and Methow rivers, and trapping locations and methods will remain as described in Snow et al. (2012). Biological data (species, length, origin, scale samples, genetic samples [Twisp River only]) will be collected from fish collected each day. Scale samples will be taken from random samples of steelhead juveniles to estimate the age structure of the emigrants. The Twisp trap will be fished from early March through late November, and the Methow Trap will be fished from late February through late November, as conditions allow at both trapping locations. Steelhead greater than 65 mm will be PIT tagged. Trap efficiency trials will be conducted at various flows as the number of available fish for trials allows. Population estimates will be calculated by expanding the number of fish caught on a daily basis by the estimated trap efficiency on that day as estimated using a flow-efficiency model.

Approach 2: The efficacy of this approach is currently being analyzed and continued implementation of this approach will be determined based on this assessment. Under this approach, juvenile population estimates are derived through in-stream PIT tagging coupled with survival modeling in the Twisp River, Methow and/or Chewuch rivers. Sampling may be limited to testing the methodology. Steelhead will be captured by electrofishing at sites chosen using General Random Tessellation Sampling (GRTS) or other random sample method. The standing crop of juveniles will be estimated by both multiple-pass removal estimates or mark-recapture estimates coupled with single-pass electrofishing extrapolated to the amount of habitat in the stream. Captured fish will be PIT tagged. Survival of the fish will be estimated through emigration using a multi-state survival model (J. Skalski and R. Buchanan, personal communication). The number of emigrants will be estimated using this PIT tag based survival model. This approach will be implemented for the fourth time in the fall of 2017. The results of the pilot studies in 2014-2017 will be used to improve the assessment. As informative results from the initial implementation become available, this approach may be modified to better meet M&E objectives.

Module 7: Steelhead Population Genetic Monitoring

Required to meet:

Objective 7: Determine if genetic diversity, population structure, and effective population size have changed in natural spawning populations as a result of the hatchery program.

Hypotheses related to genetic diversity, population structure, and effective population size were addressed in the 2008-2010 work plans and will not be addressed in 2018. However, to provide the ability to conduct future analysis, we will collect and archive representative tissue samples (opercle-punch or fin clip) from all steelhead broodstocks, and from natural origin steelhead collected on the spawning grounds and at the Twisp River Weir. Samples will have associated data recorded (fish origin, age, date, location, sex, and biological characteristics).

Table 3. Cross reference of steelhead M&E implementation modules and M&E objectives.

	Objective	Modules	Data
1	Determine if conservation programs have increased the number of naturally spawning and naturally produced adults of the target population and if the program has reduced the natural replacement rate (NRR) of the supplemented population.	2, 4	• Adult returns • Sex and Origin of Adults • Number of Spawners
2	Determine if the proportion of hatchery fish on the spawning grounds affects the freshwater productivity of supplemented stocks.	2, 4, 6	• Adult Returns • Sex and Origin of Adults • Number of Spawners • Juvenile Population Estimates
3	Determine if the hatchery adult-to-adult survival (i.e., hatchery replacement rate, HRR) is greater than the natural adult-to-adult survival (i.e., natural replacement rate, NRR) and the target hatchery survival rate.	1, 2, 4	• Broodstock Data • Adult returns • Sex and Origin of Adults • Number of Spawners
4	Determine if the proportion of hatchery-origin spawners (pHOS or PNI) is meeting management target.	2, 4	• Adult returns • Sex and Origin of Adults • Number of Spawners
5	Determine if the run timing, spawn timing, and spawning distribution of the hatchery component is similar to the natural component of the target population or is meeting program-specific objectives.	2, 4	• Run timing • Spawn timing • Spatial Distribution of Spawning • Adult returns • Sex and Origin of Adults • Number of Spawners
6	Determine if the stray rate of hatchery fish is below the acceptable levels to maintain genetic variation among stocks.	4, 5	• Sex and Origin of Adults • Number of Spawners • Spatial Distribution of Spawning
7	Determine if genetic diversity, population structure, and effective population size have changed in natural spawning populations as a result of the hatchery program.	1, 2, 4, 7	• Sample Broodstock • Sample Adult Returns • Sample Spawners • Sample Juveniles • Various Population Genetic Analyses
8	Determine if hatchery programs have caused changes in phenotypic characteristics of natural populations.	1, 2	• In-Hatchery Metrics • Adult Phenotype Metrics
9	Determine if hatchery fish were released at the programmed size and number.	1	• In-Hatchery Metrics
10	Determine if appropriate harvest rates have been applied to conservation, safety-net, and segregated harvest programs to meet the HCP/SSSA goal of providing harvest opportunities while also contributing to population management and minimizing risk to natural populations.	3	• Various Harvest Data (PTAGIS, RMIS, Agency Reports, etc.)

Spring Chinook

Module 8: Spring Chinook In-Hatchery Metrics

Required to meet:

Objective 3: Determine if the hatchery adult-to-adult survival (i.e., hatchery replacement rate, HRR) is greater than the natural adult-to-adult survival (i.e., natural replacement rate, NRR) and the target hatchery survival rate.

Objective 8: Determine if hatchery programs have caused changes in phenotypic characteristics of natural populations.

Objective 9: Determine if hatchery fish were released at the programmed size and number.

Biological data for origin, sex, age, size, fecundity, and survival of broodstock will be recorded for the Twisp and Methow Conservation hatchery programs. Number of fish, stage-specific survivals, size, coefficient of variation, condition factor, and fish health issues will be recorded. An annual review of size, number and supporting statistics of fish from each program will be compared to those values defined in the M&E Plan Appendix 6, or adjusted values agreed to by the Wells and Rocky Reach HCP Hatchery Committees and PRCC HSC. Values within acceptable precision (i.e., +/- 10% of HCP defined values) will constitute achievement of program objectives. Failure to achieve release targets will trigger evaluation to determine probable causation and recommendations, when necessary, for improving performance.

Hatchery personnel will assess fecundity of spawned females when fertilized eggs are at the eyed stage, and will provide data to evaluation staff. To assess overall egg mass, we will collect total egg weight samples just after removal from lethally-spawned females, and will record the weight of female fish after egg removal.

Module 9: Spring Chinook Adult Stock Assessment

Required to meet:

Objective 1: Determine if conservation programs have increased the number of naturally spawning and naturally produced adults of the target population and if the program has reduced the natural replacement rate (NRR) of the supplemented population.

Objective 2: Determine if the proportion of hatchery fish on the spawning grounds affects the freshwater productivity of supplemented stocks.

Objective 3: Determine if the hatchery adult-to-adult survival (i.e., hatchery replacement rate, HRR) is greater than the natural adult-to-adult survival (i.e., natural replacement rate, NRR) and the target hatchery survival rate.

Objective 4: Determine if the proportion of hatchery-origin spawners (pHOS or PNI) is meeting management target.

Objective 5: Determine if the run timing, spawn timing, and spawning distribution of the hatchery component is similar to the natural component of the target population or is meeting program-specific objectives.

Objective 7: Determine if genetic diversity, population structure, and effective population size have changed in natural spawning populations as a result of the hatchery program.

Objective 8: Determine if hatchery programs have caused changes in phenotypic characteristics of natural populations.

The Twisp Weir and Methow Hatchery volunteer trap(s) will be operated for spring Chinook broodstock collection primarily between July 1, 2018 and August 30, 2018 (Twisp Weir is operated under the auspices of steelhead collection and sampling through June 30, but spring Chinook will be collected opportunistically prior to July 1). Wells Dam fish ladders will be operated between about 1 May and 30 June for spring Chinook broodstock collection and overall population stock assessment. Activities will include sampling all adult spring Chinook captured (origin, length, sex, genetic tissue sample, record any marks or tags, retain natural origin Twisp returns for broodstock, handle any non-target species captured according to operational protocols and permit conditions, and PIT tags may be applied to the pelvic girdle of released fish).

Carcass recoveries and coded wire tag data will be the primary means of stock assessment (see the spawner survey section for more information). Samples and data for run composition, age, origin, size, spawn timing, egg retention, and population genetic analyses will be collected. HRR will be estimated and values that fall below the expected values or the corresponding estimate of NRR (Appendix 2 of the M&E Plan) will be evaluated to determine whether in-hatchery or out-of-hatchery factors contributed to the reduced survival. SAR will be estimated for each program and for the natural origin fish of the Twisp River and Methow Basin. SAR for the Chewuch River natural origin fish will be estimated if appropriate PIT tag groups are available.

The pHOS and PNI will be estimated for the Twisp and MetComp programs and populations. Numbers and proportions of hatchery origin returns removed for adult management for the Twisp and Methow programs will be estimated and reported consistent with terms and conditions (Appendix 3 of the M&E Plan) in the Methow Hatchery Spring Chinook ESA permit.

Module 10: Spring Chinook Contribution to Harvest

Required to meet:

Objective 10: Determine if appropriate harvest rates have been applied to conservation, safety-net, and segregated harvest programs to meet the HCP/SSSA goal of providing harvest opportunities while also contributing to population management and minimizing risk to natural populations.

In years when the expected returns of hatchery adults exceed the level required to meet program goals for the Methow Hatchery spring Chinook programs, surplus fish may be available for harvest. The contribution to harvest will be reported based on numbers of fish released for programs that are consistent with harvest. Conservation fishery data derived from creel census (funded and conducted by WDFW) will be reported to NMFS annually, and harvest data reported outside the scope of this plan (PTAGIS, RMIS, etc.) will be summarized.

Module 11: Spring Chinook Spawner Surveys

Required to meet:

Objective 5: Determine if the run timing, spawn timing, and spawning distribution of the hatchery component is similar to the natural component of the target population or is meeting program-specific objectives.

Spawner surveys will be conducted at least weekly in all spawning reaches of the rivers supplemented by the Methow Hatchery (Table 4) using standard spawning ground survey methodology and data analysis as described in Snow et al. (2012), and may incorporate surveyor efficiency models to estimate precision. Locations of redds will be recorded using GPS. Data collected will provide the number of redds, and timing and spatial distribution of spawning by origin. Carcasses encountered will be sampled for location of recovery, sex, origin, age, egg retention, CWT, PIT tag, and other relevant biological data.

Table 4. Spring Chinook spawning ground surveys and methods.

River	Spawning ground methodology	Spawner composition	Age composition
Methow	Total ground	Carcasses	Wells Dam
Chewuch	Total ground	Carcasses	Wells Dam
Twisp	Total ground	Carcasses	Wells Dam

Module 12: Estimation of Spring Chinook Stray Rates

Required to meet:

Objective 6: Determine if the stray rate of hatchery fish is below the acceptable levels to maintain genetic variation among stocks.

Stray rates of Twisp, Chewuch, and Methow conservation programs will be estimated by CWT recoveries within and outside of the Methow Basin. The Regional Mark Information System (RMIS) database will provide all necessary CWT information needed to estimate stray rates for each brood year for within- and outside-basin stray rates based on spawning escapement estimates. Brood year stray rates for Chinook will require multiple-year CWT recoveries (i.e., all age classes) from broodstock and carcass recoveries on the spawning grounds to account for all cohort age classes. The estimated number of strays for the entire brood year will be calculated by dividing the number of strays by the total number of hatchery fish that returned. Stray rates within, and between independent populations will be calculated in a similar manner as brood year stray rates, except on an annual basis and based on the estimated spawning escapements of the receiving populations.

Module 13: Juvenile Spring Chinook Population Assessment

Required to meet:

Objective 2: Determine if the proportion of hatchery fish on the spawning grounds affects the freshwater productivity of supplemented stocks.

The population abundance of juvenile spring Chinook will be estimated in the rivers supplemented by the PUDs' spring Chinook hatchery programs. Sampling locations and methods may utilize a combination of the following methods: screw traps, mark-recapture population estimates, electrofishing removal population estimates, snorkel surveys, and PIT tag based survival modeling.

Approach 1: The efficacy of this approach is currently being analyzed and continued implementation of this approach will be determined based on this assessment. Under this approach, rotary screw smolt traps are used in the Twisp and Methow rivers, and trapping locations and methods will remain as described in Snow et al. (2012). Biological data (species, length, origin, scale samples, genetic samples) will be collected from fish trapped each day. The Twisp trap will be fished from early March through late November, and the Methow Trap will be fished from late February through late November, as conditions allow at both trapping locations. Spring Chinook greater than 65 mm will be PIT tagged. Trap efficiency trials will be conducted at various flows as the number of available fish for trials allows. Population estimates will be calculated by expanding the number of fish caught on a daily basis by the estimated trap efficiency on that day as estimated using a flow-efficiency model. A similar methodology will be employed with the Twisp PIT tag antenna array to estimate over-winter emigration provided that adequate numbers of spring Chinook parr are PIT tagged under Approach 2.

Approach 2: The efficacy of this approach is currently being analyzed and continued implementation of this approach will be determined based on the assessment. Under this approach, juvenile population estimates are derived through in-stream PIT tagging coupled with survival modeling in the Twisp River, Methow and/or Chewuch rivers. Spring Chinook will be captured by electrofishing at sites chosen using General Random Tessellation Sampling (GRTS) or other random sample method. The standing crop of juveniles will be estimated by multiple-pass removal estimates or mark-recapture estimates coupled with single-pass electrofishing extrapolated to the amount of habitat in the stream. Captured fish will be PIT tagged. Survival of the fish will be estimated through emigration using a multi-state survival model (J. Skalski and R. Buchanan, personal communication). The number of emigrants will be estimated using this PIT tag based survival model. This approach was implemented for the fourth time in the fall of 2017. The results of the pilot studies in 2014-2017 will be used to assess whether to continue the field sampling for this work in 2018. As informative results from the initial implementation become available, this approach may be modified to better meet M&E objectives.

Module 14: Spring Chinook Population Genetic Monitoring

Required to meet:

Objective 7: Determine if genetic diversity, population structure, and effective population size have changed in natural spawning populations as a result of the hatchery program.

Hypotheses related to genetic diversity, population structure, and effective population size were addressed in the 2008-2010 work plans and will not be addressed in 2018. However, to provide the ability to conduct future analysis, we will collect and archive tissue samples (opercle-punch or fin clip) from all spring Chinook broodstock, and from natural origin spring Chinook collected on spawning grounds and at the Twisp River Weir. Samples will have associated data recorded (fish origin, age, date, location, sex, and biological characteristics).

Table 5. Cross reference of spring Chinook M&E implementation modules and M&E objectives.

	Objective	Modules	Data
1	Determine if conservation programs have increased the number of naturally spawning and naturally produced adults of the target population and if the program has reduced the natural replacement rate (NRR) of the supplemented population.	9, 11	• Adult returns • Sex and Origin of Adults • Number of Spawners
2	Determine if the proportion of hatchery fish on the spawning grounds affects the freshwater productivity of supplemented stocks.	9, 11, 13	• Adult Returns • Sex and Origin of Adults • Number of Spawners • Juvenile Population Estimates
3	Determine if the hatchery adult-to-adult survival (i.e., hatchery replacement rate, HRR) is greater than the natural adult-to-adult survival (i.e., natural replacement rate, NRR) and the target hatchery survival rate.	8, 9, 11	• Broodstock Data • Adult returns • Sex and Origin of Adults • Number of Spawners
4	Determine if the proportion of hatchery-origin spawners (pHOS or PNI) is meeting management target.	9, 11	• Adult returns • Sex and Origin of Adults • Number of Spawners
5	Determine if the run timing, spawn timing, and spawning distribution of the hatchery component is similar to the natural component of the target population or is meeting program-specific objectives.	9, 11	• Run timing • Spawn timing • Spatial Distribution of Spawning • Adult returns • Sex and Origin of Adults • Number of Spawners
6	Determine if the stray rate of hatchery fish is below the acceptable levels to maintain genetic variation among stocks.	11, 12	• Sex and Origin of Adults • Number of Spawners • Spatial Distribution of Spawning
7	Determine if genetic diversity, population structure, and effective population size have changed in natural spawning populations as a result of the hatchery program.	8, 9, 11, 14	• Sample Broodstock • Sample Adult Returns • Sample Spawners • Sample Juveniles • Various Population Genetic Analyses
8	Determine if hatchery programs have caused changes in phenotypic characteristics of natural populations.	8, 9	• In-Hatchery Metrics • Adult Phenotype Metrics
9	Determine if hatchery fish were released at the programmed size and number.	8	• In-Hatchery Metrics
10	Determine if appropriate harvest rates have been applied to conservation, safety-net, and segregated harvest programs to meet the HCP/SSSA goal of providing harvest opportunities while also contributing to population management and minimizing risk to natural populations.	10	• Various Harvest Data (PTAGIS, RMIS, Agency Reports, etc.)

Summer Chinook

Module 15: Summer Chinook In-Hatchery Metrics

Required to meet:

Objective 3: Determine if the hatchery adult-to-adult survival (i.e., hatchery replacement rate, HRR) is greater than the target hatchery survival rate.

Objective 9: Determine if hatchery fish were released at the programmed size and number.

Biological data for origin, sex, age, size, fecundity, and survival of broodstock will be recorded for the Wells yearling and subyearling hatchery programs. Number of fish, stage-specific survivals, size, coefficient of variation, condition factor, and fish health issues will be recorded. An annual review of size, number and supporting statistics of fish from each program will be compared to those values defined in Appendix 6, or adjusted values agreed to by the Wells HCP Hatchery Committee. Values within acceptable precision (i.e., +/-10% of HCP defined values) will constitute achievement of program objectives. Failure to achieve release targets will trigger evaluation to determine probable causation and recommendations, when necessary for improving performance.

Module 16: Summer Chinook Adult Stock Assessment

Objective 3: Determine if the hatchery adult-to-adult survival (i.e., hatchery replacement rate, HRR) is greater than the natural adult-to-adult survival (i.e., natural replacement rate, NRR) and the target hatchery survival rate.

Stock assessment will be performed on broodstock collected at Wells Hatchery. Activities will include sampling all adult summer Chinook broodstock for origin, length, sex, genetic tissue sample (for CRITFC PBT), record any marks or tags, handle any non-target species captured according to operational protocols and permit conditions. Coded wire tag data will be the primary means of stock assessment. Samples and data for run composition, age, origin, size, spawn timing, egg retention, and population genetic analyses will be collected. HRR will be estimated and values that fall below the expected value (Appendix 2 of the M&E Plan) will be evaluated to determine whether in-hatchery or out-of-hatchery factors contributed to the reduced survival. SAR will be estimated for each program.

Module 17: Summer Chinook Contribution to Harvest

Required to meet:

Objective 10: Determine if appropriate harvest rates have been applied to conservation, safety-net, and segregated harvest programs to meet the HCP/SSSA goal of providing harvest opportunities while also contributing to population management and minimizing risk to natural populations.

In years when the expected returns of hatchery adults exceed the level required to meet program goals, surplus fish may be available for harvest. The contribution to harvest will be reported based on numbers of fish released for programs that are consistent with harvest and harvest data funded, collected, and reported outside the scope of this plan (PTAGIS, RMIS, etc.).

Module 18: Estimation of Summer Chinook Stray Rates

Required to meet:

Objective 6: Determine if the stray rate of hatchery fish is below the acceptable levels to maintain genetic variation among stocks.

Stray rates of Wells yearling and subyearling summer Chinook will be estimated through CWT recoveries reported in RMIS. The RMIS database will provide all necessary CWT information to estimate stray rates for each brood year for within- and outside-basin stray rates based on spawning escapement estimates. Brood year stray rates for Chinook will require multiple-year CWT recoveries (i.e., all age classes) from broodstock and carcass recoveries on the spawning grounds to account for all cohort age classes. The estimated number of strays for the entire brood year will be calculated by dividing the number of strays by the total number of hatchery fish that returned. Stray rates in independent populations will be calculated in a similar manner as brood year stray rates, except on an annual, run-year basis and based on the estimated spawning escapement.

Module 19: Summer Chinook Population Genetic Monitoring

Required to meet:

Objective 7: Determine if genetic diversity, population structure, and effective population size have changed in natural spawning populations as a result of the hatchery program.

Hypotheses related to genetic diversity, population structure, and effective population size were addressed in the 2008-2010 work plans and will not be addressed in 2018. However, to provide the ability to conduct future analysis, we will collect and archive tissue samples (opercle-punch or fin clip) from summer Chinook broodstock. Samples will have associated data recorded (fish origin, age, date, location, sex, and biological characteristics).

Table 6. Cross reference of summer Chinook M&E implementation modules and M&E objectives.

	Objective	Modules	Data
1	Determine if conservation programs have increased the number of naturally spawning and naturally produced adults of the target population and if the program has reduced the natural replacement rate (NRR) of the supplemented population.	NA	NA
2	Determine if the proportion of hatchery fish on the spawning grounds affects the freshwater productivity of supplemented stocks.	NA	NA
3	Determine if the hatchery adult-to-adult survival (i.e., hatchery replacement rate, HRR) is greater than the natural adult-to-adult survival (i.e., natural replacement rate, NRR) and the target hatchery survival rate.	15, 16	• Broodstock Data • Adult returns • Sex and Origin of Adults
4	Determine if the proportion of hatchery-origin spawners (pHOS or PNI) is meeting management target.	NA	NA
5	Determine if the run timing, spawn timing, and spawning distribution of the hatchery component is similar to the natural component of the target population or is meeting program-specific objectives.	NA	NA
6	Determine if the stray rate of hatchery fish is below the acceptable levels to maintain genetic variation among stocks.	18	• Sex and Origin of Adults • Number of Spawners • Spatial Distribution of Spawning
7	Determine if genetic diversity, population structure, and effective population size have changed in natural spawning populations as a result of the hatchery program.	19	• Sample Broodstock • Sample Adult Returns • Sample Spawners • Sample Juveniles • Various Population Genetic Analyses
8	Determine if hatchery programs have caused changes in phenotypic characteristics of natural populations.	NA	NA
9	Determine if hatchery fish were released at the programmed size and number.	15	• In-Hatchery Metrics
10	Determine if appropriate harvest rates have been applied to conservation, safety-net, and segregated harvest programs to meet the HCP/SSSA goal of providing harvest opportunities while also contributing to population management and minimizing risk to natural populations.	17	• Various Harvest Data (PTAGIS, RMIS, Agency Reports, etc.)

DELIVERABLES

Annual Reports: Reporting will follow the schedule in Table 7.

Table 7. Monitoring and Evaluation Annual Report Review Dates.

Date	Reporting Phase
June 1	WDFW Internal Review
July 15	Draft submitted to PUDs for 30 day review
August 15	PUDs comments to WDFW
September 15	Draft to HC for 30 day review
October 15	HC comments to PUDs and WDFW
November 1	Final Report submitted to NMFS and HC

The annual report will summarize all field activities conducted during the contract period (January 1 – December 31). The report will be in a scientific format, organized so that the HCP HCs and the PRCC HSC members can clearly and concisely evaluate M&E Plan results. Data tables and figures will be cumulative such that all comparable data from previous years is included and that the most recent report supersedes all previous reports. Monitoring indicators and the data used in calculations will be presented for each hypothesis evaluated.

Monthly Reports: Monthly reports will be provided to keep Douglas PUD, Grant PUD, Chelan PUD, as well as the HCP HCs and PRCC HSC members and co-managers informed on all hatchery and evaluation related activities. Unless otherwise requested by the PUDs, the role of monthly reports will remain the same. Upon request, additional information can be included in the monthly reports.

COORDINATION

Douglas PUD's M&E contractor will be required to closely coordinate and collaborate with hatchery staff at the Wells and Methow hatcheries. Hatchery staff conduct many of the in-hatchery routine sampling and data collected by hatchery staff must be provided to evaluation staff to ensure the data are included the M&E Plan reports. However, special meetings with the hatchery staff are typically conducted prior to significant events (i.e., broodstock collection, spawning, release of juveniles) to ensure proper methodologies are used and critical data are collected. Evaluation staff will be present at all significant events to collect data needed for evaluation purposes. Coordination between evaluation staff, hatchery staff, and the ESA Permit compliance officer is required to ensure that conditions of ESA Section 10 permits are not violated. All ESA reporting related to the hatchery programs is the responsibility of the ESA compliance officer.

References

Hillman, T., T. Kahler, G. Mackey, J. Murauskas, A. Murdoch, K. Murdoch, T. Pearsons, and M. Tonseth. 2013. Monitoring and evaluation plan for PUD hatchery programs, 2013 update. Report to the HCP and PRCC Hatchery Committee members.

Murdoch, A. R., C. Snow, C. Frady, A. Repp, M. Small, S. Blankenship, T. Hillman, M. Miller, G. Mackey, and T. Kahler. 2012. Evaluation of hatchery programs funded by Douglas County PUD 5-year report 2006-2010. Wells HCP Hatchery Committee, East Wenatchee, WA.

Snow. C., C. Frady, A. Repp, A. Murdoch, M. Small, and S. Bell. 2012. Monitoring and evaluation of Wells and Methow hatchery programs: 2011 annual report. Douglas County Public Utility District, East Wenatchee, Washington.

Wells HCP Hatchery Committee. 2007. Conceptual approach to monitoring and evaluation for hatchery programs funded by Douglas County Public Utility District. Douglas PUD Habitat Conservation Plan Hatchery Committee, East Wenatchee, Washington. Last updated September 2007.

Exhibit B

Budget

Methow Basin Natural Evaluation Budget: 1 January 2017 to 31 December 2017 NOT UPDATED YET		
Salaries		
Research Scientist 2 (2 months at 5,804/ month)		11,608
Fish Biologist 4 (12 months at 5,804/month)		69,648
Fish Biologist 3 (12 months at 5,657/month)		67,884
Fish Biologist 2 (12 months at $4,208/month)		50,496
Perm Sci Tech 2 (21.5 months at $3,287/month)		70,671
Temp Sci Techs (66.5 months at $3,287/month)		218,586
Office Assistant Senior (1 month at $2,768/month)		2,768
	Subtotal	**491,660**
Benefits		
OASI and Medicare (7.65% of salaries; 2016 = same)		37,612
Retirement (11.18% of salaries; 2016 = same)		54,968
Labor and Industries ($171/month x 27 months; 2016 = $161/mo)		21,717
Health Insurance rep ($894.00/month x 60.5 months; 2016 = 840/mo)		54,087
Health Insurance non-rep ($894.00/month x 66.5 months; 2016 = 840/mo)		59,451
	Subtotal	**227,835**
	Total Salaries and Benefits	**719,495**
Goods and Services		
Office supplies (paper, notebooks, tally meters, etc.)		1,000
Utilities (phone; 3 @ $220 month, electricity [smolt trap])		2,640
Copier rental ($140.00/month for 12 months)		1,680
Snow plowing at office		1,000
Sampling supplies (knives, bags, scale, vests, etc.,)		800
Cellular phones		200
Waders and hip boots		2,800
Portable toilet		520
MS-222/Alcohol		1,000
Gas and maintenance (34,000 miles @ $0.35/mile)		11,900
Vehicle lease (7 vehicles, $1,914/month)		22,968
Rope and fasteners (crosbys, nuts and bolts)		500
Crane rental		1,200
Equipment maintenance and repair, projected to include:		10,000
Smolt trap safety upgrades = 3,500		
PIT antenna maintenance = 5,000		
DNA SAMPLING		
BY 14 Sub Chinook from Methow smolt trap (100@$43/sample)		4,300
	Total Goods and Services	**62,508**
Travel		
16 days @ $150/day		**2,400**
Total Salaries, Goods and Services, Equipment, and Travel		**784,403**
Agency Indirect (28.23%)		**221,437**
	Budget Total	**1,005,839**

Methow Basin Natural Evaluation Budget: 1 January 2017 to 31 December 2017 Cost by Task NOT UPDATED YET		
Task		**Cost**
Task 1	Steelhead In-Hatchery Metrics	$138,600
Task 2	Steelhead Adult Stock Assessment	$55,440
Task 3	Report Steelhead Contribution to Harvest	$7,920
Task 4	Steelhead Spawning Distribution and Timing	$47,520
Task 5	Estimation of Steelhead Stray Rates	$7,920
Task 6a	Steelhead Juvenile Population Assessment: Approach 1	$164,340
Task 6b	Steelhead Juvenile Population Assessment: Approach 2	$15,840
Task 7	Steelhead Population Genetic Monitoring	$0
Task 8	Spring Chinook In-Hatchery Metrics	$138,600
Task 9	Spring Chinook Adult Stock Assessment	$79,200
Task 10	Spring Chinook Contribution to Harvest	$7,920
Task 11	Spring Chinook Spawner Surveys	$95,040
Task 12	Estimation of Spring Chinook Stray Rates	$7,920
Task 13a	Juvenile Spring Chinook Population Assessment: Approach 1	$164,340
Task 13b	Juvenile Spring Chinook Population Assessment: Approach 2	$15,840
Task 14	Spring Chinook Population Genetic Monitoring	$0
Task 15	Summer Chinook In-Hatchery Metrics	$15,840
Task 16	Summer Chinook Adult Stock Assessment	$7,920
Task 17	Summer Chinook Contribution to Harvest	$27,720
Task 18	Estimation of Summer Chinook Stray Rates	$7,920
Task 19	Summer Chinook Population Genetic Monitoring	$0
	Total	$1,005,839

TRANSITION PLAN FOR WELLS AND METHOW FISH HATCHERIES

WELLS HYDROELECTRIC PROJECT NO. 2149

October 16, 2017

Tables of Contents

1.0 Organizational Chart **5**
2.0 Personnel and Staffing **7**
2.1 Timing and Strategy for Hiring Personnel 7
2.2 Job Descriptions 7
2.3 Duties 8
2.3.1 Worker Training 9
2.3.2 Orientation 11
2.3.3 Certifications 11
2.3.4 PUD Strategic Plan and Administrative Bulletin 11
2.3.5 Compensation 12
3.0 Culture/Tone of Work Place **12**
4.0 Fish Accounting Pre and Post Transition **13**
5.0 Permits – ESA, CWA, NPDES, Fish Transfer Permits, HPA **14**
5.1 ESA Permits 14
5.1.1 Spring Chinook (Grant/Douglas PUDs) 14
5.1.2 Spring Chinook (Chelan PUD) 14
5.1.3 Steelhead (Douglas PUD Programs) 14
5.1.4 Steelhead (Grant PUD Programs) 15
5.1.5 Summer Chinook (Douglas/Grant/Chelan PUDs) 15
5.1.6 Coho Salmon (Douglas PUD) 15
5.1.7 Bull Tout (Douglas 2012) 16
5.2 NPDES Permits 16
5.3 Hydraulic Permit Application 17
5.4 Fish Transfer and Stocking Permits 17
6.0 Monitoring and Evaluation Plan **18**
6.1 Marking, Tagging, and CWT and Scale Reading 18
7.0 Pathology **19**
8.0 Outreach Plan – Agencies, Tribes, PUDs **19**
9.0 Trapping **19**
10.0 Adult Management and Surplusing **20**
11.0 Genetics **20**
12.0 Fish Husbandry **21**
12.1 Fish Culture Practices – Expertise and Training 22

12.2 Fish Feed Contract ... 22

13.0 Equipment Inventory ... 22

13.1 Transfer Titles - Vehicles ... 22

14.0 Insurance ... 24

15.0 Janitorial and grounds keeping ... 24

16.0 Diesel Fuel and service ... 25

17.0 Trash ... 25

18.0 Safety ... 25

19.0 Housing ... 25

19.1 Utilities ... 26

19.2 Titles for Houses ... 26

19.3 Land Titles ... 26

20.0 Computers, Phones and Communication Equipment ... 27

20.1 Office Furniture ... 27

20.2 Wells Hatchery Network Connectivity ... 27

20.3 Wells Hatchery Phones ... 28

20.4 Wells Hatchery PCs and Printers ... 28

20.5 Methow Hatchery Network Connectivity ... 29

20.6 Methow Hatchery Phones ... 30

20.7 Methow Hatchery PCs and Printers ... 30

20.8 Twisp Weir and Pond ... 30

20.9 Chewuch Pond ... 30

20.10 Software Technology ... 30

21.0 Emergency Procedures ... 31

22.0 As-built Drawings ... 31

23.0 Hazardous Materials Handling and Accounting ... 31

24.0 Security Badges ... 32

25.0 Keys ... 32

26.0 Chewuch Pond ... 32

27.0 Twisp Pond ... 32

28.0 Twisp Weir ... 32

29.0 Grant and Chelan Interlocal Cooperative Agreements ... 33

30.0 Off-license Settlement – Trout Production ... 33

Attachment C

1.0 ORGANIZATIONAL CHART

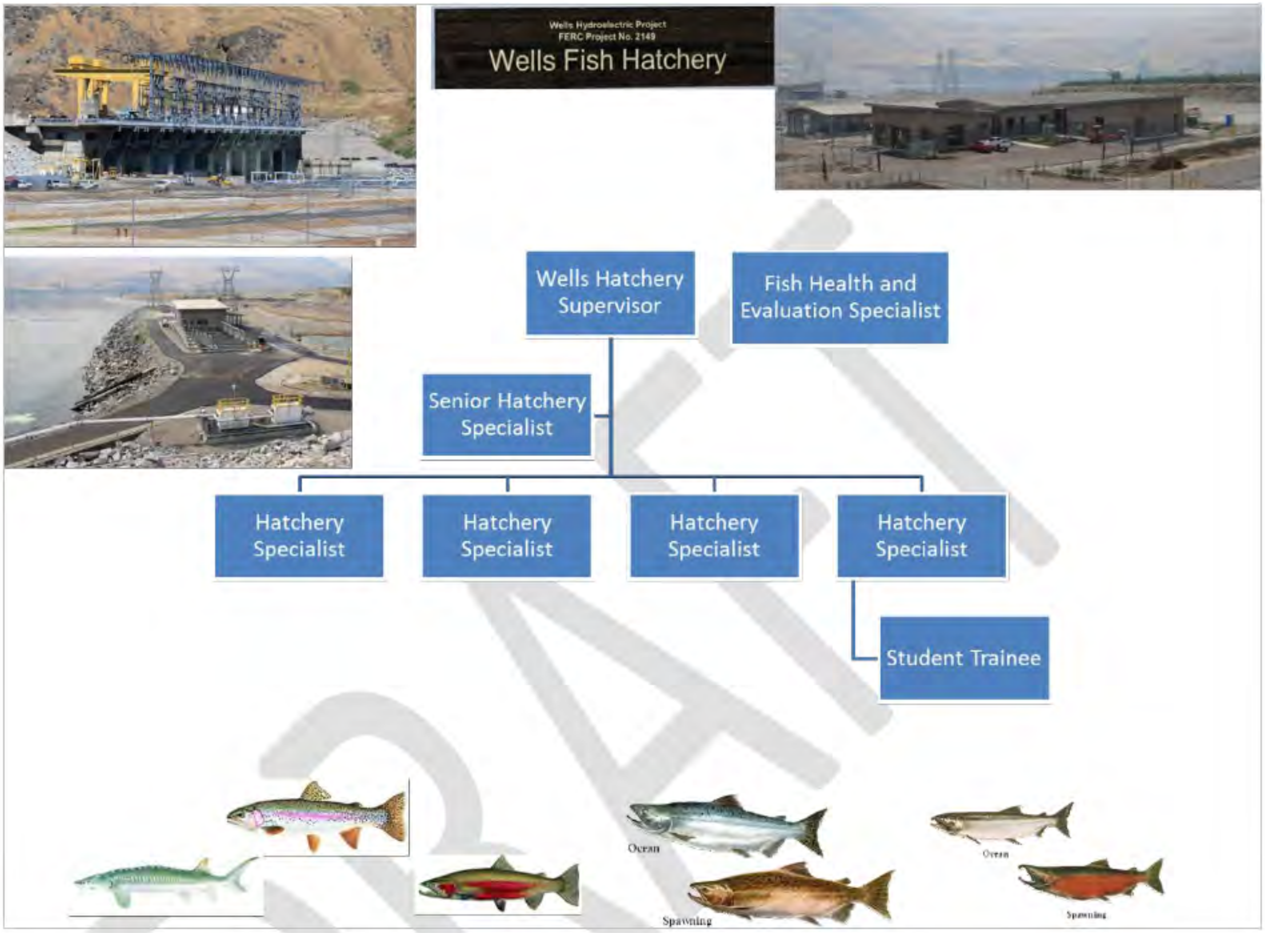


Figure 1. Wells Fish Hatchery Organizational Chart

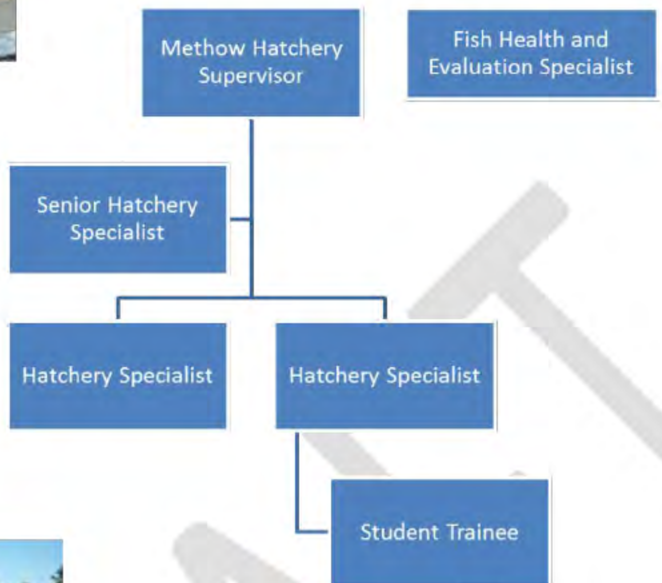


Figure 2. **Methow Fish Hatchery Organizational Chart**

2.0 PERSONNEL AND STAFFING

2.1 Timing and Strategy for Hiring Personnel

The Public Utility District No. 1 of Douglas County (District) has identified the need to hire and train 11 full time hatchery workers: 2 Hatchery Supervisors, 2 Senior Hatchery Specialists, 6 Hatchery Specialists, a Fish Health and Evaluation Specialist, and up to three additional seasonal/temporary workers, on an as needed basis.

The Hatchery Supervisor positions were posted on September 1, 2017. The other eight hatchery worker (Hatchery Senior Specialists and Hatchery Specialists) job notices were posted on September 7, 2017. The Fish Health and Evaluation Specialist position was posted on September 18, 2017. Interviews began on September 15, 2017 and will continue through October 18, 2017, or as needed. Positions will be filled as qualified candidates are identified and will remain open until filled.

We accomplished our goal of having the Hatchery Supervisor positions filled first and all other positions filled as shortly thereafter as possible, so that the new supervisors were included in the interview/hiring process for the Senior Hatchery Specialist and Hatchery Specialist positions.

Brandon Kilmer has formally accepted the Methow Hatchery Supervisor position. Brandon started September 29th. Pat Phillips has accepted the Wells Hatchery Supervisor position and started October 2nd. David Dinsmore has accepted the Methow Senior Hatchery Specialist positions and will start November 1st. The District has interviewed for the Wells Senior Hatchery Specialist position, and we hope to fill this position by November 1st. The Fish Health Specialist position will be filled by November 15, 2017.

All of the remaining positions will be filled by November 15th so that at least two weeks of training and transition can occur prior to the end of the contractual transition period (November 28th).

2.2 Job Descriptions

The job descriptions were posted on the PUD website (Douglaspud.org). Postings were removed when interviews began and there were sufficient numbers of qualified applicants. See http://www.douglaspud.org/your-pud/job-listings

As of October 2nd all jobs have closed with the notable exception of the Fish Health and Evaluation Specialist. Applications received to date included ten applications for the Methow Supervisor, 12 for the Wells Supervisor, 21 for the Methow Senior Specialist, 28 for the Wells Senior Specialist, 30 for the Methow Hatchery Specialists and 49 for the Wells Hatchery Specialist positions.

2.3 Duties

The duties listed below provide a general outline of the responsibilities for the hatchery operations across all levels of staffing, and will include permitting, planning, development of operational protocols, implementation of hatchery actions under the protocols, maintenance and operations, data collection and management and reporting.

- Trapping, fish sorting, and workup. Fish will be trapped for broodstock, Monitoring and Evaluation (M&E) sampling, and gene flow management according to protocols developed under the Wells Habitat Conservation Plan (HCP) and Endangered Species Act (ESA) processes. Coordination and collaboration with staff from the M&E program and other parties as appropriate.
- Spawning steelhead and salmon – egg and milt take, tracking matings, biological sampling, fertilizations, laying down eggs in incubation stacks, husbandry of incubating eggs and all life stages thereafter (see item below). Coordination and collaboration with staff from the M&E program.
- Fish culture from egg through release point for: steelhead, spring Chinook, summer Chinook, coho salmon, white sturgeon, rainbow trout, various other trout, kokanee and other species if and when such programs are fully authorized and developed.
- Operation of the Twisp Weir and Twisp Acclimation Pond. Coordination and collaboration with staff from the M&E program.
- Coordination and ongoing contractual relationship support with the Twisp Valley Irrigation Company and the Chewuch Canal Company.
- Coordination with USFWS on maintenance of Foghorn Ditch.
- Operation and maintenance of Foghorn fishway and intake.
- Proper and safe operation of all equipment at the hatcheries.
- Data entry, auditing, data storage, reporting. Coordination and collaboration with staff from the M&E program to assist data transfer, analyses, and reporting.
- Driving various vehicles, including CDL rated trucks (Class B).
- Attend District and departmental meetings.
- Employ strong communication skills with other District staff, contractors, sharing partners, etc.
- Maintenance of equipment and facilities.
- Maintenance of the grounds (snow plowing, irrigation system operation, tending to plants, grass areas, landscaping).
- Maintenance of buildings.
- Maintenance of vehicles.
- Operation of the hatcheries through the Supervisory Control and Data Acquisition (SCADA) systems and optimization of the systems via SCADA.
- Operation and maintenance of groundwater wells. Department of Ecology (Ecology) data collection.
- Operation and maintenance of surface water supply sources. Ecology data collection.
- Obtaining and maintaining permits (NPDES, HPA, Fish Transfer, etc.).

- Reports – support for writing reports, ESA reporting, NPDES reporting, and various other reporting responsibilities, data requests, etc. Coordination and collaboration with District staff and staff from the M&E program.
- Work collaboratively with M&E staff and District personnel to ensure optimal and efficient assessment of the hatchery programs.
- Attend professional trainings and conferences as appropriate.
- Staff shall strive to meet the District's mitigation and sharing partner's mitigation with the highest level of professionalism and quality as possible.
- Work with, hire, and manage District contractors to achieve District's goals and meet all District responsibilities.
- Participate in fishway drawdowns (Fish Rodeo) and other activities related to fish passage, and fishway maintenance and operations.
- Perform all required environmental and safety inspections, sampling, and reporting, and training as required by permits, state and federal rules and regulations, and District policies.
- Work with regulators – compliance with state and federal rules, laws, permit conditions, etc., related to the District's hatchery programs and M&E programs.
- Develop work plans, budgets, budget requests, purchase requests related to the hatchery programs and facilities.
- Perform project/contract management and oversite at the hatchery facilities.
- Surplusing fish – provide operational support and facility oversite when surplusing fish. Coordinate with Washington Department of Fish and Wildlife (WDFW), and tribes and other entities that may receive fish. It is WDFW's purview and responsibility to determine the disposition of surplus fish. The District will support this effort in our facilities.
- Adult management (gene flow management). Provide operational support when conducting adult management. Follow adult management plans established by the HCP committees under the appropriate ESA permits. Coordinate with federal, WDFW, and co-manager authorities to ensure proper execution of the adult management plans. It is WDFW's purview and responsibility to determine the disposition of surplus fish. The District will support this effort in our facilities.
- ESA reporting. Coordination and collaboration with District staff, staff from the M&E program, and federal agencies to ensure timely and proper reporting under ESA.
- Coordinating with other agencies and tribes as related to their use of District facilities and collaborative programs that may involve other entities.

2.3.1 Worker Training

Training will be provided and mandated as appropriate for each position. All employees will be trained on all District policies, safety policies, and human resource-specific training regarding workplace conduct.

Training video development is underway for the new Wells Hatchery. The District is creating in-depth training videos for all of the systems, processes and operations activities at the Wells Hatchery. These videos feature factory representatives and technicians, construction supervisors, and District staff explaining and demonstrating how all features of the new facility work, maintenance of the features, and how these features integrate to form a cohesive fish-rearing infrastructure. The videos will be completed by October 15th and until final are available in draft format for review and training.

Trainings may include, but not be limited to:

- Sexual harassment training
- Workplace safety
- Formalin training
- Respirator training
- Confined space training
- District workplace policies
- District purchasing procedures
- District bid document procedures
- CDL Class B with tanker and air brake endorsements
- Fork lift operator
- Tractor operation
- Snow plow operation
- Operation of Wells Hatchery training videos (see discussion, above) and in person training
- Operation of Methow Hatchery (in person training)
- Biosecurity protocols
- Professional development – as required and appropriate
- Endangered Species Act – ESA permit conditions compliance
- Trapping protocols (operations)
- Broodstock protocols
- Habitat and Conservation Plan – understanding the HCP
- Aquatic Settlement Agreement (ASA) – understanding the ASA
- Off-License Settlement Agreement (OLSA) –understanding the OLSA
- Hatchery Sharing Agreements – understanding the hatchery sharing agreements
- Acting on the behalf of the District and proper implementation of its mitigation programs
- Survival studies – planning and execution of District survival studies
- Washington State Boat Operator Training
- Pesticide application
- Computers and phones – District policies and technical use of devices
- Network security (cyber security)
- Cell phone policies
- Vehicle use policies
- North American Electric Reliability Corporation (NERC) and Federal Energy Regulatory Commission (FERC) requirements and awareness
- Wells Hatchery training – training videos and in-person trainings
- SCADA systems training and support
- District FERC License reporting tasks and requirements
- Dam safety training and awareness

- Dam security, emergency action plan at dam
- Develop and train: hatchery emergency action plans for the fish
- Develop and train: hatchery emergency action plans for human safety

2.3.2 Orientation

- Human Resource Paperwork
  - Survivor benefits, deferred compensation, W-2 payroll deductions
- Vehicles
  - Mileage sheet
  - Keys and maintenance logs and schedules
  - Gas cards
- Cellular phone reimbursement and telephone extensions
  - Administrative bulletin on cell phone use

- Network access
  - Username, passwords, RSA credentials
  - Purchase requests, purchase orders, work orders, NISC, ESS
  - Training for timesheet
  - Per diem books, petty cash
  - Remote access
  - Notebook computer assignments
- Wells Hatchery training – training videos and in-person trainings (see above)
- Methow Hatchery training (see above)
- SCADA systems training and support

2.3.3 Certifications

Each employee will receive proper training in order to receive certification and/or licensing for any duties or responsibilities needed for their particular position.

- CDL Class B license with air brake and tanker endorsements
- Respirator
- Confined space
- DVM – prescriptions
- Fork lift
- Pesticide applicator
- CPR & First Aid
- Washington State Boat Operator License
- Others as needed

2.3.4 PUD Strategic Plan and Administrative Bulletin

Mission Statement: To provide the best possible utility services at the lowest possible cost consistent with sound business principles.

Value Statements:

- Douglas PUD makes policy decisions in open public meetings with consideration of community needs, public input, and the best interests of the District
- Douglas PUD is fiscally responsible
- Douglas PUD is environmentally responsible
- Douglas PUD is service oriented and responsible to its public owners
- Douglas PUD values its employees
- Douglas PUD employees take ownership in the services they provide and the assets for which they are responsible
- Douglas PUD provides a safe workplace and promotes a safe community
- Douglas PUD pursues regional issues through, and is committed to, the success of its industry associations

Planning Statements:

- Douglas PUD follows an Integrated Resource Plan for electric supply focused on meeting resource needs with owned assets or long-term contracts
- Douglas PUD prefers renewable resources in new power-supply decisions
- Douglas PUD is committed to local and bulk electric system security and reliability
- Douglas PUD promotes information-age technology development
- Douglas PUD monitors growth potential to plan system changes proactively

2.3.5 Compensation

In addition to salary grades that exceed the State's hatchery salary grades, all of the PUD's hatchery employees will benefit from the PUD's benefit package including the full medical, dental, vision, deferred compensation, VEBA, short- and long-term disability, worker compensation and life insurance benefits.

All of the hatchery workers will be expected to cover standby time at some time during the year due to planned and unplanned absences by designated standby employees. Hatchery housing is a requirement of employment for those employees designated as being essential for the function of the facilities. Employees in District hatchery housing will be required to cover their own utility expenses with the notable exception of phone and power (Wells Hatchery) and phone (Methow Hatchery). Compensation levels for each position are designed to reflect the job duties that have been assigned to each employee.

3.0 CULTURE/TONE OF WORK PLACE

The District's workplace culture will be held to the highest standards that include, but are not necessarily limited to, the following attributes:

- Professionalism
- Integrity
- Honesty

- Goal-oriented
- Respect for others
- Report problems to supervisors
- Supervisors must act on observed or reported information regarding possible workplace violations
- Motivated workforce
- Creative problem solving
- All employees contribute to improving the District's programs and workplace
- Positive attitude
- Collaborative – teamwork approach and environment
- Excellent communication
- Support and acceptance of those who report mistakes or problems
- Compliance with rules and regulations

4.0 FISH ACCOUNTING PRE AND POST TRANSITION

Work with WDFW to provide current numbers of fish on station and records pertaining to the fish on station (mortalities, transfers, releases, egg take, etc.).

Set up fish accounting system for Wells Hatchery. The District will develop a data management system for the hatcheries that captures the types of data entered into WDFW FishBooks to the extent the similar data can be reported to co-managers and in reports. The District's Information Services Department (IS) will assist the Natural Resources Department (NR) in developing this new more user-friendly fish accounting and tracking database. Greg Mackey (NR) will take the lead in the database development in coordination with Charlie Snow and hatchery staff:

- Obtain samples of FishBooks data structure.
- Create draft data structure for the District's database development.
- Set up Excel or Access database for interim data management while the full database is developed (if needed).
- IS and NR will work together to develop a SQL database (SQL Server).
- IS and NR will work together to develop a front end for the database (MS Access).
- Hatchery staff and M&E Program staff will be involved in the development of the database so it meets their needs.
- Train staff and implement the database.
- The database should be available to all NR staff (hatchery and East Wenatchee staff).
- Establish permission levels for the staff (read only, data entry, data steward, and administrator).

Establish HCP Hatchery Committee-approved formal methods of accounting for fish at various life stages. Work with WDFW M&E Program staff to ensure sampling methods are transparent and consistent with past methodologies. Seek improvement to methodologies where needed.

5.0 PERMITS – ESA, CWA, NPDES, FISH TRANSFER PERMITS, HPA

The new hatchery managers, working with established NR staff, will be responsible for obtaining and complying with the applicable hatchery permits. However, in the transition window, existing NR staff must take the lead role in obtaining any necessary permits that are not already in the District's possession or name.

As of September 25, 2017 the District is not aware of any additional permits necessary for the operation of the hatcheries other than those identified below. The list below is prioritized in terms of which permits are needed first.

5.1 ESA Permits

There are six ESA permits that provide the District with ESA direct and/or incidental take coverage in association with the operation of the Methow and Wells hatcheries. Permit No. 1391 authorizes incidental take associated with operation of the Wells Project in accordance with the Wells HPC, including the HCP hatchery programs. Additionally, there are separate permits for the respective hatchery programs: two permits for the Methow spring Chinook program, one permit for the Wells, Methow, Twisp, Okanogan and Omak steelhead programs, one permit for the summer Chinook program at Wells Hatchery, and one bull trout hatchery operation permit.

5.1.1 Spring Chinook (Grant/Douglas PUDs)

Under Permit No. 18925, the District is a Permit Holder authorized to take ESA-listed species in the course of operating and monitoring the spring Chinook hatchery program at Methow Hatchery. WDFW remains responsible for the disposition of fish deemed surplus to recovery needs. The District plans to continue to have WDFW perform M&E covered by this permit (with the District's assistance, as currently occurs). District hatchery employees will work with WDFW M&E staff to identify clearly defined roles and responsibilities for recording M&E data for the in-hatchery evaluation activities.

5.1.2 Spring Chinook (Chelan PUD)

Under Permit No. 20533, the District, as an agent, is authorized to take ESA-listed species in the course of operating and monitoring the spring Chinook program Methow Hatchery. WDFW remains responsible for the disposition of fish deemed surplus to recovery needs. The District plans to continue to have WDFW perform M&E covered by this permit (with the District's assistance, as currently occurs). District hatchery employees will work with WDFW M&E staff to identify clearly defined roles and responsibilities for recording M&E data for the in-hatchery evaluation activities.

5.1.3 Steelhead (Douglas PUD Programs)

Under Permit No. 1395, the District is a Permit Holder authorized to take ESA-listed species in the course of operating and monitoring the summer steelhead hatchery program at Wells Hatchery. Additionally, per the Wells HPC, the District is in an active consultation for a new permit with NOAA to replace Permit No. 1395. The District plans to continue to have WDFW perform the M&E actions covered by this permit (with the District's assistance, as currently occurs). WDFW remains responsible for the disposition of fish deemed surplus to recovery needs, including fisheries. District hatchery employees will work with WDFW M&E staff to identify clearly defined roles and responsibilities for recording M&E data for the in-hatchery evaluation activities.

The District filed a Hatchery Genetic Management Plan with the National Marine Fisheries Service in 2011 requesting coverage for these programs to replace Permit No. 1395, per the Wells HCP. The District anticipates receiving a new permit in mid-2018 for the steelhead programs.

5.1.4 Steelhead (Grant PUD Programs)

Under Permit No. 1395, the District is a Permit Holder for Grant PUD's steelhead programs at Wells Hatchery (see above). District hatchery employees will work with WDFW M&E staff and Colville Confederated Tribes (CCT) staff to identify clearly defined roles and responsibilities for recording M&E data for the in-hatchery evaluation activities. The District does not conduct any actions under this program that results in incidental take outside the hatchery facility. The CCT conduct broodstock collection and release juveniles into the Okanogan River and tributaries. All of these actions occur under the jurisdiction of the CCT Tribal Resource Management Plan. The CCT are expected to continue conducting the off-station M&E tasks identified in this permit.

5.1.5 Summer Chinook (Douglas/Grant/Chelan PUDs)

Under Permit No. 1347, the District is a Permit Holder authorized to take ESA-listed species in the course of operating and monitoring the summer/fall Chinook hatchery program at Wells Hatchery. WDFW remains responsible for the disposition of fish deemed surplus to recovery needs, including fisheries. The District plans to continue to have WDFW perform M&E actions covered by this permit (with the District's assistance, as currently occurs). District hatchery employees will need to work with WDFW M&E staff to identify clearly defined roles and responsibilities for recording M&E data for the in-hatchery evaluation activities.

The District filed a Hatchery Genetic Management Plan with the National Marine Fisheries Service in 2013 requesting coverage for these programs to replace Permit No. 1347, per the Wells HCP. The District anticipates receiving a new permit in mid- to late-2018.

Douglas PUD's Okanogan spring and summer Chinook mitigation obligations and Methow summer Chinook obligations are met through a cooperative rearing agreement between BPA, CCT, and Douglas PUD. These fish are produced at the Chief Joseph Hatchery, and the CCT and BPA have ESA coverage for their authorized action at this facility.

5.1.6 Coho Salmon (Douglas PUD)

Douglas PUD's Coho salmon mitigation obligations are scheduled to start with brood year 2018 in the Methow Basin in close association with the actions being carried out by the Yakama Nation. Yakama Nation staff will be responsible for capturing brood stock. Douglas PUD will be responsible for producing juveniles at Wells Hatchery for release to the Twisp River drainage from the Twisp Acclimation Pond. The Yakama Nation has ESA coverage for their authorized actions at both the Wells and Methow hatcheries and associated acclimation facilities, including brood collection and juvenile releases.

5.1.7 Bull Tout (Douglas 2012)

The District's bull trout permit (2012) provides incidental take coverage for all of the District's current hydro and hatchery programs including brood collection and release of fish reared at the Wells and Methow hatcheries.

5.2 NPDES Permits

Several steps have been identified to complete hatchery compliance with National Pollutant Discharge Elimination System (NPDES) permitting. Steps include submitting to the Washington Department of Ecology (Ecology) an Upland Fin-Fish Hatching and Rearing General Permit Coverage Modification Due to Change in Facility Status (Transfer Application) for both Methow and Wells Fish Hatcheries. The Washington Department of Fish and Wildlife Service (WDFW) will need to complete their section of the transfer application and return it to the District. Transfer Applications were signed by the District's General Manager and mailed to WDFW September 14, 2017 via certified mail.

As of September 28, 2017, an account has been set up with Secure Access Washington, which will be the electronic reporting mechanism once the District takes over NPDES sampling and reporting. The District submitted to Ecology an Electronic Signature Agreement Form (ESAF) along with the Transfer Application. In addition, the District's General Manager will need to sign a letter that gives qualified District employees signing authority within the Secure Access Washington reporting platform (Signing Authority Letter). Each District employee that is granted signing authority for NPDES reporting will need to complete an ESAF document that lists both hatchery permit numbers on it (WAG 135000 and WAG 135009). The Transfer Application, ESAF request form(s), and Signing Authority Letter will be submitted to Ecology's Central Regional Office immediately following WDFW returning the signed Transfer Applications.

Additional steps will include updating the Site Specific Plans, the Solid Waste Management Plans, and the Pollution Prevention Plans, for each hatchery with new hatchery drawings and locations of sampling, designating staff, etc. This may also include developing a Standard Operating Procedures document for where and how samples are taken from each facility. New hatchery supervisors at Methow and Wells hatcheries will work closely with existing District NR staff to complete these updated plans. Revised plans will be submitted to Ecology's Central Regional Office.

The District will also seek quotes from qualified vendors to analyze various monthly and non-routine samples such as total suspended solids. Other samples will be taken onsite at hatcheries using qualified equipment (e.g. pH meter). Cascade Analytical of Wenatchee has been identified as a qualified laboratory for analyzing these samples. They are currently performing similar work for the CCT's Chief Joseph Hatchery.

Ecology's Central Regional Office and the District have tentatively scheduled a site inspection for the spring of 2018.

Ecology and the District have also discussed requirements to seek fish food with low PCBs from vendors and PCB monitoring that is currently ongoing in Spokane, which may influence PCB reduction at all hatcheries in Washington State that discharge waters into the Columbia River.

Annual Chemical Use Reporting, Quarterly Reporting, and Permit Expiration/Update deadlines, biennial inspections will be added to the District's FERC and Water Quality Reporting Compliance Database. The District's Compliance Officer will add these compliance criteria and ensure that hatchery supervisors and other key District staff are sent reminders via email in order to maintain routine compliance deadlines. Although these steps are not required for NPDES permitting they are consistent with the District's existing internal compliance monitoring and allow the District to meet compliance criteria in advance of deadlines per District standards.

5.3 Hydraulic Permit Application

The Twisp Weir traps have been installed and removed each year under the WDFW state-wide HPA. The District shall seek its own HPA for installation of the Twisp Weir traps (and any seasonal adjustments to the existing Methow outfall trap), although WDFW M&E staff annually assist in installing and operating the traps at the weir, and the WDFW HPA may still be used for such installation. HPA permitting will likely also be required for work that may be conducted in the future on the Methow Hatchery outfall trap and channel, and possibly other District-owned or funded facilities such as the Twisp Pond and Foghorn fishway and intake. Certain other activities, such as planting in-stream egg incubators or installing scour monitors may require an HPA, but may also be covered via state-wide HPA when performed by or in coordination with the M&E staff.

The District has determined that it will seek and receive their own HPA for the installation of the Twisp and Methow traps, and certain other activities as described above. These permits will not be needed until March 2018 but the permit application will be filed to ensure that proper authorization is received in ample time to install the Twisp traps. Application for the HPA permits was initiated prior to September 20, 2017.

5.4 Fish Transfer and Stocking Permits

On a case by case basis, the District Hatchery Supervisors will request fish transfer and fish stocking permits from WDFW. WDFW will need to sign each transfer or stocking request for each group of juvenile and adult fish transferred between hatcheries, and to acclimation or release sites. All of the District's fish movements between facilities and acclimation ponds and release sites are known many months in advance and are either associated with the implementation of the HCP, Aquatic Settlement Agreement, or Off-License Settlement Agreement, or agreements held by District hatchery sharing partners.

The District will explore receiving an annual fish transfer permit from WDFW to reduce the tedious permit request/receipt work load on both District hatchery personnel and WDFW.

6.0 MONITORING AND EVALUATION PLAN

The District's M&E Plan will continue to function as it has for the past ten years. WDFW will perform the activities identified in the HCP Hatchery Committee-approved Monitoring and Evaluation Plan in cooperation with District personnel. This includes the conduct of the in-hatchery M&E as well as the field M&E. The District's Fish Health Specialist will coordinate and collaborate with WDFW M&E staff to conduct sampling and manage data. Production of reports and analyses will continue to be completed in collaboration between WDFW M&E and District staff.

Regarding the in-hatchery M&E work, there are times when the hatchery staff collect data that are used by the M&E program in the WDFW M&E reports and conversely, the hatchery needs data collected by the M&E staff. The District will continue to collect and provide that information as required by the M&E plan. The District will also engage with the M&E staff to ensure the proper flow of information to the hatchery staff. The WDFW M&E staff, led by Charlie Snow, will engage in the implementation of the Transition Plan. District and WDFW M&E staff will coordinate the assignment of data collection and reporting roles.

District hatchery employees will work with WDFW M&E staff to identify clearly defined roles and responsibilities for recording and exchanging M&E data for the in-hatchery evaluation activities. The Fish Health and Evaluation Specialist will be responsible for ensuring that the M&E plans are properly implemented at all of the District's hatchery facilities.

6.1 Marking, Tagging, and CWT and Scale Reading

Marking and tagging will conform to the requirements established in ESA permits and through the HCP committees and ASA committee. The co-managers, through the HCP process and under the ASA, will determine marking plans. The status quo marking plan will be followed until a new marking plan can be approved by the HCP Hatchery Committee.

At this time, the next coded wire tagging (CWT) and fin clip marking would not occur until spring or summer 2018. This provides some time to establish necessary arrangements for CWT and fin clipping. Currently WDFW performs all of the District's marking, tagging, and CWT- and scale-reading functions. Continuation of this arrangement is pending discussions with WDFW.

PIT tagging in the hatcheries is currently performed by Biomark (under contract with the District).

7.0 PATHOLOGY

The District is seeking to hire a doctor of veterinary medicine (DVM) licensed in Washington State for the Fish Health and Evaluation Specialist position. This position will be responsible for all fish health matters at the hatcheries and will conform to or exceed standard-of-care levels for fish culture facilities. The Fish Health and Evaluation Specialist will be an integral part of the hatchery team and will be involved in all aspects of fish rearing and handling that relate to fish health and will ensure a seamless coordination of activities between hatchery rearing and M&E staff. The Fish Health and Evaluation Specialist will also be responsible for conducting research at the two facilities to identify and test new ways to treat diseased fish and to contain active outbreaks of disease in the facility. Areas of emphasis include finding alternatives to antibiotics and formalin.

When the District hires the DVM, the new employee will be responsible for purchasing all of the laboratory equipment and supplies necessary to ensure that proper screenings and sampling can take place in a timely manner. Microscopes, chemicals, a new work station in the research room at Wells Hatchery and in the administration offices will need to be provided to the new Fish Health and Evaluation Specialist. The District's DVM will obtain the services of necessary specialized laboratories, either via contract or on a case-by-case basis.

If a suitable candidate cannot be hired for the Fish Health and Evaluation Specialist, the District will pursue contracting for fish-health services.

8.0 OUTREACH PLAN – AGENCIES, TRIBES, PUDS

Call the HCP Coordinating and Hatchery committee members to inform them of the District's decision to take over operation of the hatcheries and discuss transition-planning scenarios and concepts (completed during week of August 28, 2017). Provide the HCP Hatchery Committee with a list of transition issues (completed on September 20, 2017). Provide the HCP Hatchery Committee with a copy of the Public Transition Plan (scheduled for the first week of October).

The District has and will continue to provide updates to HCP committees, tribes and agencies, as needed, and during scheduled HCP and ASA meetings (and others as needed). The District will pursue potential collaboration or partnerships that may be advantageous to the District and collaborators for improving the hatchery programs.

9.0 TRAPPING

Fish trapping will conform to all ESA permit condition and protocols or conditions established by the HCP committees, including the Broodstock Protocol. Staff will be trained to use trapping facilities and on the trapping rules, as noted above. Trapping will be coordinated with staff from the M&E program and will be a collaboration of District staff and WDFW M&E staff as needed to optimize the trapping operations. Trapping will also be coordinated and supervised during the YN coho and CRITFIC sockeye trapping. The same supervision will be required for any other non-District trapping request and operation. Real-time reporting of trapping results, as needed, will be conveyed through the M&E staff, or directly through District staff.

Staff will be trained as to the Broodstock Protocols, and ESA permit conditions and HCP committees trapping requirements. The training will be coordinated with staff from the M&E program to ensure that all personnel are working from a common basis of knowledge.

M&E and District crews will be involved in setting up and operating trapping, including coordination of fish assessments and target numbers. The extent and focus of this coordinating will depend on the specifics of the trapping.

10.0 ADULT MANAGEMENT AND SURPLUSING

WDFW is currently and will continue to be responsible for the disposition of fish captured for adult management and surplusing. The PUD will be responsible for trapping at District hatchery facilities and providing to WDFW those fish determined surplus to recovery needs. District hatchery staff will work collaboratively with WDFW, as the responsible party, but also with USFWS, Colville Tribes, Yakama Nation and the Spokane Tribes (and others as appropriate) to ensure that surplus hatchery fish are made available to authorized personnel within these organizations. The District's Hatchery Supervisor and Safety Officer will ensure strict adherence to worker safety and humane surplusing during all adult management activities. Indemnification and facility use agreements will be required for all tribal entities that are invited by WDFW to participate in surplusing activities at the District's hatchery facilities.

The District is currently funding a long-term Relative Reproductive Success Study on Methow Basin steelhead where hatchery-origin steelhead have been removed at the Twisp Weir to attain a certain ratio of hatchery to wild fish upstream of the weir. The need to conduct this adult management for the study ended in 2017, but adult management is expected to continue with a defined target (yet to be established via the HCP Hatchery Committee) for the proportion of hatchery fish to allow upstream. WDFW (via the M&E program) is currently the District contractor for these actions.

11.0 GENETICS

The operation and monitoring of the District's hatchery programs include the following genetic services:

Spring Chinook broodstock stock assignment – Will be budgeted under the M&E contract.

Broodstock and run sampling for population genetic analysis (steelhead, spring Chinook, summer Chinook) – sample collection performed through the M&E contract; past analyses were performed through stand-alone contracts (for analyses performed periodically).

Juvenile Chinook assignment – covered under the M&E contract.

Twisp Steelhead Reproductive Success – performed through a stand-alone contract with WDFW.

For genetic services not performed under the M&E contract the District will review options among labs capable of performing the specified work.

12.0 FISH HUSBANDRY

Fish husbandry will follow current best-management practices for biosecurity, spawning, holding adult and juvenile fish, incubation, treatment of fish for disease or pathogens, fish health, appropriate feeding regimes, rearing densities and flow indices, water quality, humane treatment of the animals, predator control, and any other actions or factors that influence the quality and quantity of the fish produced at District facilities.

The hatchery supervisors will be responsible for developing the fish-husbandry protocols and keeping them current. The hatchery staff will be expected to maintain best practices and remain educated on advances in fish culture, and implement advances as they are appropriate and advantageous to the program(s) at the District's facilities. Experimental fish-culture approaches must be proposed to and approved by the appropriate governing committee(s) if those approaches may alter conformance to the specific rearing targets in the various agreements and management plans for the District's and its sharing partners' programs.

The following resources will be used as guiding documents for fish health and culture practices:

Co-managers (Washington Department of Fish and Wildlife and Western Washington Treaty Indian Tribes). 1998. Co-managers of Washington fish health policy. Washington Dept. Fish and Wildlife, 600 Capitol Way N, Olympia, WA. 98501-1091.

IHOT (Integrated Hatchery Operations Team). 1995. Policies and procedures for Columbia Basin anadromous salmonid hatcheries. Annual Report 1994. Bonneville Power Administration, Portland, OR. Project Number 92-043.

Pacific Northwest Fish Health Protection Committee (PNFHPC). 1989. Model comprehensive fish health protection program. 19 pp.

Piper, R.G., I.B. McElwain, L.E. Orme, J.P. McCraren, L.G. Fowler, and J.R. Leonard. 1982. Fish Hatchery Management. United States Department of the Interior. Fish and Wildlife Service. Washington D. C. 517 p.

Washington Department of Fish and Wildlife (WDFW). 1996. Fish health manual. Fish Health Division, Hatcheries Program. Washington Dept. Fish and Wildlife, 600 Capitol Way N, Olympia, WA. 98501-1091.

12.1 Fish Culture Practices – Expertise and Training

All of the District's hatchery workers will be required to have extensive hatchery or aquaculture experience including professional, technical, and/or on-the-job training experience before coming to work for Douglas PUD. This includes the Supervisors, Senior Hatchery Specialists and Hatchery Specialists. Fish-culture practices and procedures will follow guidance provided by the HCP Hatchery Committee, experience of District staff, and other respected resources such as Piper et al., etc. Staff will be encouraged to review current literature, attend continuing education, conferences, and training events to advance their knowledge of fish-culture practices.

Vocational hatchery culture training or higher levels of education are highly desirable in these programs. Work experience coupled with demonstrated ability to culture fish with excellence will also be highly desirable.

12.2 Fish Feed Contract

Fish feed currently used at District facilities includes products from three major vendors: EWOS, Rangen, and BioOregon. Bio-Oregon is the largest single provider for fish feed for the Wells and Methow hatcheries. The District is initiating contractual purchase agreements with feed vendors informed by an inventory of existing feed and new estimates of monthly feed deliveries. Delivery and storage at both facilities will be coordinated with new District hatchery personnel.

Selected feed will remain consistent with that feed that has been used for the current cohorts on station. However, the Hatchery Supervisors may revise the feed choice at any time, as has been their practice. Feed deliveries will be set up to ensure sufficient feed is on station at each hatchery for all programs.

13.0 EQUIPMENT INVENTORY

The District will work with existing WDFW staff to perform inventories of equipment and supplies, determine which items should have a District number and label and record, develop an inventory list, and develop a list of necessary purchases prior to November 28th.

The District will train hatchery supervisors and senior hatchery specialists on the new PUD purchasing system. The hatcheries make a tremendous number of purchases each year, some of which are very time sensitive requiring specialized procurement procedures that ensure rapid deliveries of products.

13.1 Transfer Titles - Vehicles

The District will work with existing WDFW staff to request transfer of vehicle titles or certificates of ownership back to the District as per the contract. An inventory of all vehicles or items for which WDFW may hold title or certificate of ownership is required in order to request all titles and certificates of ownership. Titles or certificates of ownership include vehicles, ATVs, fish pumps, and tractors. The District's Purchasing Department will assist with titles to vehicles and other items that may have title or certificates of ownership.

The District would prefer to receive title to all of the hatchery vehicles by October 31st so that new PUD hatchery employees can use existing vehicles for hatchery duties. The District's vehicle insurance policy covers all of the District contractors, allowing all of the new and existing hatchery workers (WDFW or PUD employees) to perform station-service duties during the transition window.

If necessary, the District has several surplus and excess vehicles that can be used for a short-term (30 days) basis to move equipment and material around the hatchery site.

Table 1. Inventory of vehicles associated with the Wells Hatchery.

License Number	VID	VIN	Veh Type	Year	Make	Model/Desc	Inventory Number	Special Use	Prog Code	Cost Code	BienYr	MI
14744E	989	1GDP7H1C1YJ521621	V	2000	GMC	FISH TANK TRUCK	FW007138	SU	F	11	2019	00053260
16458E	350168	1GDP7H1C32J507081	V	2002	GMC	PLANTING TRUCK 34...	FW009291	SU	F	11	2019	00053260
19328E	550354	1GCDT136X58213352	V	2005	CHEV	COMPACT 4X4 TRUCK	FW012727	SU	F	2	2019	00053260
20371E	850420	1FTRF14WX7NA49343	V	2007	FORD	1/2 TON 4X4 TRUCK	FW014917	SU	F	4	2019	00053260
21779E	1050478	1FDAF57Y79EA15201	V	2009	FORD	F550 4X4 1 1/2 TON ...	FW016156	SU	F	12	2019	00053260
23937E	1150505	1FTFW1EV7AFA61265	V	2010	FORD	F150 1/2 TON 4X4 CR...	FW016669	SU	F	4	2019	00053260
26957E	1170766	1FTBF2B64GEB18005	V	2016	FORD	F250 SUPERCAB	FW21723	SU	F	6	2019	00053260

Table 2. Inventory of vehicles associated with the Methow Hatchery.

X	Tag No.	Item Description		Qty	Date New	Value at Acquisition	Value as of 07/07/2017	Amour Deprec
X	G013066	PUMP FISH 6" INTAKE		1.0	02/11/1987	15,372.50	0.00	15,3
		Manufacturer: NEILSON	Serial #: A8824			Disp-Date:		DIsp-Autho
		Model No.: 51916LG	Extra: ON COUNTY TRAILER C48580					User Name:DINSM(
	X002024	TRACTOR		1.0	10/29/1993	17,744.18	0.00	17,7
		Manufacturer: KUBOTA	Serial #: L2950D51771			Disp-Date:		DIsp-Autho
		Model No.: L2850	Extra: TAG TO LEFT OF STEERING WHEEL					User Name:DINSM(
X	X002057	TRAILER FLATBED UTILITY 7X14' 1993		1.0	10/29/1993	1,500.00	0.00	1,5
		Manufacturer: WILSON 07338E	Serial #: 4BMFS1627R2500134			Disp-Date:		DIsp-Autho
		Model No.: W/SIDEBOARDS	Extra:					User Name:DINSM(
X	FW012633	CAMERA DIGITAL		1.0	03/12/2005	351.22	0.00	3
		Manufacturer: OLYMPUS	Serial #: 515723309			Disp-Date:		DIsp-Autho
		Model No.: STYLUS 410	Extra:					User Name:DINSM(
X	FW013535	TRUCK 1 TON 4X4 FLATBED 2006		1.0	08/22/2005	27,476.42	0.00	27,4
		Manufacturer: CHEVROLET 19398E	Serial #: 1GBJK34G46E143752			Disp-Date:		DIsp-Autho
		Model No.: SILVERADO 3500	Extra: W/500 GAL TANK FW015009 (IN SUMMER MONTHS)					User Name:DINSM(

X	Tag No.	Item Description		Qty	Date New	Value at Acquisition	Value as of 07/07/2017	Amou Deprec
X	FW015659	TRUCK 2008		1.0	04/01/2008	33,931.44	0.00	33,9
	Manufacturer:	FORD 21759E	Serial #: 1FDAF56Y78ED52029			Disp-Date:		Disp-Autho
	Model No.:	F550XL SUPERDUTY	Extra: W/800 GAL TANK FW004339					User Name:DINSM
X	FW018779	ATV 2011		1.0	06/06/2012	9,195.92	0.00	9,1
	Manufacturer:	ARCTIC CAT +730769	Serial #: 4UF11MPV7BT300235			Disp-Date:		Disp-Autho
	Model No.:	PROWLER XT 550	Extra: TAG UNDER HOOD					User Name:DINSM
	FW020462	ULTRASOUND VETERINARY EQUIPMENT		1.0	06/02/2014	7,112.98	5,235.94	1,8
	Manufacturer:	HONDA	Serial #: 31240330			Disp-Date:		Disp-Autho
	Model No.:	HS-101V	Extra: LINEAR RECTAL TRANSDUCER S/N 31102290					User Name:DINSM
X	FW021282	CHAINSAW 18"		1.0	04/01/2015	367.83	224.78	1
	Manufacturer:	STIHL	Serial #: 500530824			Disp-Date:		Disp-Autho
	Model No.:	MS 251	Extra:					User Name:KLMEF
X	FW021283	SNOW PLOW		1.0	04/16/2015	6,810.30	3,632.16	3,1
	Manufacturer:	BOSS	Serial #: 220002			Disp-Date:		Disp-Autho
	Model No.:	8' 2" VXT	Extra:					User Name:KLMEF
X	FW021403	TRAILER TRAVEL 22" 2015		1.0	06/09/2015	15,488.78	8,776.98	6,7
	Manufacturer:	FOREST RIVER 26903E	Serial #: 4X4TCS618FT182113			Disp-Date:		Disp-Autho
	Model No.:	CASCADE LITE	Extra: TAG IN CUPBOARD					User Name:WAHLS
X	FW021722	TRUCK 3/4 TON 4X4 EXT CAB 2016		1.0	11/18/2015	30,800.05	20,020.03	10,7
	Manufacturer:	FORD 26964E	Serial #: 1FT7X2B62GEB18006			Disp-Date:		Disp-Autho
	Model No.:	F250	Extra:					User Name:KLMEF
X	FW022451	TRACTOR 65HP W/LOADER & CUTTER		1.0	09/14/2016	40,326.19	36,629.62	3,6
	Manufacturer:	JOHN DEERE	Serial #: PXCG083108413			Disp-Date:		Disp-Autho
	Model No.:	5065E	Extra: W/H240 LOADER FW022452, AP13G PALLET FORK, & RC2060 ROTARY...					User Name:KLMEF
X	FW022452	LOADER FRONT END		1.0	09/14/2016	6,565.22	5,562.20	1,0
	Manufacturer:	JOHN DEERE	Serial #: P0H240XKGC025680			Disp-Date:		Disp-Autho
	Model No.:	H240	Extra: USUALLY W/JD5065E TRACTOR FW022451					User Name:KLMEF
X	FW022881	TANK FISH FIBERGLASS 800 GAL		1.0	04/12/2017	26,353.70	25,621.65	7
	Manufacturer:	REIFF MANUFACTURING	Serial #: 477907			Disp-Date:		Disp-Autho
	Model No.:	5020	Extra:					User Name:KLMEF
	ITEMS: 16				TOTAL:	$ 250,160.67	$ 107,347.85	$ 142,8

14.0 INSURANCE

Insurance for the existing WDFW hatchery vehicles will be converted to District coverage once title to the vehicles has been transferred back to Douglas PUD per the contract. Similarly, once the title to the hatchery housing at Wells Hatchery has been transferred back to the District, then appropriate insurance will be established to protect the District's investment.

All of the new buildings, pumps and associated hatchery equipment at Wells Hatchery will need to be moved off of the builder liability policy and to the District's comprehensive insurance policy as soon as the owner begins to occupy and operate the new buildings. The square footage of these buildings has been provided to the District's insurance agent.

15.0 JANITORIAL AND GROUNDS KEEPING

The District will obtain a janitorial and/or landscaping contract for the Wells Hatchery and possibly the Methow Hatchery. In the short-term, janitorial services will be covered via a purchase authorization. Long-term janitorial services for Wells Hatchery will be bid along with services for the boat launches and Vista Overlook Park.

Landscaping will be covered under the District's existing contract until December 2017. The scope of work for this contract already covers all of the East Wenatchee headquarters building and all of the landscape surrounding Wells Dam and Hatchery. In the short-term no modifications to the contract are necessary to cover the new hatchery grounds per the existing weed-control plan.

A new bid document for landscaping services will be issued by the end of 2017 toward coverage for a new term starting in January 2018.

16.0 DIESEL FUEL AND SERVICE

The District will establish a contract to purchase diesel fuel for the Methow Hatchery backup generator. The District will also establish a contract for maintenance and repair of the Methow Hatchery backup generator. The Hatchery Supervisor will take the lead on these items.

17.0 TRASH

The District will establish a contract to have trash picked up at the Wells Hatchery and Methow Hatchery. The Hatchery Supervisors will establish a plan to handle trash and recycling at their respective facilities. The Hatchery Supervisors will take the lead on this item.

18.0 SAFETY

Workplace safety is a core mission of Douglas PUD. The District's Safety Officer will prepare a Workplace Safety Training and Procedures Manual for each facility. These documents will be ready for implementation prior to December 1, 2017. New safety grating, railing, and signage currently being installed at Wells Hatchery should be completed by October 31st. Formalin eye-wash and showers are scheduled for installation by November 15th.

19.0 HOUSING

The District will determine which employees/positions shall occupy the on-station hatchery houses and be responsible for stand-by duties associated with the hatcheries.

The District will also need to establish a rental agreement that can be signed as part of the employment package. The rental agreement must include the rules of conduct for tenants, the assignment of costs for utilities, and the reason that on-station housing exists (emergency and stand-by support). The agreement must also address damage to District houses and damage repair/repayment procedures, the need for the employer to undertake quarterly inspections, the expectation that each home will be properly maintained and that behavior at the houses will be safe, ethical, and legal. The agreement must also address the responsibility for repairs and maintenance of each house.

Two of the homes at Wells are currently vacant and will both be cleaned, new interiors fitted, where applicable, and an owner occupancy release provided. Both homes were inspected on September 18, 2017. The southern home needs new paint, carpet, and siding. The northern home needs touchup paint on the interior and a simple carpet cleaning. The third home at Wells Hatchery will need to be vacated prior to inspection.

Neither of the houses at Methow Hatchery have been inspected yet, as the tenants still occupy the houses. Repairs to the houses will be performed prior to occupancy by new employees, dependent on the condition of the house and timing of occupancy. If houses must be occupied prior to repair, then a plan will be developed on a case-by-case basis to address the needed repairs.

19.1 Utilities

All new hatchery employees living in District housing will be responsible for paying their own utility bills including garbage, internet, satellite or cable TV, or other services that they desire. The only utility that the PUD will provide is phone service so that employees can be notified of hatchery emergencies and outages. Electric utilities may also be offered at the Wells hatchery houses depending upon the cost and difficulty in unbundling the houses from the current single owner electric meter that serves all three houses.

The District is in the process of installing DCCN fiber optics to the houses at the Wells Hatchery and will be assuming the CenturyLink phone accounts associated with the Methow Hatchery. WDFW has already been provided the transfer paperwork for this account-transition request.

19.2 Titles for Houses

The District's current contract with WDFW mandates the transfer of the hatchery houses at Wells Hatchery back into District ownership upon termination of the Contract. The Methow Hatchery houses remain under District ownership.

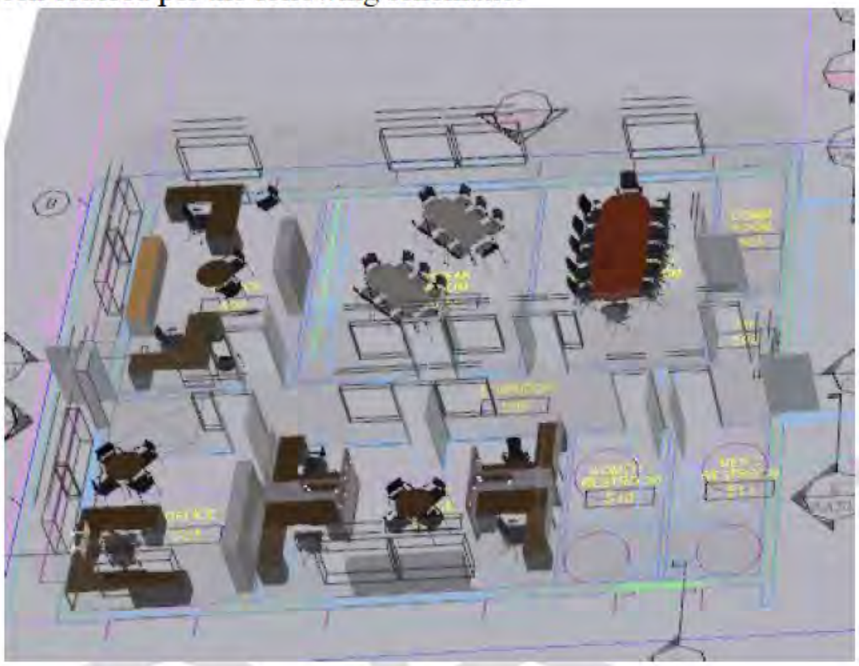
19.3 Land Titles

The District's current contract with WDFW mandates the transfer of the land under the hatchery houses at Wells Hatchery back into District ownership upon termination of the Contract. The land at the Methow Hatchery remains within District ownership.

20.0 COMPUTERS, PHONES AND COMMUNICATION EQUIPMENT

20.1 Office Furniture

Furniture has been ordered per the following schematic.



20.2 Wells Hatchery Network Connectivity

Wells hatchery will connect directly to the business network, SCADA network, phone network, and wireless network through District-owned fiber connections. Business network connectivity will be provided in the office locations (work stations) and the adult handling building through physical connections. Wireless network connectivity will be in the office areas provided by an access point that is controlled through the EW wireless management solution. Phone network connectivity will be provided in the office locations (workstations), conference room, and other areas on an as-needed basis.

Cellular connectivity will be provided by installing 2 FemToCell devices in the office area wired into the Wireless network. Verizon and AT&T will be the two cellular companies supported. A cellular booster will be installed to cover as much of the facility as possible.

The Wells Hatchery houses will get fiber connectivity provided by DCCN. The connectivity will be used to provide District owned FemToCell for work purposes and/or an IP phone supplied through the Wells phone switch. The connectivity also allows the staff residing within to obtain an internet connection through an ISP for personal purposes.

20.3 Wells Hatchery Phones

Current WDFW phone lines provided by CenturyLink will be transferred into Douglas PUD's name. Technicians will explore the possibility of using the hatchery incoming lines as additional incoming lines to the Wells Dam phone switch to increase overall capacity and provide IP Phones to the hatchery.

The Wells Hatchery houses will initially be supplied phone lines from CenturyLink, but after fiber is installed to the houses, exploration of IP Phones provided from the Wells phone switch will be explored.

20.4 Wells Hatchery PCs and Printers

The District will provide hardware in the following locations (Figure 4):

- Office West (1 desktop)
- Office East (2 desktops)
- Staff Office (1 desktop, 2 MS surface with docking station)
- Break Room (1 multi-function printer, legal only)
- Meeting Room (1 desktop, 1 large screen monitor, 1 external connection module for monitor)

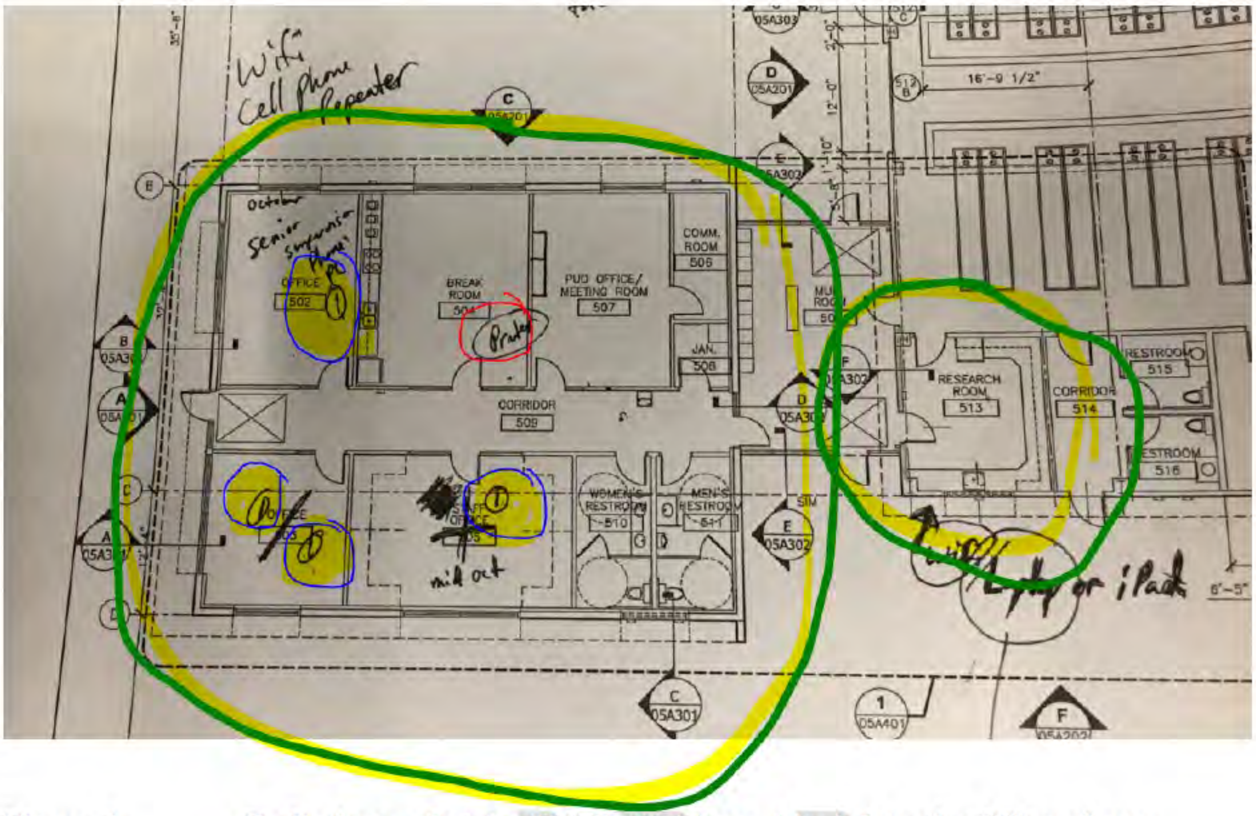


Figure 4. **Preliminary sketch of Wells Hatchery Administrative Wing of new Hatchery Building depicting layout of computer and printer infrastructure.**

20.5 Methow Hatchery Network Connectivity

Methow hatchery does not have District-owned fiber connectivity. CenturyLink provides a wireless internet connection currently that will need to be transferred into the District's name. The District is exploring the possibility of having CenturyLink run fiber lines to the facility to provide more bandwidth, but the likelihood and costs are unknown. Thus, we are proceeding with the only current connectivity option, which is the wireless connection already in place. The District will install a small firewall/router. Two point-to-point VPN's will be configured between the Methow Hatchery firewall to the East Wenatchee HQ firewalls. One VPN will be for Business network traffic, the other for Wireless network traffic.

Wireless network connectivity will be in the office area provided by an access point that is controlled through the EW wireless management solution.

This facility has cellular network coverage.

The Methow Hatchery houses can obtain internet access for personal purposes through local providers if they wish. If the District works with CenturyLink to run fiber to the facility, the option should be explored to also run it to the houses.

20.6 Methow Hatchery Phones

Current WDFW phone lines provided by CenturyLink will be transferred into Douglas PUD's name. Currently there are two lines used for voice and one for fax purposes. They are using an answering machine for messages. There isn't a good option to extend our internal phone system at this time to the facility. We will need to continue using the CenturyLink provided phone lines. When the District considers a new phone system, there may be opportunities presented that may change this.

The Methow Hatchery houses will be supplied phone lines from CenturyLink. Currently the lines are held in the occupant's names, but will be transferred to the District.

20.7 Methow Hatchery PCs and Printers

The District will provide hardware in the following locations:

- Supervisor Office (1 desktop, 1 multi-function printer, legal only)
- Staff Office (1 desktop, 1 MS surface with docking station)

20.8 Twisp Weir and Pond

Current WDFW phone lines provided by CenturyLink will be transferred into Douglas PUD's name. The Twisp Weir has two phone lines. One is used for the alarm system and the other is the landline for voice.

20.9 Chewuch Pond

Current WDFW phone lines provided by CenturyLink will be transferred into Douglas PUD's name. The Chewuch Weir has one phone line used for the alarm system. There is Verizon cellular coverage in the area (quality of coverage is not known at this point) that has been utilized by staff in the past.

20.10 Software Technology

Employees will need all standard District software (MS Office, timesheets, Purchasing (iVue), SharePoint, etc.). All hatchery employees need to be proficient on computers, which may require training.

Custom databases will be required to track fish production and other hatchery and M&E needs. The District will develop the necessary systems (see above). Initial system will be an Access Forms front end to a SQL Server database back end.

Planning includes future enabling of systems for use throughout the facilities, not just in the offices where there is a business network connection. This will most likely be handled through providing a publicly accessible interface to the system and utilize cellular enabled iPads to access the publicly available interface. The interface would require authentication to use. Since cellular access is being installed at Wells, and Methow already has it, this connection option is desired.

21.0 EMERGENCY PROCEDURES

The District will provide training for emergency procedures that already exist (such as emergency action plan for Wells Dam). Additional emergency procedures will be developed as needed, falling into two broad categories; 1) human health and safety, and 2) fish health.

1. Human health and safety emergency procedures will be governed by the District's Safety Specialist. HDR has been directed to produce a technical plan for Wells Hatchery for water-supply emergencies, and this plan will form part of the emergency plan for Wells Hatchery. Dam safety at Wells Hatchery will be paramount in such plans.

2. Fish health emergency plans will be developed by the Hatchery Supervisors in collaboration with NR staff. Training for these plans will be provided at the earliest practicable time for hatchery staff. HDR has been directed to produce a technical plan for Wells Hatchery for water supply emergencies related to fish rearing. This plan will form the core of the fish health emergency plan for Wells Hatchery. Dam safety at Wells Hatchery will be paramount in such plans.

22.0 AS-BUILT DRAWINGS

Development of as-built drawings is underway for Wells Hatchery and these drawings will be available within six months of the District's acceptance of the completion of Wells Hatchery by Lydig Construction.

As-built drawings for Methow Hatchery already exist and are available within the District.

23.0 HAZARDOUS MATERIALS HANDLING AND ACCOUNTING

The District will develop lists of all MSDS and chemicals on site, beginning with the collection of MSDS that WDFW maintained. The District will inventory all chemicals (formalin, cleaning agents, pesticides, MS222, etc.). All chemicals will be stored properly.

The District's Safety Specialist will develop procedures for hazardous material handling and accounting that conform to District, L&I, OSHA, EPA, and any other regulatory rules that may apply. Development of these procedures, and associated training and certification (as needed) must be accomplished in a timely manner.

The formalin storage rooms at the Adult Handling Building and the Incubation Building will need to be stocked with formalin within days of the hatchery turning over to District operation. This hazardous material will need to be purchased, stored and inventoried periodically throughout the year. Formalin is being used currently on adult Chinook and steelhead..

24.0 SECURITY BADGES

The District will identify security-badge privileges for staff levels. The Wells Dam staff will be notified that badges will be needed, and they will assign security badges to hatchery staff on training and orientation day, or as soon thereafter as practicable.

The District will install several Hirsch pads at the Wells Hatchery, including a pad at the new west entrance gate, administration building, and adult handling building. Security badges will be required to enter all of these sites.

25.0 KEYS

The District will identify key privileges for staff levels. The Wells Dam staff will be notified that keys will be needed, and they will assign keys to all hatchery personnel on training and orientation day.

Keys and access codes to both the gas and diesel pumps, hatchery, adult handling building, potable water building, surface water intake, west and east ladder traps are required.

26.0 CHEWUCH POND

The District will provide training and orientation for the Chewuch Pond to the Methow Hatchery staff, and as needed, to Wells Hatchery staff. The District will develop operational protocols, led by the Methow Hatchery Supervisor.

27.0 TWISP POND

The District will provide training and orientation for the Twisp Pond to the Methow Hatchery staff, and as needed, to Wells Hatchery staff. The District will develop operational protocols, led by the Methow Hatchery Supervisor.

28.0 TWISP WEIR

The District will provide training and orientation for the Twisp Weir to the Methow Hatchery staff, and as needed, to Wells Hatchery staff. The District will review and update operational protocols, led by the Methow Hatchery Supervisor. The District will receive an HPA from

WDFW prior to any work to install the traps at this location. The first opportunity to install the trap at the weir will occur in late February 2018.

29.0 GRANT AND CHELAN INTERLOCAL COOPERATIVE AGREEMENTS

The District will provide new hatchery employees with necessary training regarding the District's interlocal cooperative agreements with Grant and Chelan PUDs for fish production at Wells and Methow hatcheries, as applicable.

30.0 OFF-LICENSE SETTLEMENT – TROUT PRODUCTION

The Off-License Settlement Agreement between the PUD and WDFW requires the District to produce 20,000 pounds of trout equivalents for planting into the lakes of Okanogan, Douglas and Chelan counties impacted by the operation of the Wells Project. Douglas PUD staff will continue to work with WDFW's regional fish biologists to identify the species and life stages of fish to be provided to WDFW to satisfy this requirement.

Potential to improve the conservation benefits of steelhead hatcheries

Barry Berejikian, Chris Tatara, Katy Doctor

NOAA FISHERIES

Northwest Fisheries Science Center

Manchester Research Station

October 18, 2017

Outline

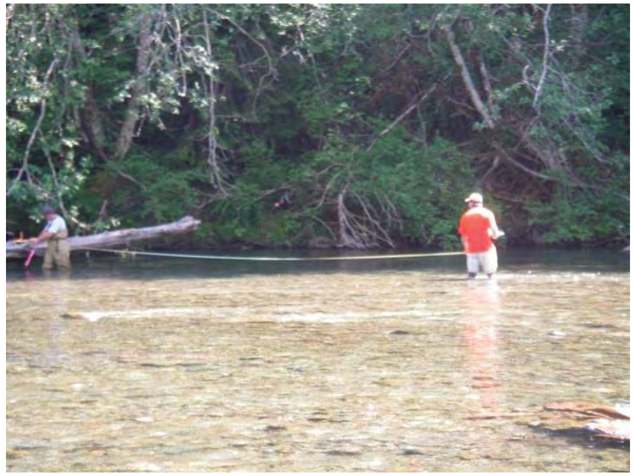
- Approaches for egg collection, rearing and release for small steelhead programs
- Effects on abundance and genetic diversity
- Alternative rearing strategies to improve smolt performance and reduce domestication selection
- Developing practical and flexible rearing strategies for conservation/supplementation programs.

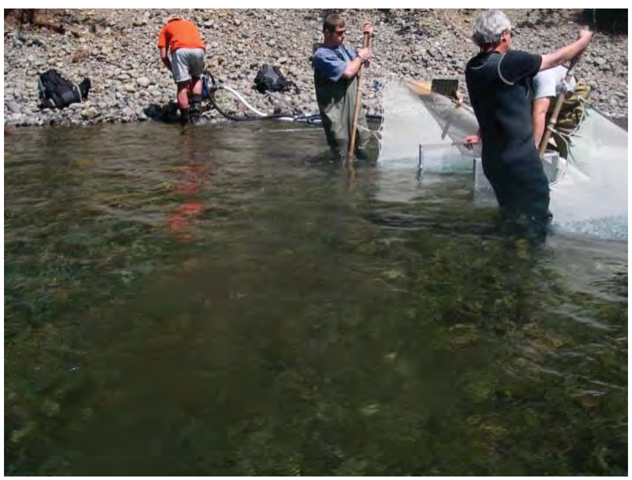
Hood Canal Steelhead Project

- Hydraulic sampling to increase diversity
- Captive rearing to adulthood.
- Age-2 (S2) smolt rearing
- Monitoring effects on natural population abundance and genetic diversity

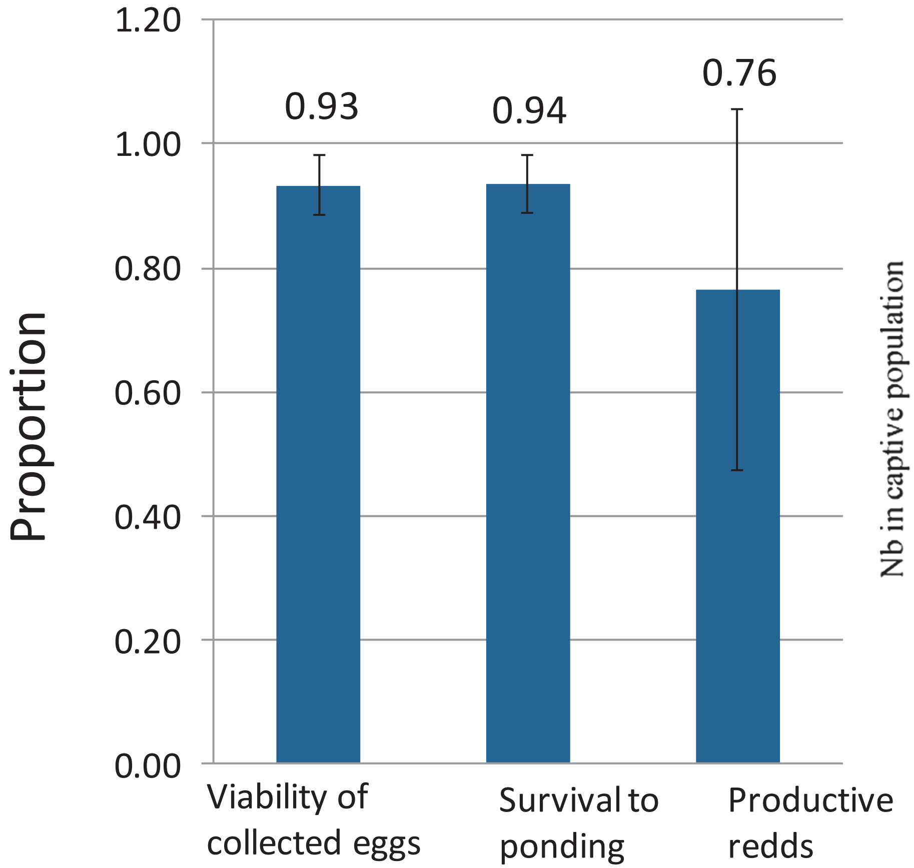
Can conservation hatcheries increase natural population abundance while maintaining genetic diversity?

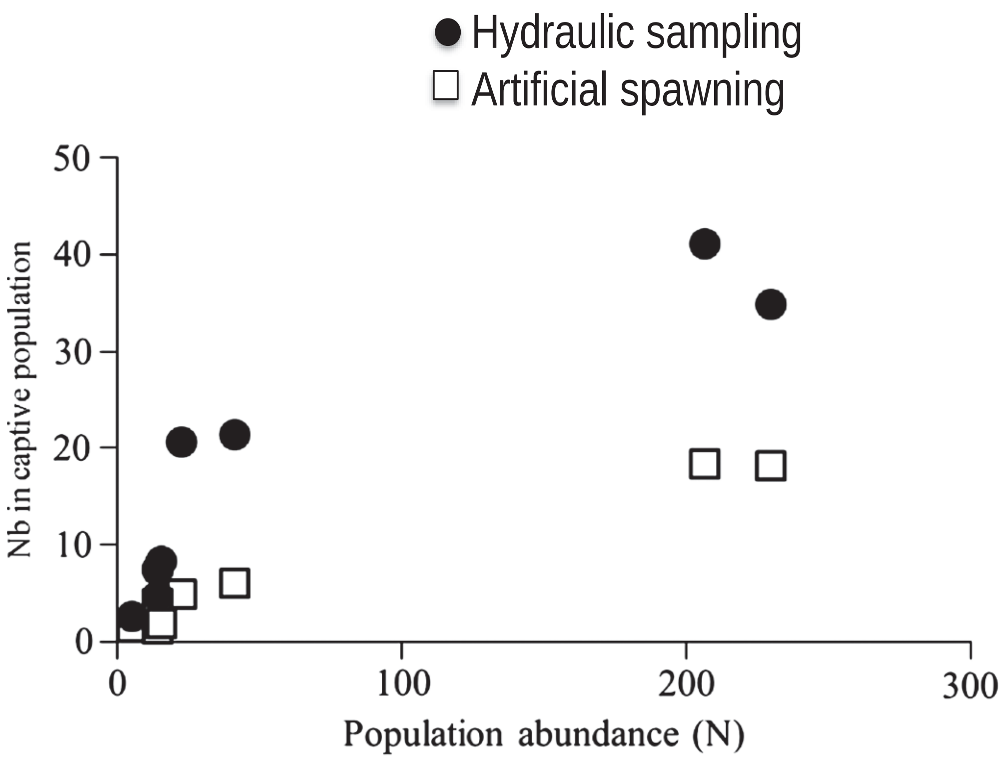
Hydraulic redd sampling – an alternative to artificial spawning



Effectiveness of hydraulic egg collections in four Hood Canal steelhead populations

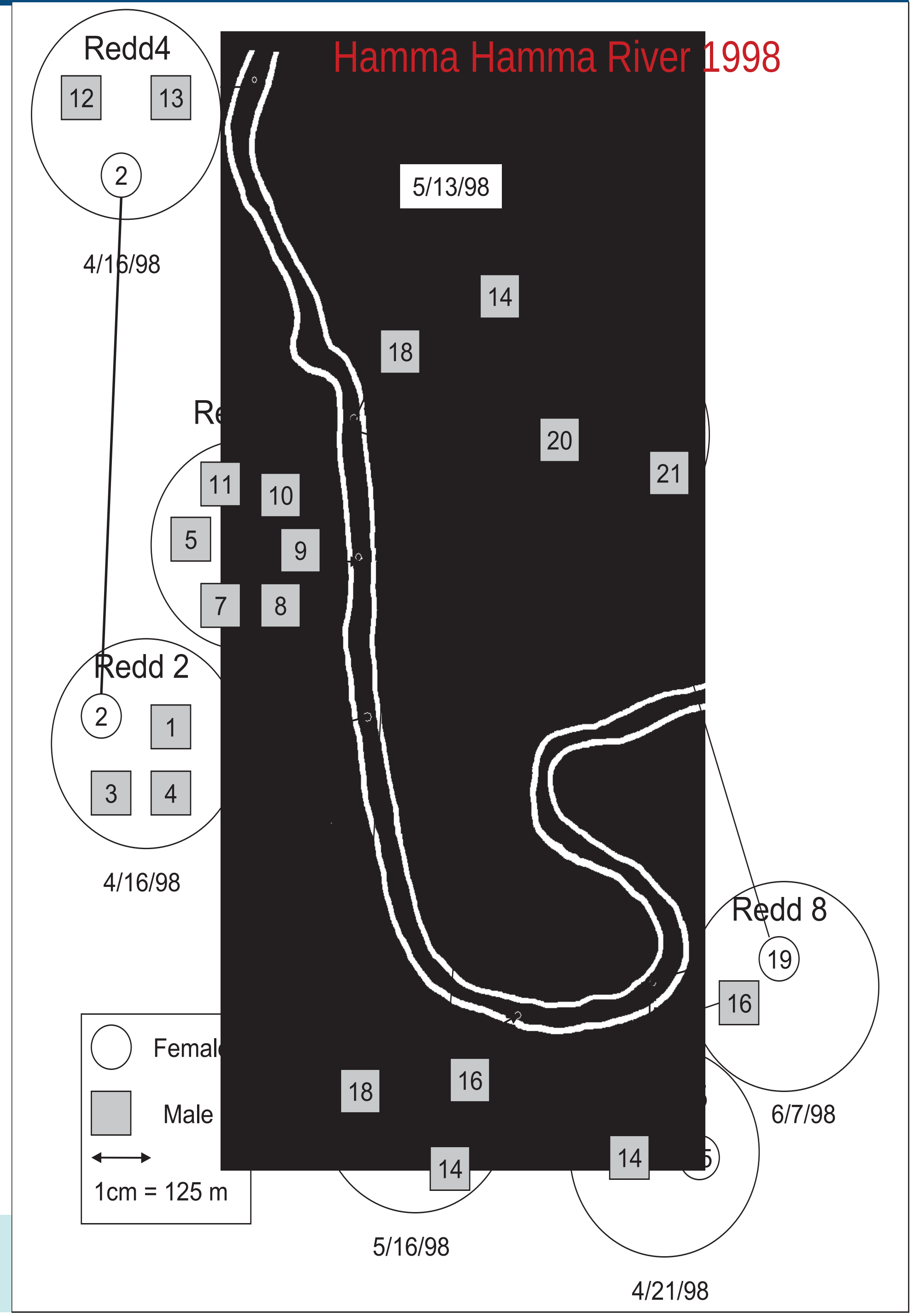




Berejikian et al. 2011c Trans. Am. Fish. Soc.

Steelhead mating patterns are complex!

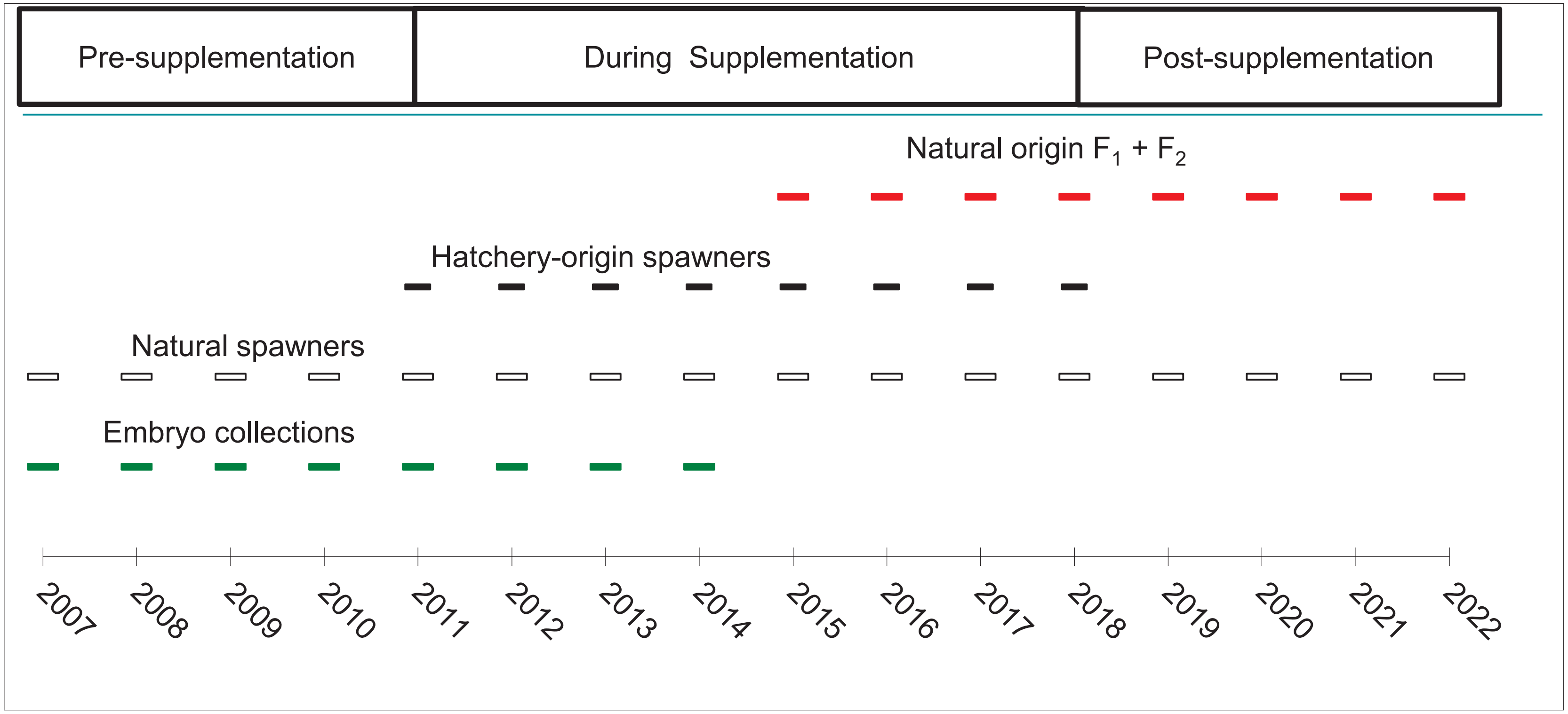
- Parentage reconstruction based on relatedness values
- Assumed female spawning completed within one week
- Assumed males could contribute throughout
- Try doing this in a hatchery!



Kuligowski et al. 2005. Trans. Am. Fish. Soc.
(also see Seamons et al. 2007)

Hood Canal Steelhead Project

Replicated, before-during-after-control-impact experiment (RBACI)

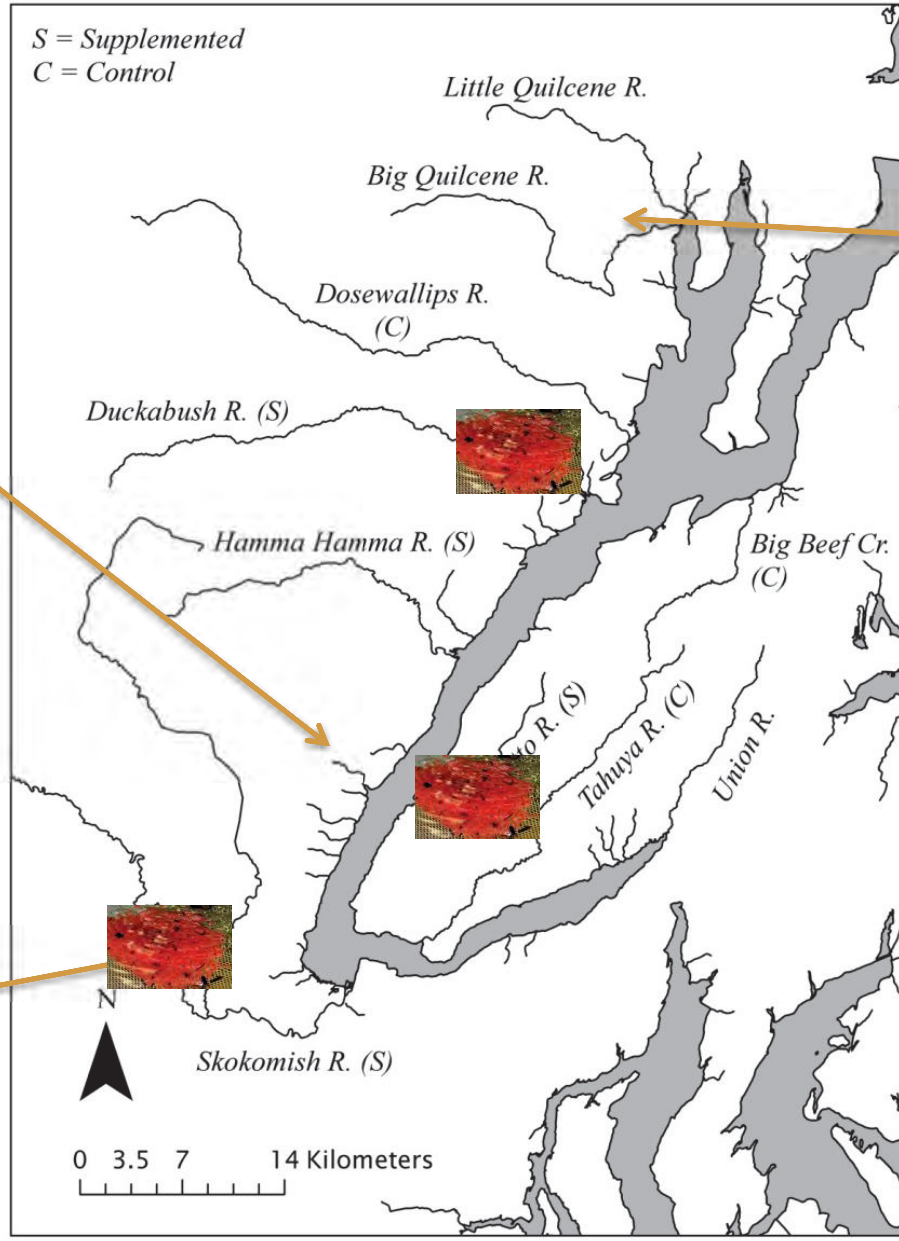


Smolt Release Group

Adult Release Group

Hood Canal Steelhead incubation and rearing facilities

LLTK Lilliwaup Hatchery



Quilcene National Fish Hatchery

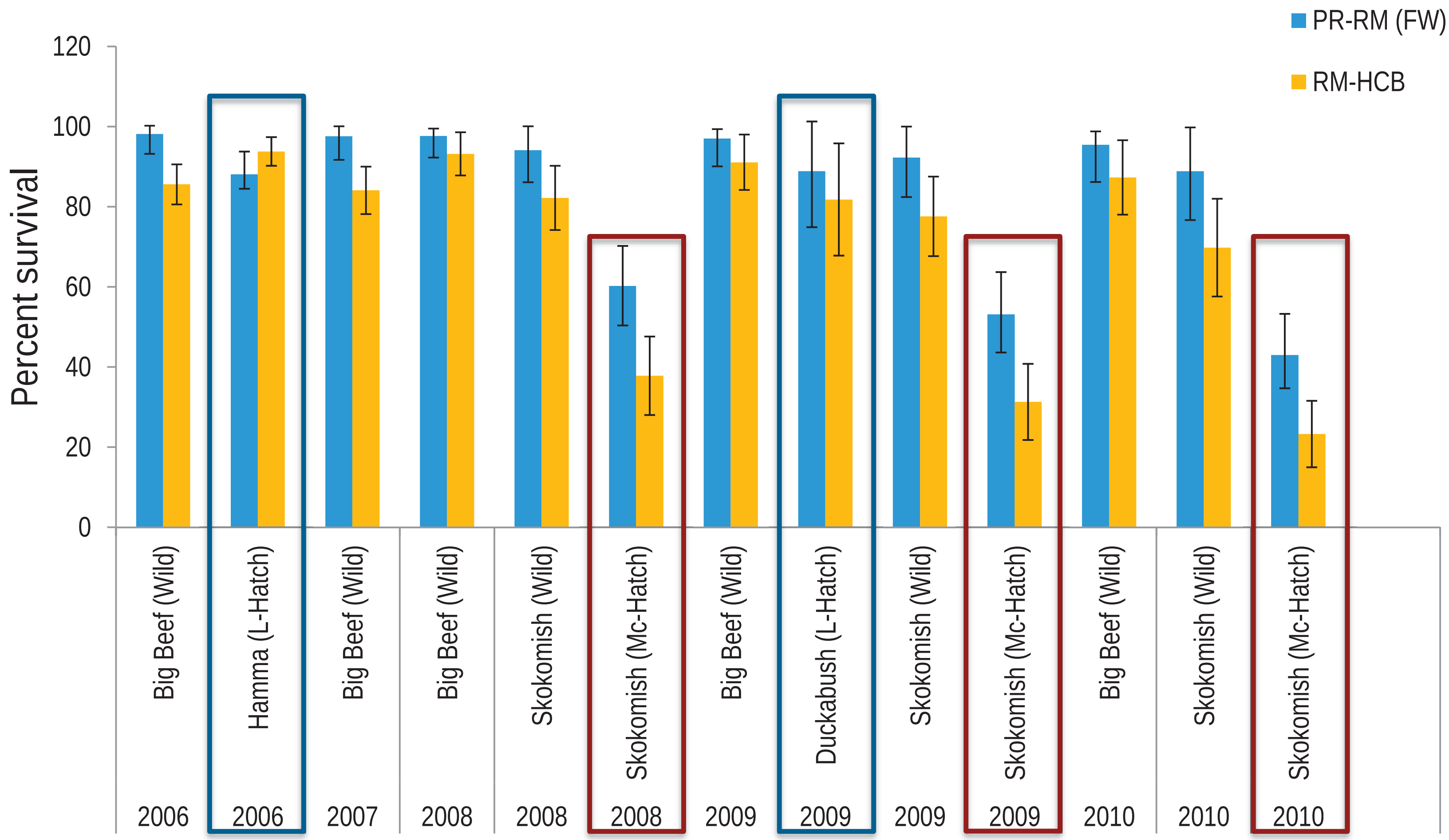
Quilcene National Fish Hatchery Photo Credit: Ron Wong

WDFW McKernan Hatchery

Hatchery releases: Smolt and Adult Release Groups

					Number of fish released					
					SRG		ARG			
River	Brood Year	Total Redds Observed	Redds for Egg Collection	Eggs Collected	Age-1	Age-2	Age-4	Age-5	Age-6	Total released
Dewatto	2007	17	16	9,429	0	7,375	226	26	1	7,628
	2008	30	18	9,065	0	6,807	0	0	0	6,807
	2009	9	9	9,523	0	6,571	228	31	3	6,833
	2010	8	7	5,861	51	4,905	0	0	0	4,956
	2011	57	19	8,495	0	5,272	213	48	4	5,537
	2012	34	12	8,081	0	6,183	0	0	0	6,183
	2013	130	16	8,293	0	6,473	245			6,718
	2014	17	12	6,021	0	4,239	0	0	0	4,239
Duckabush	2007	10	6	2,623	0	1,574	164	45		1,783
	2008	11	8	6,101	0	4,671	65	70	4	4,810
	2009	8	1	49	0	0	0	0	0	0
	2010	18	6	3,149	140	1,743	196	0	0	2,079
	2011	77	12	5,967	0	2,550	0	0	0	2,550
	2012	64	10	6,010	0	4,782	211	10		5,003
	2013	34	8	7,016	0	4,713	0	0	0	4,713
	2014	39	8	2,136	0	1,700	0	0	0	1,700
Skokomish	2007	235	35	33,965	4,091	23,747	54	17	0	27,909
	2008	155	50	34,595	200	20,529	0	0	0	20,729
	2009	280	40	29,843	0	26,642	228	29	0	26,899
	2010	169	38	29,710	0	23,989	0	0	0	23,989
	2011	243	36	31,405	0	22,717	329	28	2	23,076
	2012	307	30	30,705	0	27,258	0	0	0	27,258
	2013	668	39	30,414	0	18,005	185			18,190
	2014	390	42	30,531	0	14,769	0	0	0	14,769
Total					4,482	247,214	2,344	304	14	239,589

Downstream and early marine survival rates

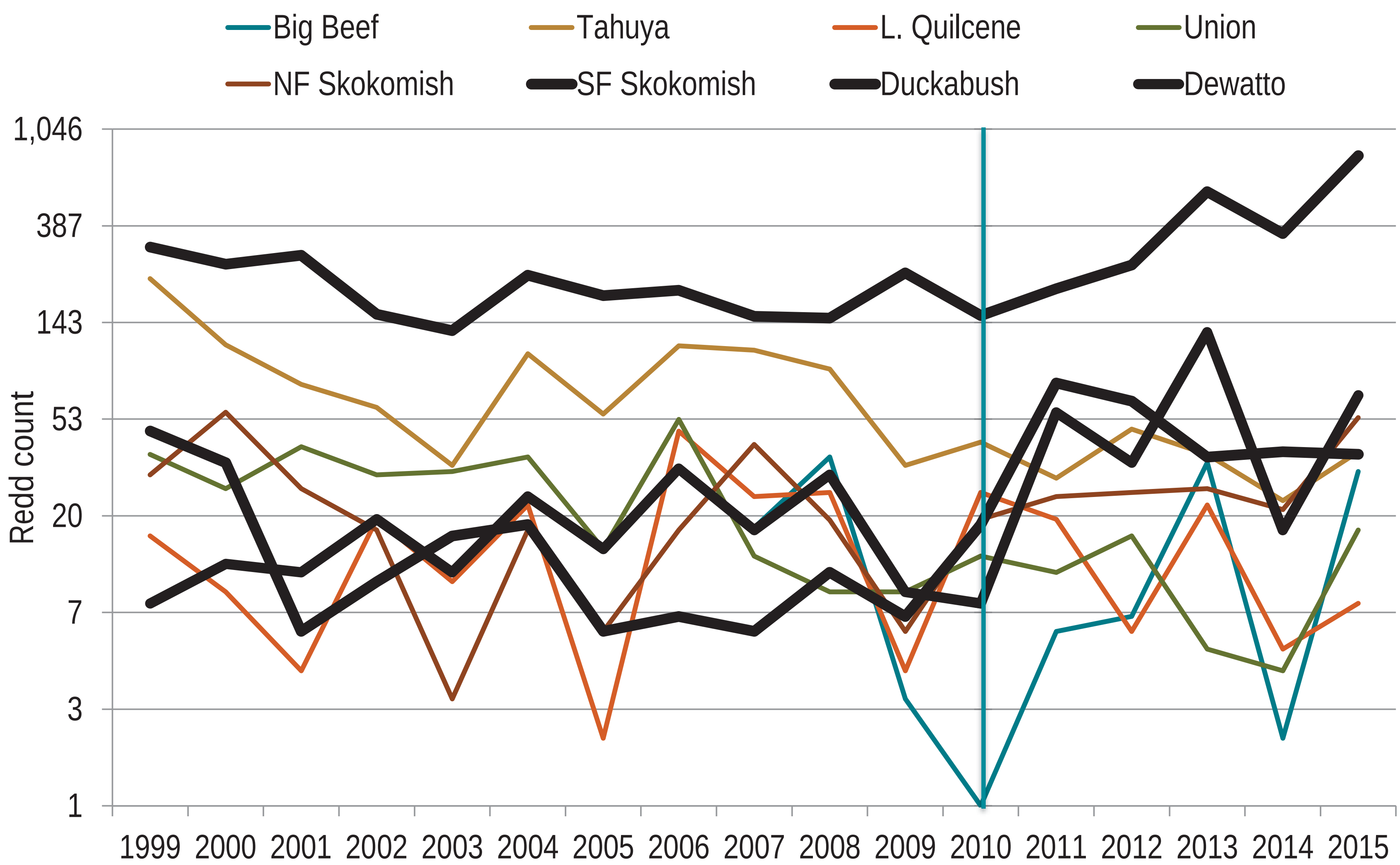


Moore et al. 2012 PLOS One

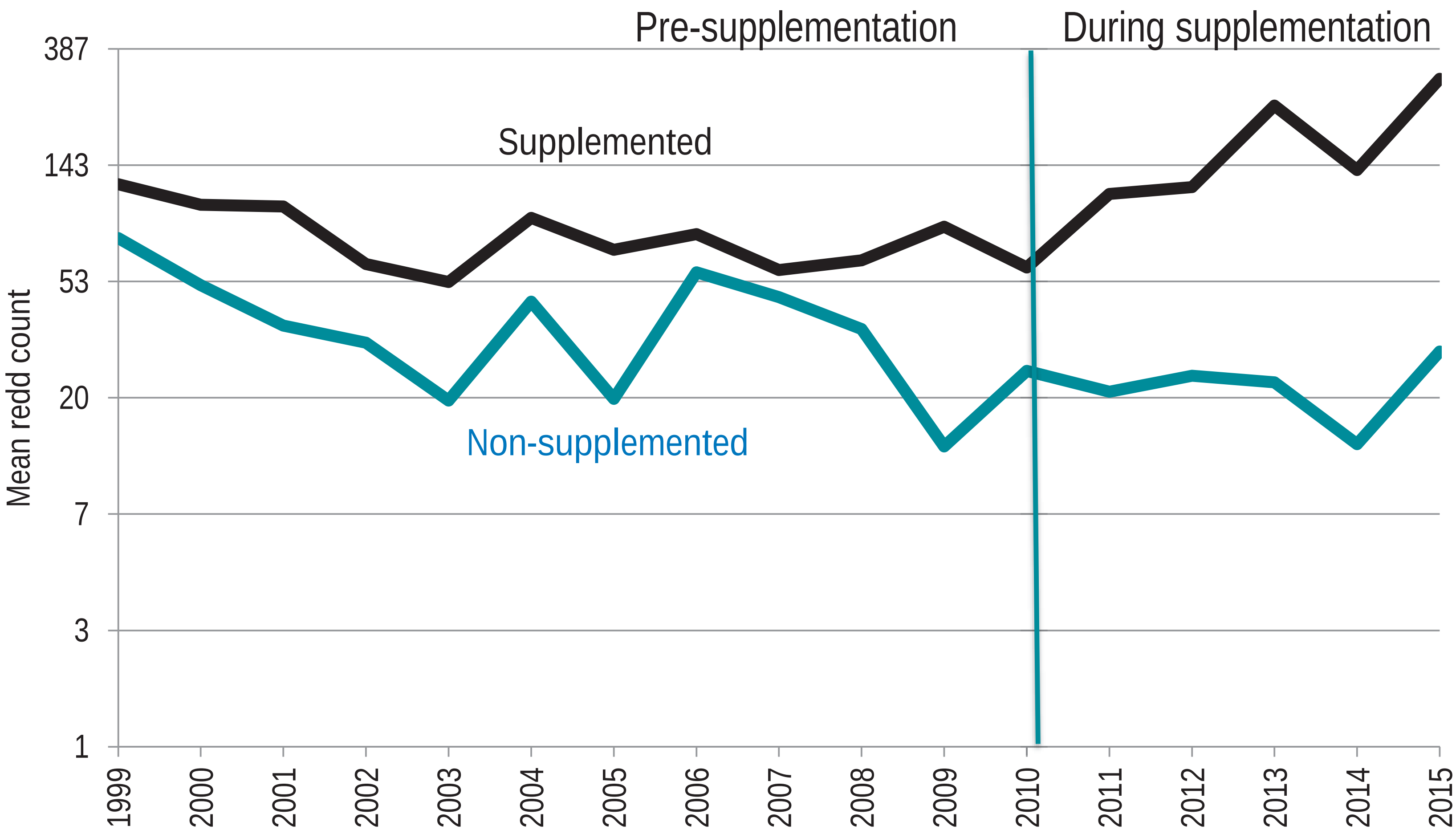
Potential causes of differences in smolt quality

	Lilliwaup Hatchery (Duckabush & Dewatto)	McKernan Hatchery (Skokomish)
Mean water temperature	8.9º C	8.6 º C
Feed Manufacturer	Bio-Oregon	Bio-Oregon
Feeding frequency	3x/d, 4 days/wk	2-3x/d, 7 days/wk
Mean density index (to age-1)	0.0066	0.290
Mean density index (age-1 to age-2)	0.0065	0.056
Vessel size/shape (to age-1)	10' circular	16' circular
Vessel size/shape (age-1 to age-2)	20' circular	12 x 140' raceway
# of size sorts (to age-1)	2	1

Redd Abundance



Mean redd counts



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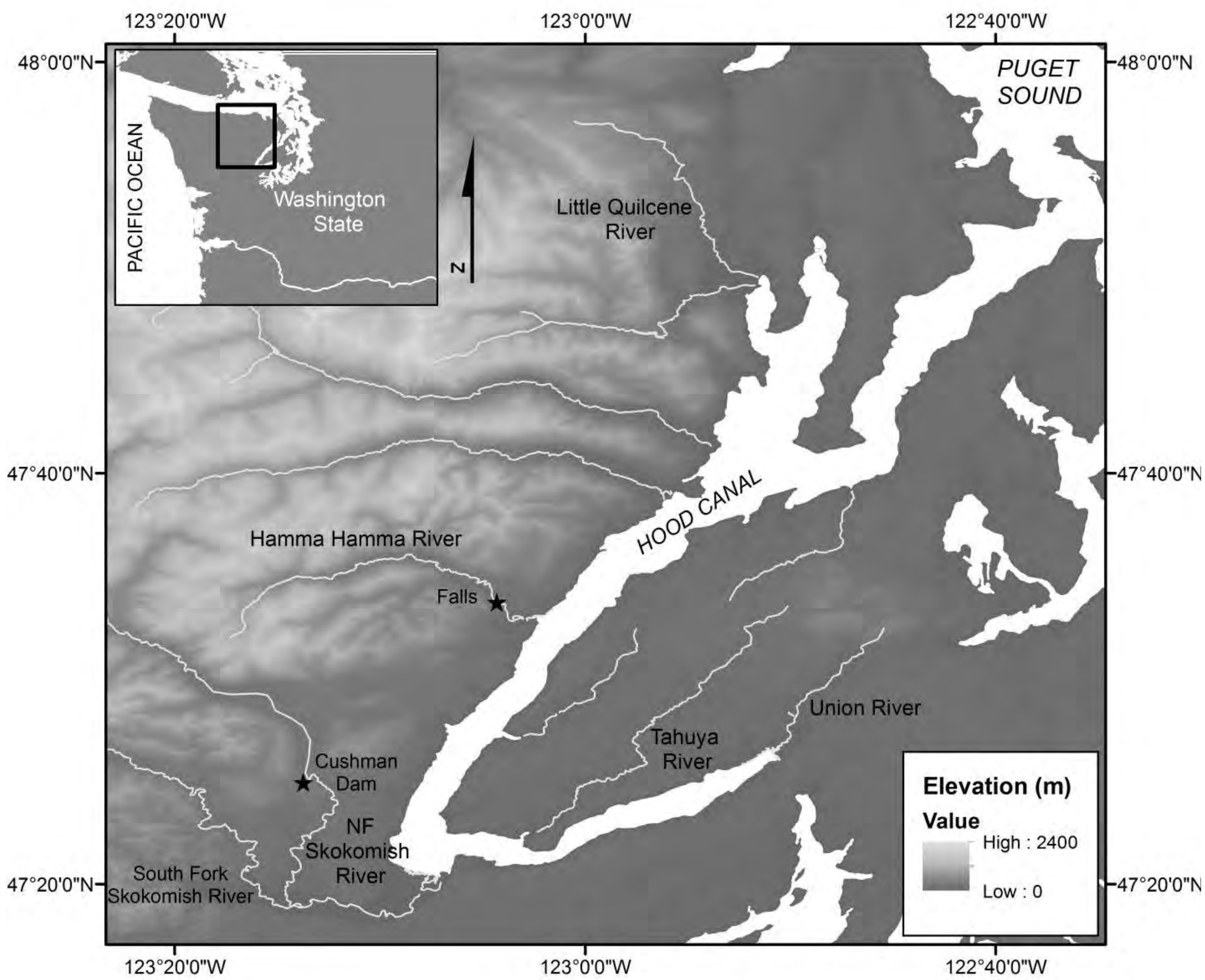
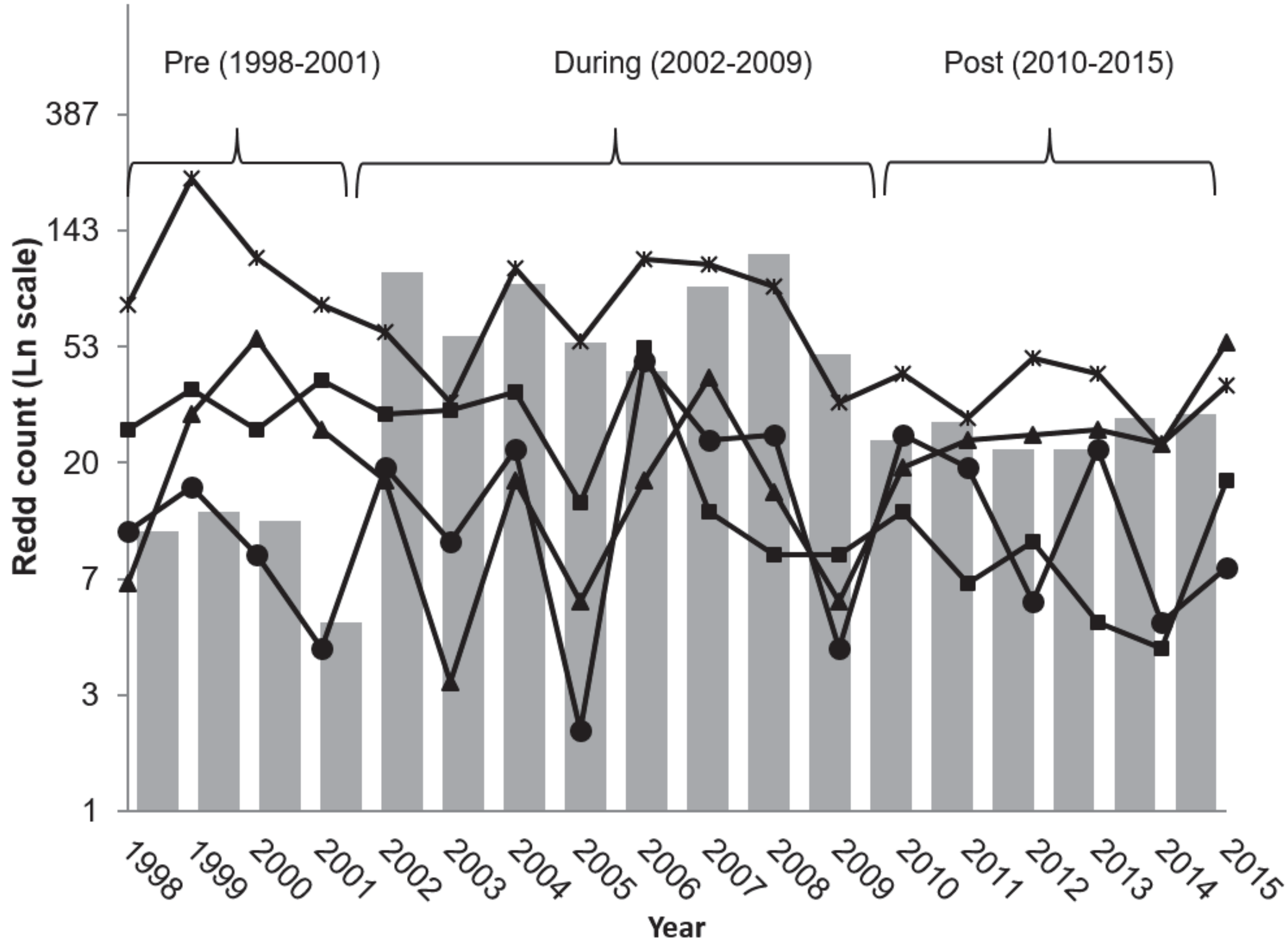
Hamma Hamma 1998-2015



Redd counts before, during, after supplementation



Berejikian and Van Doornik. PLOS One (in review)

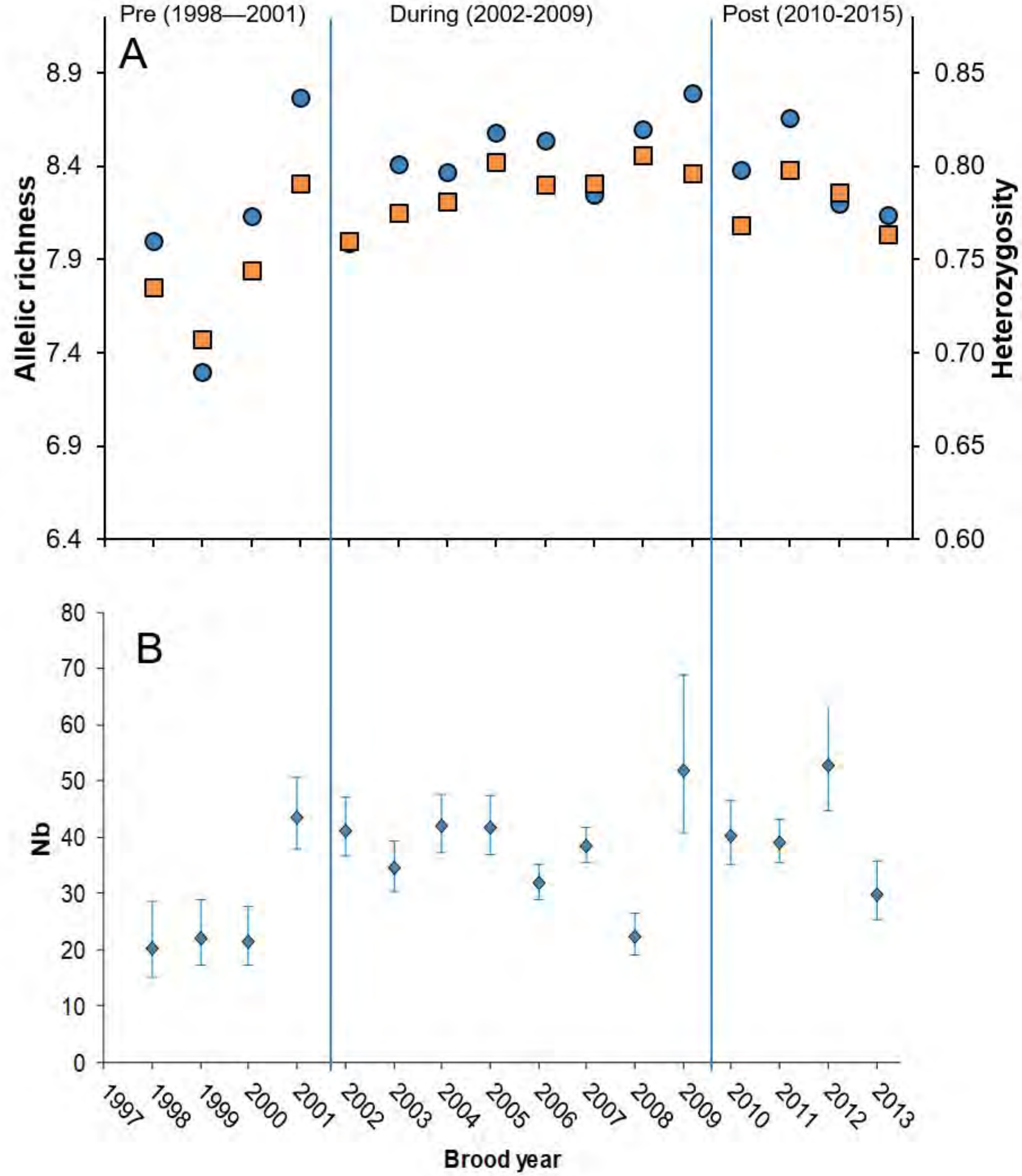
BACI ANOVA Results

Table 1. Results of the test for the effects of supplementation on redd abundance.

Source of variation	df	MS	F-Ratio	p-Value
CATEGORY	1	1.026	3.015	0.091
PERIOD	1	0.402	1.181	0.285
PERIOD x CATEGORY	**1**	**4.325**	**12.705**	**0.001**
POPULATION(CATEGORY)	**3**	**5.476**	**16.086**	**0.000**
YEAR(PERIOD)	8	0.400	1.174	0.342
Error	35	0.340		

Berejikian and Van Doornik. PLOS One (in review)

Genetic diversity



Berejikian and Van Doornik. PLOS One (in review)

Summary

- Hydraulic sampling can be used to increase N_b in small conservation programs
- Better suited to steelhead populations in rain-driven systems or for summer-spawning species (spring chinook salmon)
- Conservation programs can increase natural spawning in the short-term and in the generation post-supplementation

Problem: Fitness loss in steelhead can be heritable


Downloaded from http://rsbl.royalsocietypublishing.org/ on June 29, 2016

Biol. Lett. (2009) 5, 621–624
doi:10.1098/rsbl.2009.0315
Published online 10 June 2009

biology letters
Conservation biology

Carry-over effect of captive breeding reduces reproductive fitness of wild-born descendants in

nature COMMUNICATIONS

ARTICLE

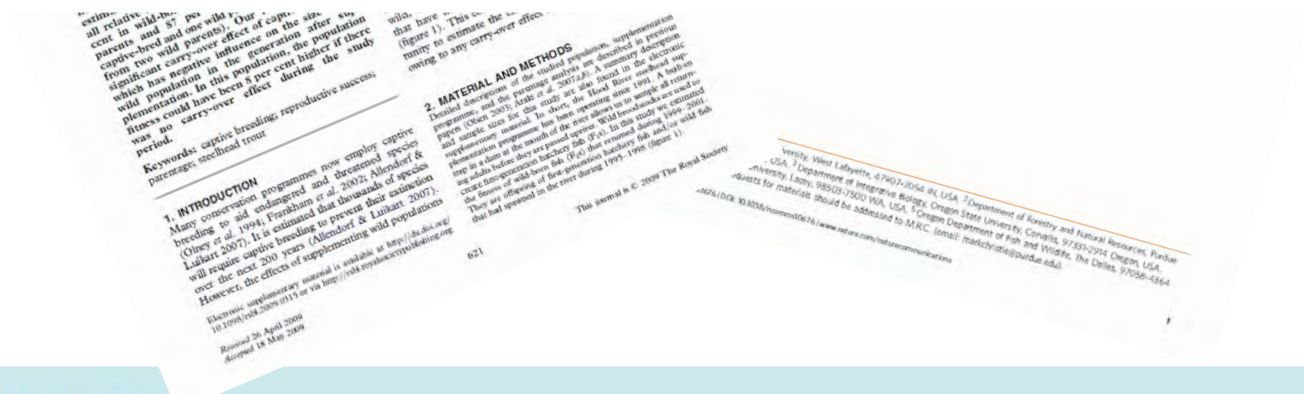
Received 29 Jun 2015 | Accepted 7 Jan 2016 | Published 17 Feb 2016

OPEN

A single generation of domestication heritably alters the expression of hundreds of genes

Mark R. Christie[1,2,3], Melanie L. Marine[3], Samuel E. Fox[3,4], Rod A. French[5] & Mich

These differences in fitness and gene expression could be due to inherited genetic and/or epigenetic differences


1. INTRODUCTION

2. MATERIAL AND METHODS

Keywords: captive breeding; reproductive success; parentage; steelhead trout

Received 26 April 2009
Accepted 18 May 2009

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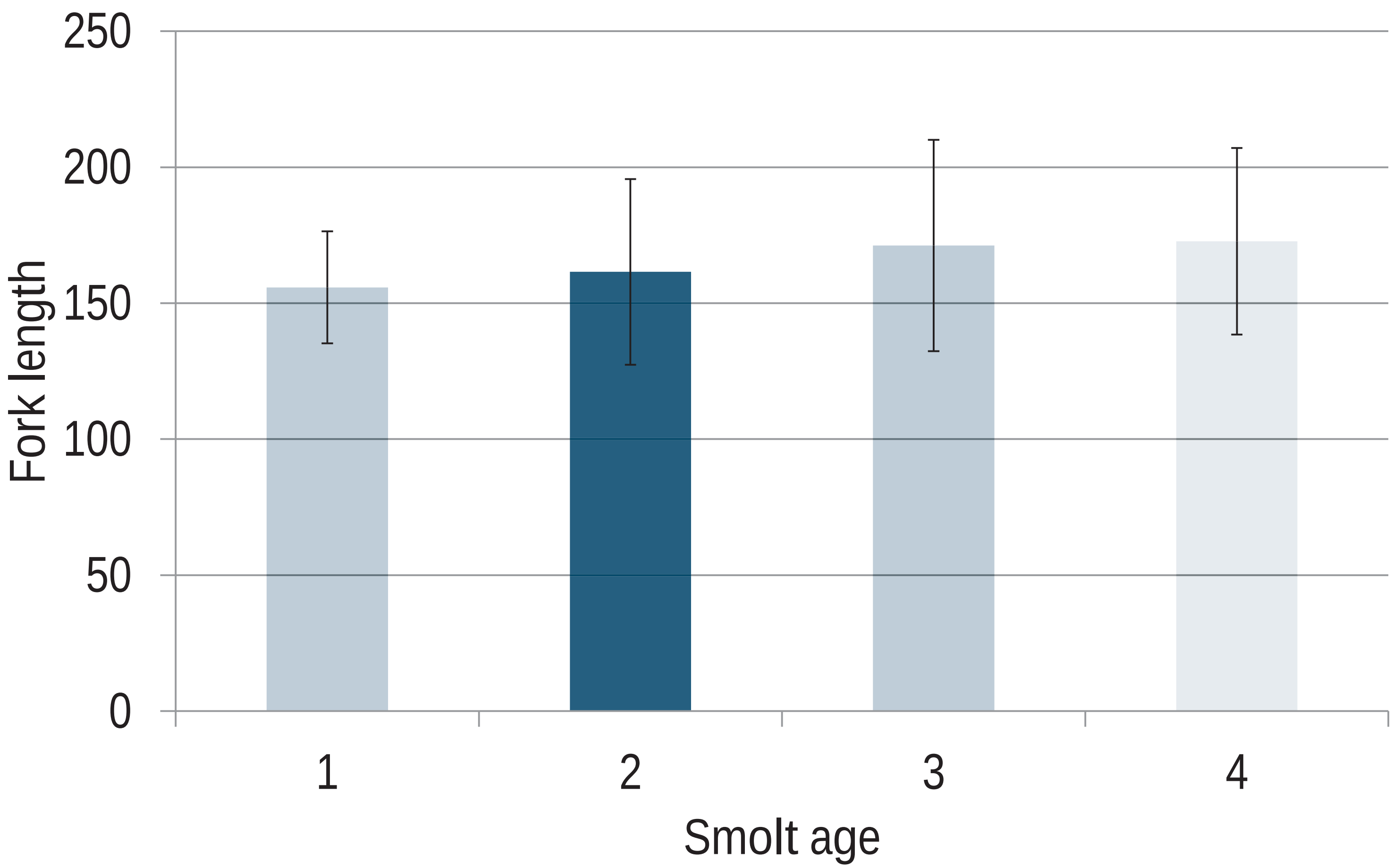
Potential causes of heritable fitness loss

- Deleterious mutations
- Inbreeding depression
- Genetic drift
- Domestication selection: adaptation to the hatchery environment
  - Differential selection on traits in captivity (or after release) compared to the natural environment
  - Heritability for the trait
  - Growth rate (and correlated traits: aggression, risk-taking, metabolic rate)

What are the effects of rearing steelhead to age-2 smolt?

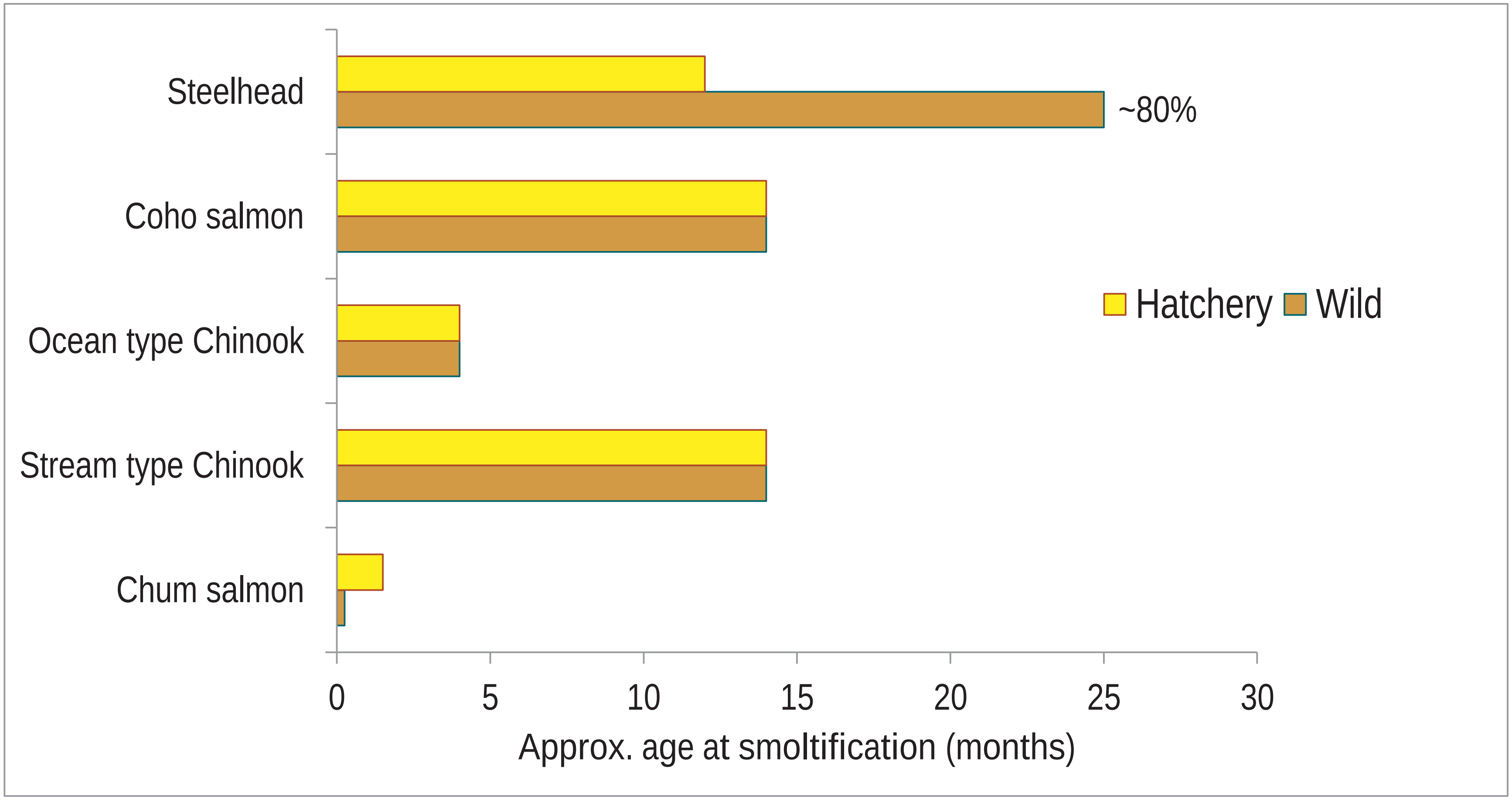
Smolting is a threshold trait in steelhead trout



NOAA FISHERIES

Data from Peven et al. 1994, N. Am. J. Fish. Manage.

Age-at-release in hatchery-reared anadromous salmonids



Winthrop National Fish Hatchery

North American Journal of Fisheries Management 37:700–713, 2017

ISSN: 0275-5947 print / 1548-8675 online
DOI: https://doi.org/10.1080/02755947.2017.1317676

ARTICLE

Age and Method of Release Affect Migratory Performance of Hatchery Steelhead

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Abstract

Hatchery programs that are designed to aid recovery of natural populations of anadromous salmonids, including steelhead *Oncorhynchus mykiss*, require locally derived, natural-origin broodstock. In such programs, achieving smoltification size thresholds may require extending hatchery rearing beyond age 1. We compared out-migration survival and travel rates of 142,990 PIT-tagged steelhead smolts released at age 1 (S1 rearing strategy) or age 2 (S2 rearing strategy) over five release years at Winthrop National Fish Hatchery (WNFH, Okanogan County, Washington). An S2 rearing cycle produced larger smolts with more uniform size distributions, resulting in higher survival during the first portion of their out-migration than for S1 smolts in three of the five release years. The S2 smolts migrated more rapidly to the ocean than S1 smolts in all years except 2011 and arrived in the Columbia River estuary 5.4 d earlier on average than the S1 smolts. The S1 steelhead that did not leave during the volitional release were subsequently forced from the hatchery to measure their survival. Nonvolitional S1 migrants were smaller and had survival rates that were 2.3–66.3 times lower than those of S1 steelhead that left WNFH on their own. The same was true for S2 steelhead, but the magnitude of the survival difference between volitional migrants and fish forced from the raceways was less variable and ranged from 2.5- to 4.6-fold. We conclude that S2 rearing can be a successful strategy for producing smolts from local natural-origin broodstock, with out-migration survival and travel times that are equivalent to or better than those of S1 smolts produced from nonlocal broodstock.

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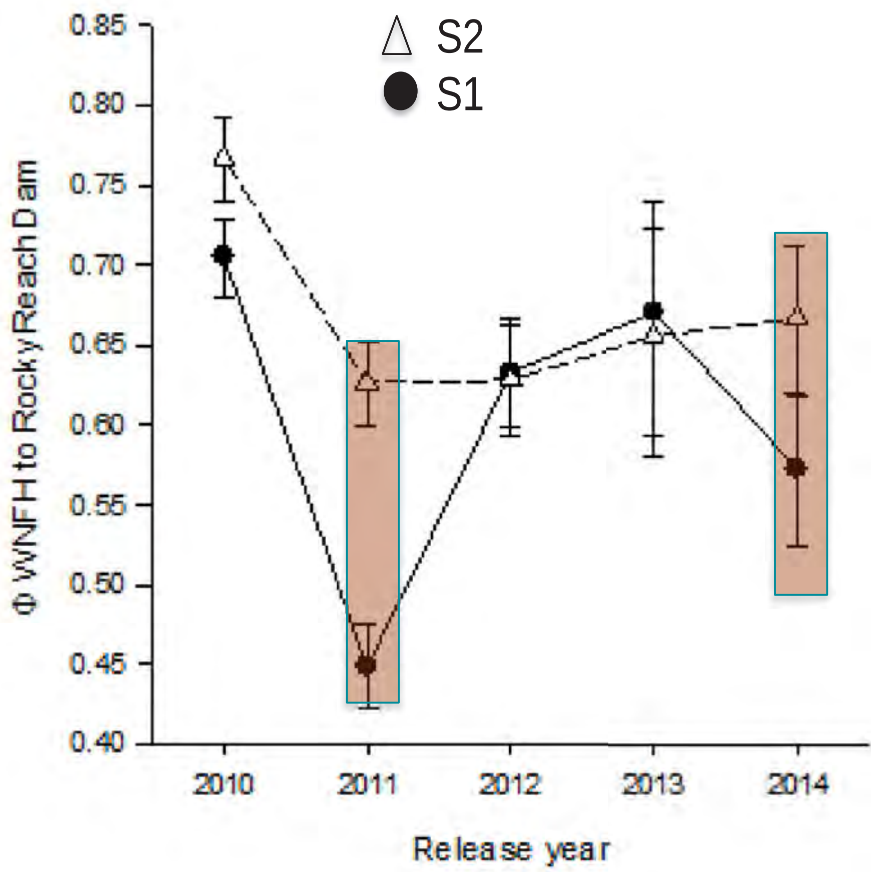
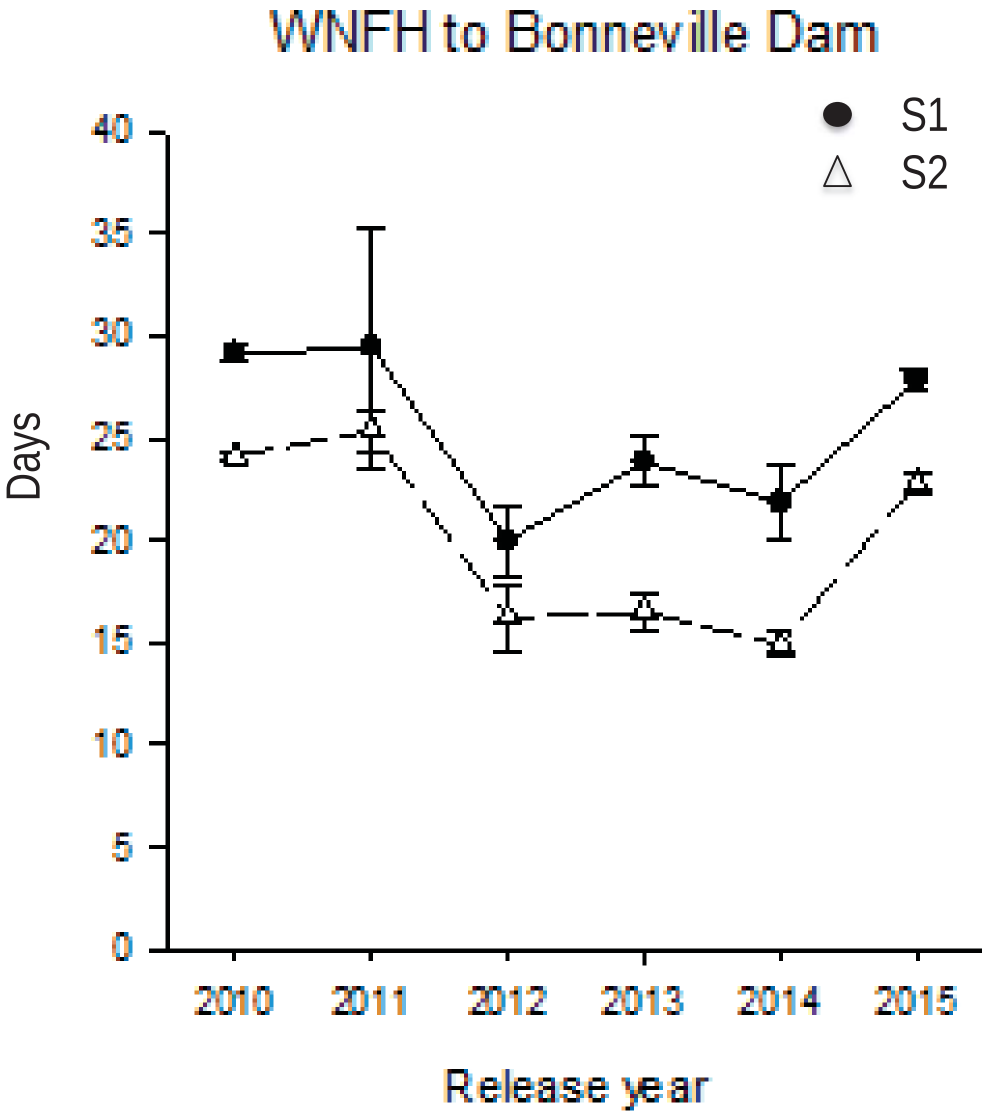
Received July 25, 2016; accepted March 31, 2017

Size affects downstream migration

Release year	Rearing type	Fork Length	Mass (g)
2011	S1	158.3 (35.1)	48.2 (30.0)
	S2	186.6 (25.7)	72.3 (29.2)
2012	S1	172.2 (28.4)	60.6 (25.4)
	S2	185.5 (21.7)	70.0 (22.8)
2013	S1	195.1 (21.6)	82.6 (26.0)
	S2	193.7 (22.0)	83.6 (25.9)
2014	S1	177.2 (23.4)	62.8 (22.3)
	S2	190.6 (18.6)	76.0 (20.5)



Outmigration travel rate



Tatara et al. 2017. N. Am. J. Fish. Manage.

Winthrop NFH S1 v S2 summary

1. Survival of S2 steelhead to RRJ was either higher than or not significantly different from survival of S1 steelhead.

2. Body size at release explained most of the differences in survival to RRJ both within and between the S1 and S2 rearing groups.

3. S2 steelhead migrated more rapidly than S1 steelhead.

4. The rate of out-migration was faster in years of volitional release than in years of forced release.

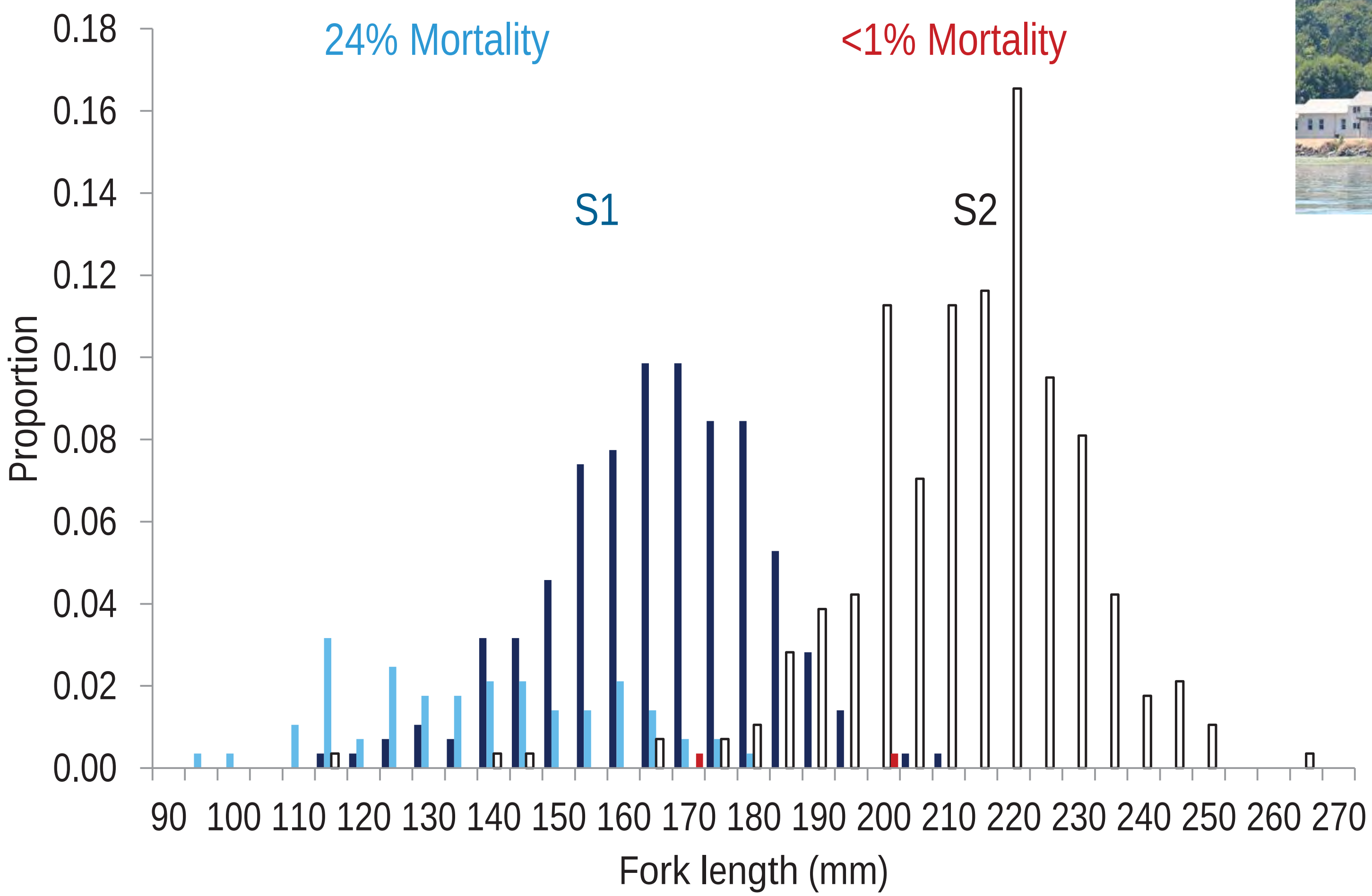
5. Volitional migrants from both treatments were larger and had higher survival than steelhead that were forced from the hatchery after the volitional release period ended.

Tatara et al. 2017. N. Am. J. Fish. Manage.

Can heritable size-selective mortality be avoided?

- Experimental design
  - 28 individual families
  - S1 and S2 rearing regimes (n = 4 tanks/treatment)
  - Pedigree analysis to assign offspring to families
  - Responses
    - Growth rate and body size at smoltification
    - Seawater challenge
    - Heritability

Size at smoltification and seawater survival



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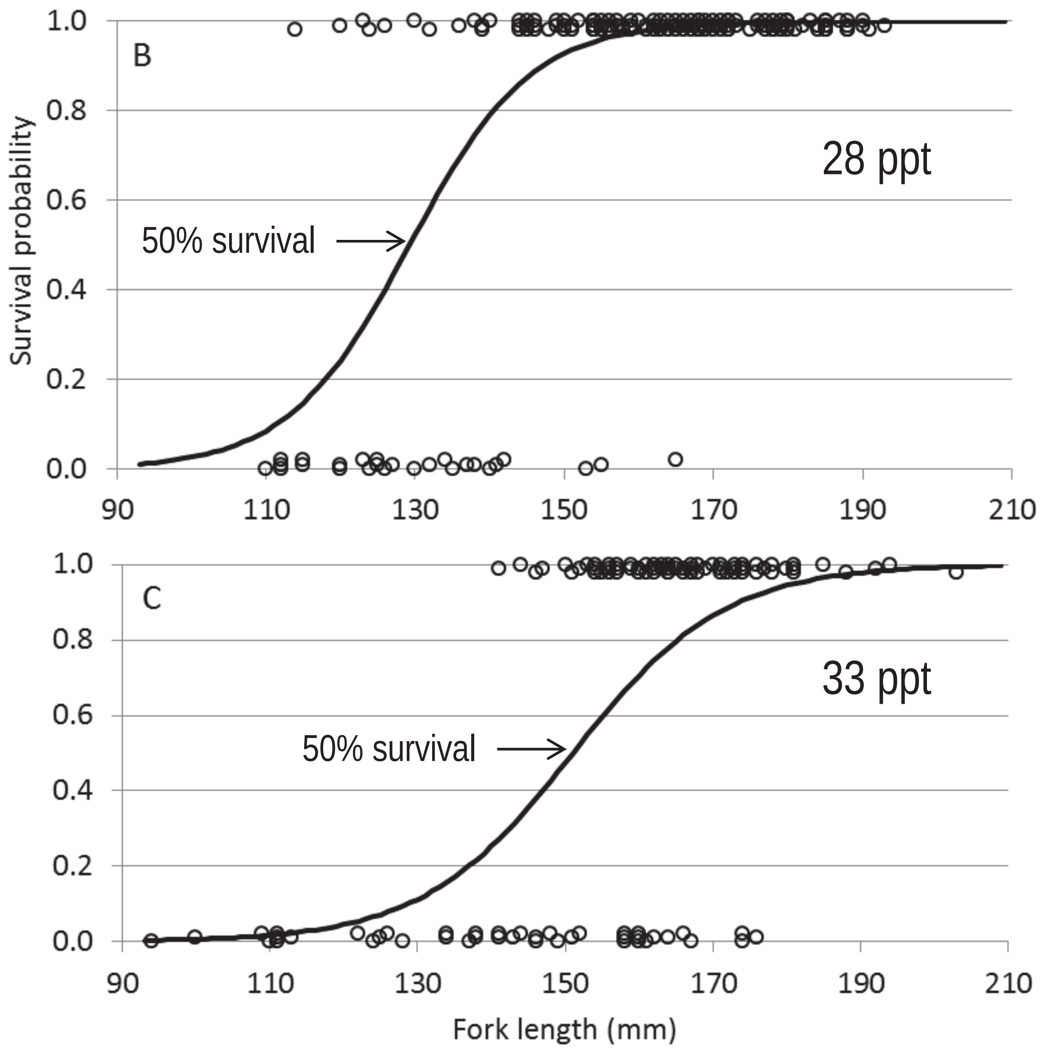
Size selective mortality in S1 steelhead smolts



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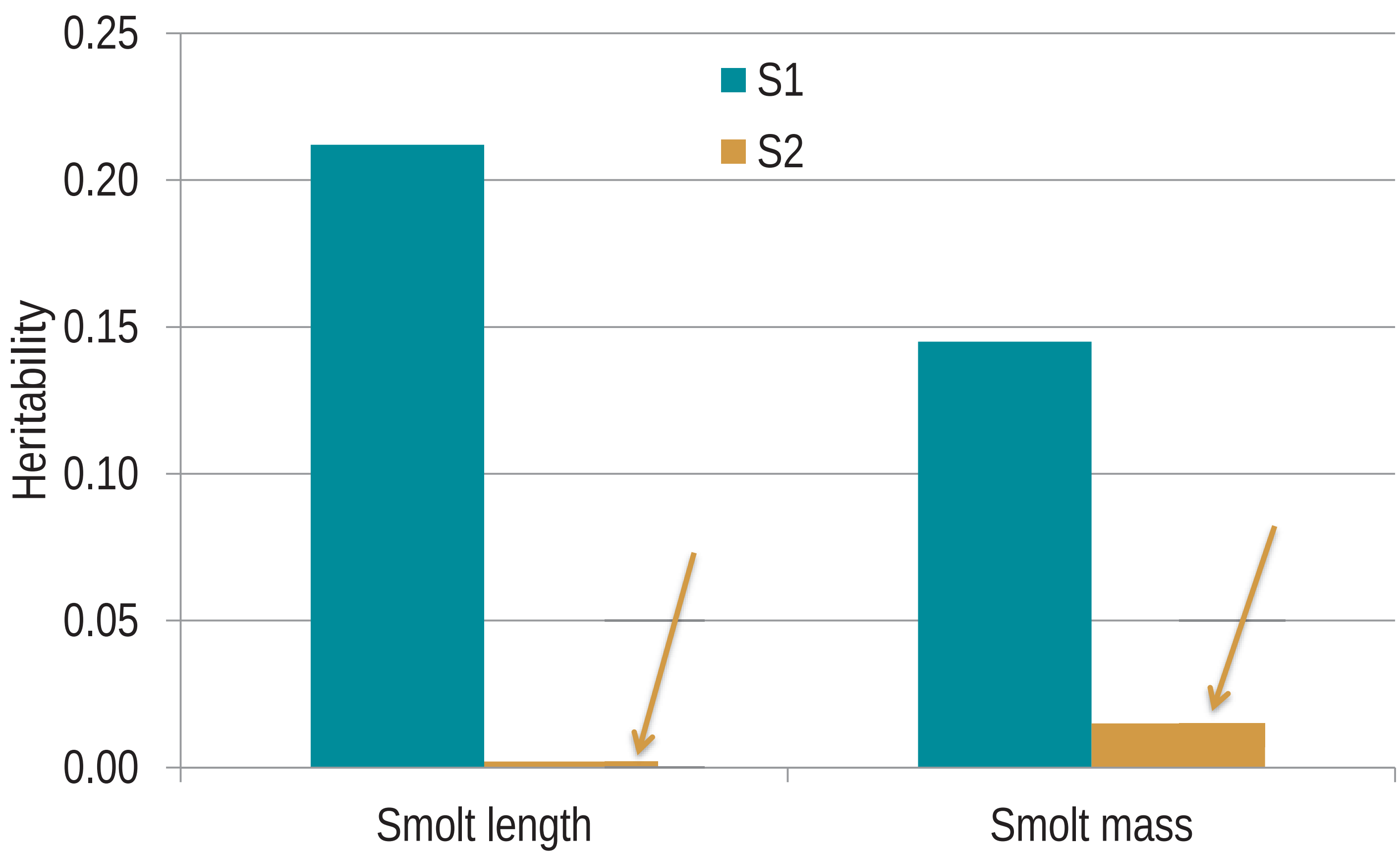
Heritability of body size at release

Within a population, how much of the variability is due to inherited differences (range 0 to 1)?



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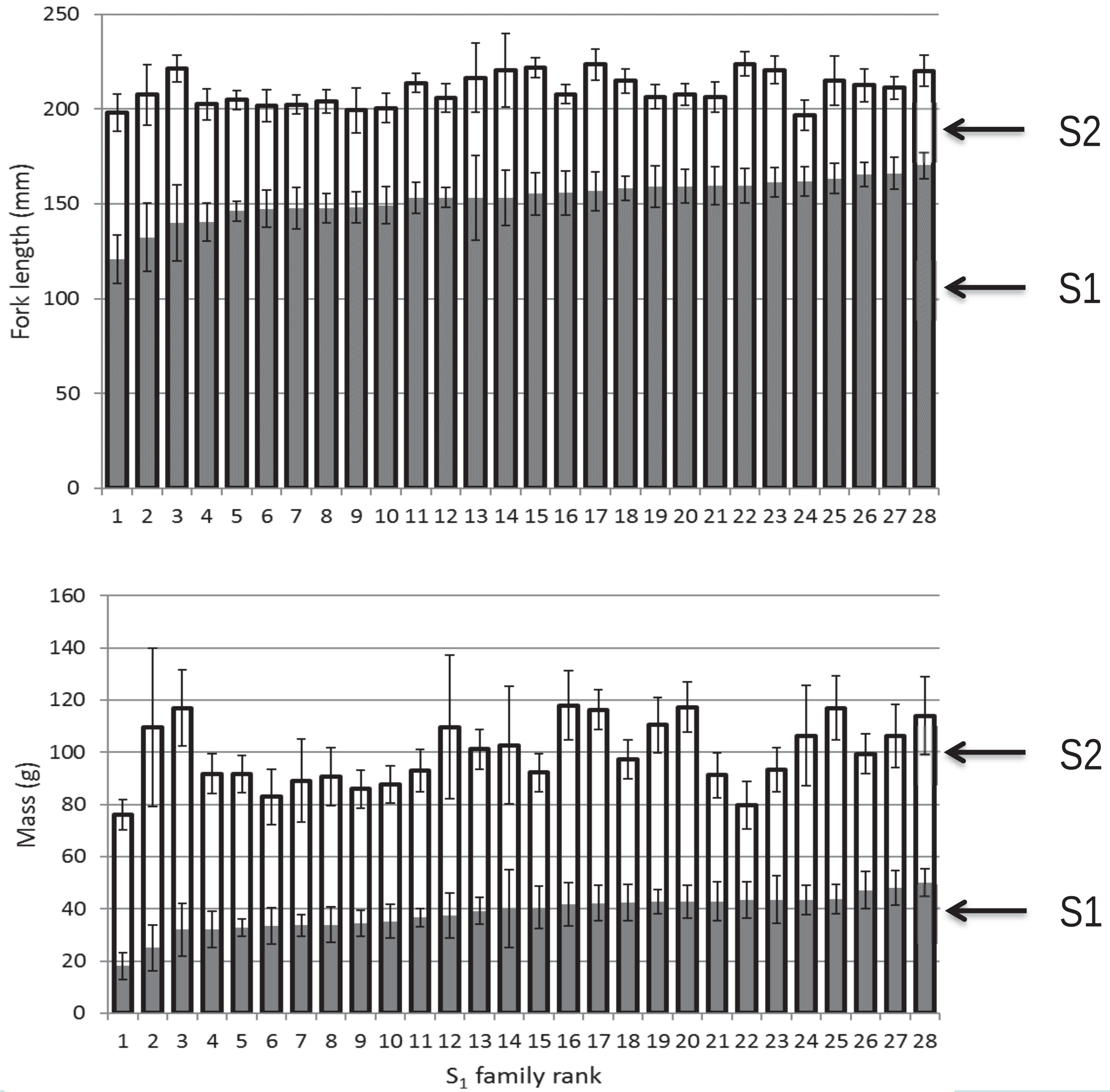
Body size varies among families



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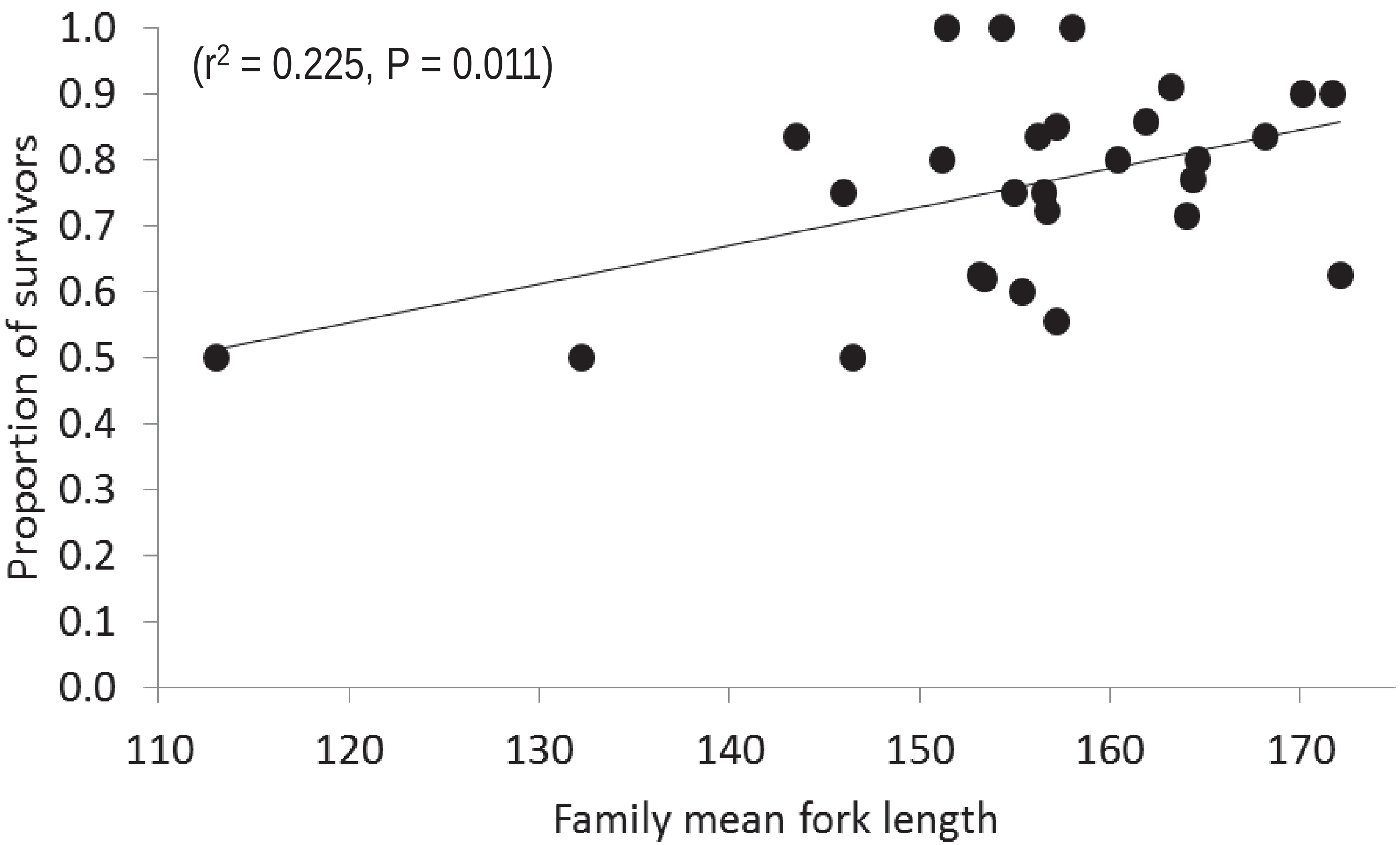
Family mean body size correlates with survival



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Summary

- Body size at the time of release from hatcheries influences
  - Downstream migration
  - Survival in seawater challenge

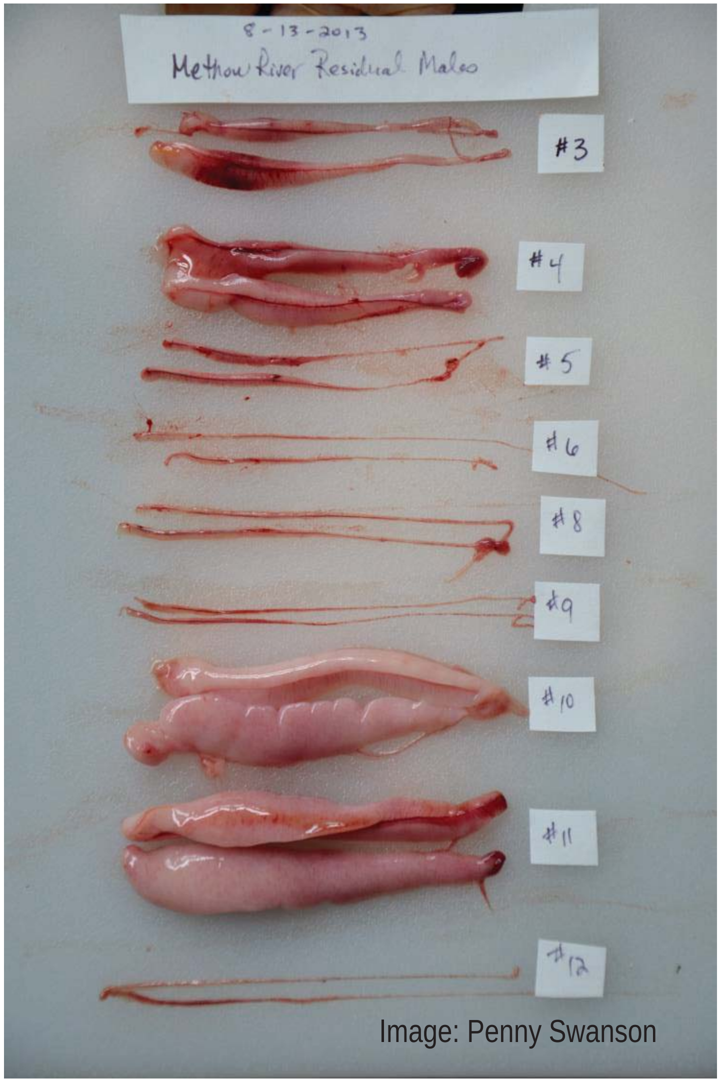
- In S1 rearing regime
  - Size-selective mortality
  - Response to selection is possible

- In S2 rearing regime
  - No size-selective mortality
  - No possible response to selection (low heritability)

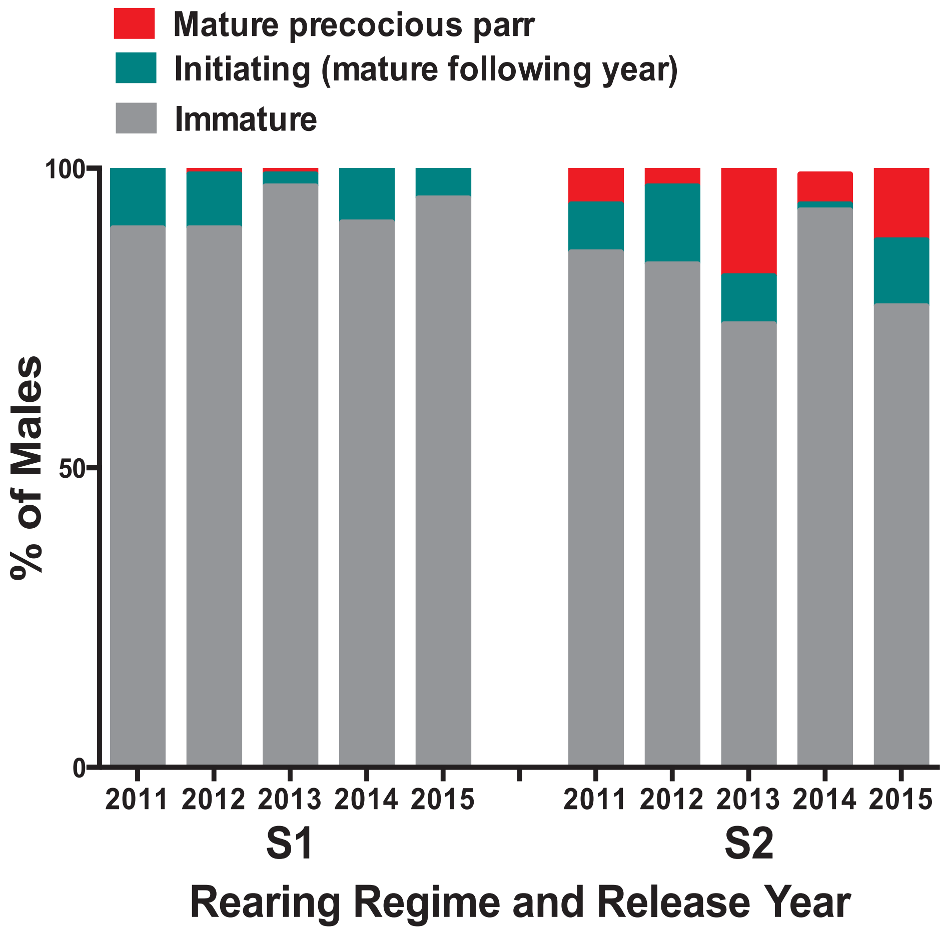
- Practical changes to hatchery practices show promise for reducing domestication selection

Are there negative effects associated with S2 steelhead programs?

Precocious maturation in steelhead

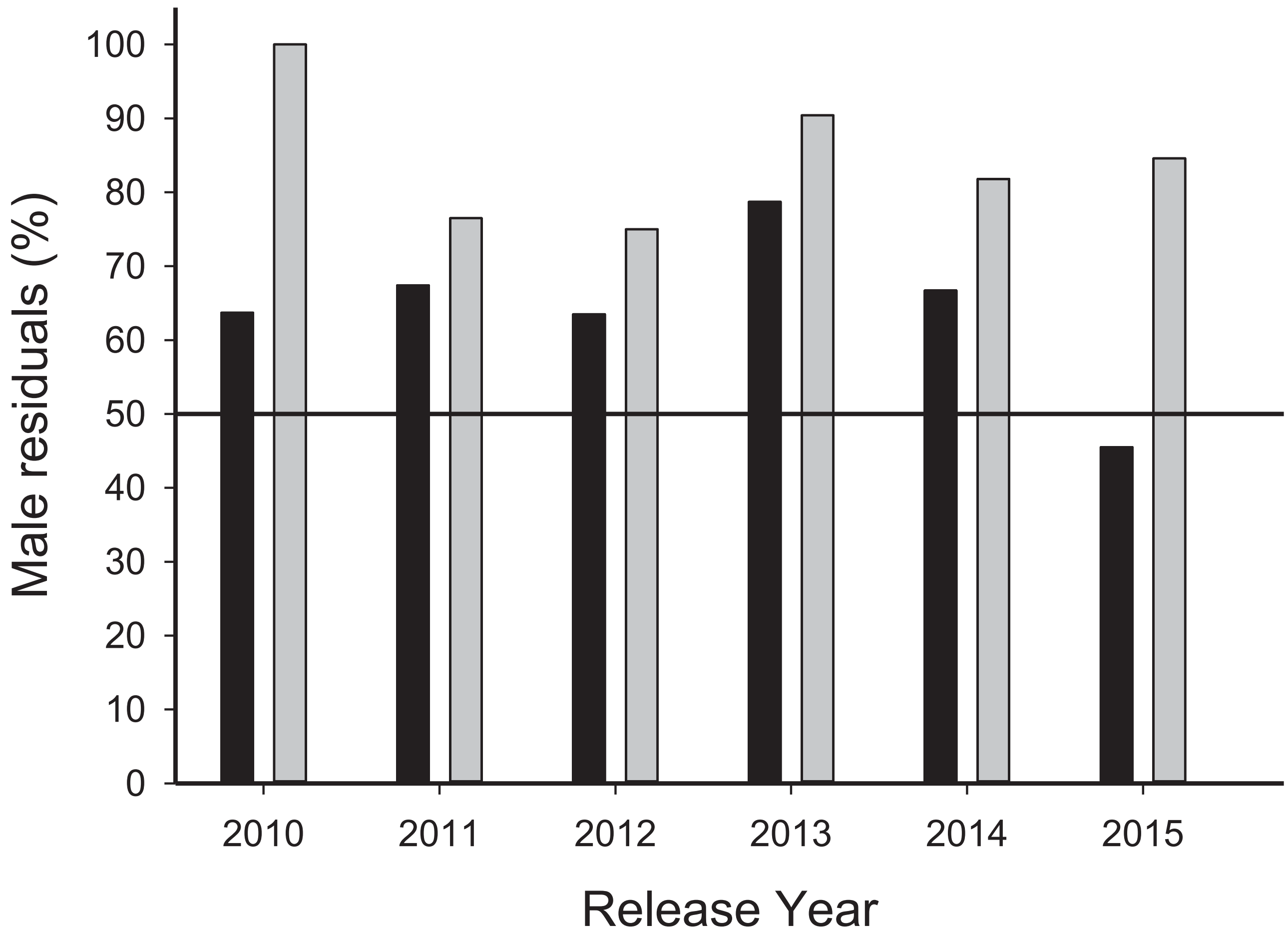


Precocious parr at the Winthrop NFH



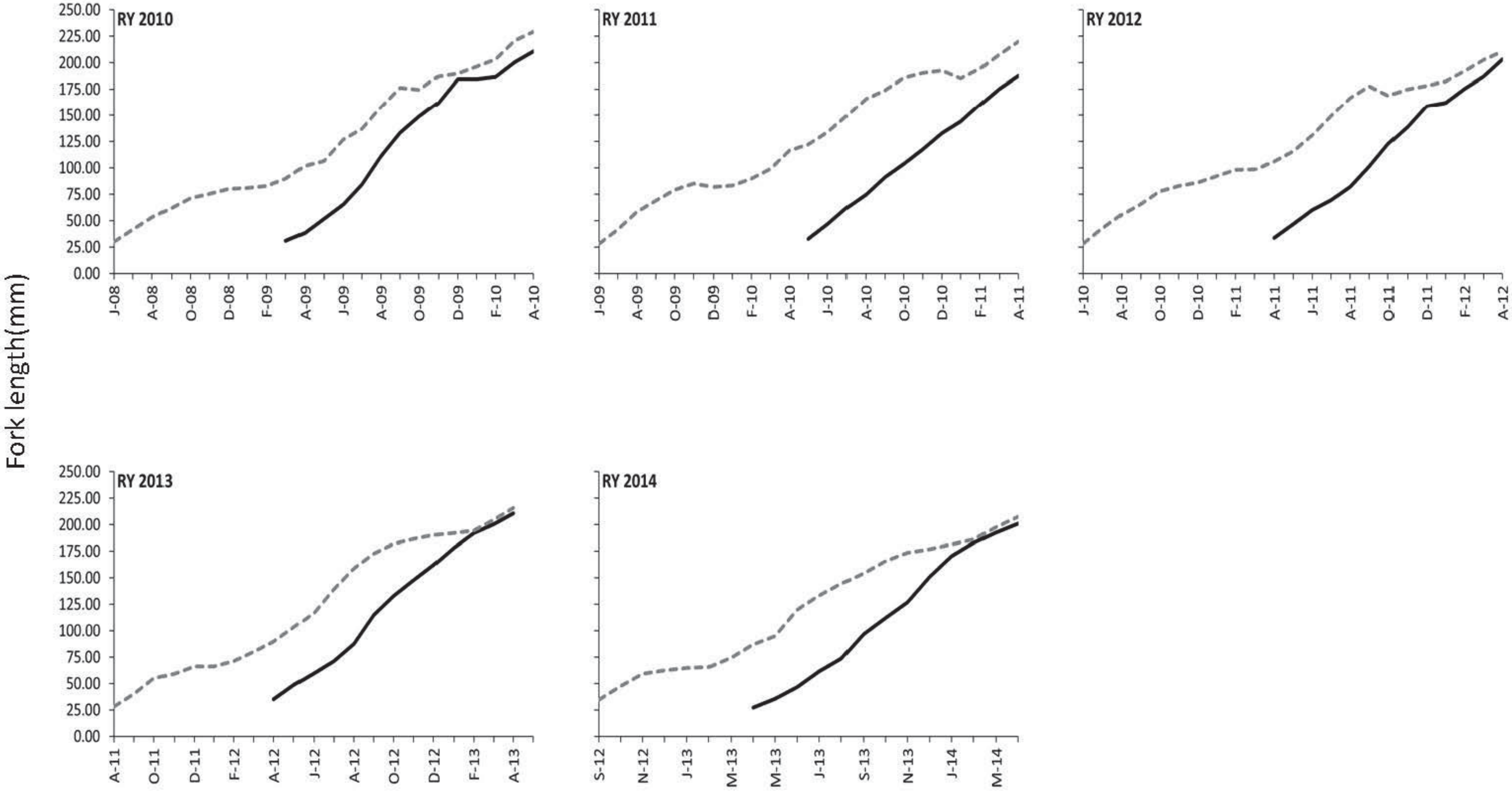
P. Swanson et al. unpublished data

Male residualism



S1 and S2 Growth profiles

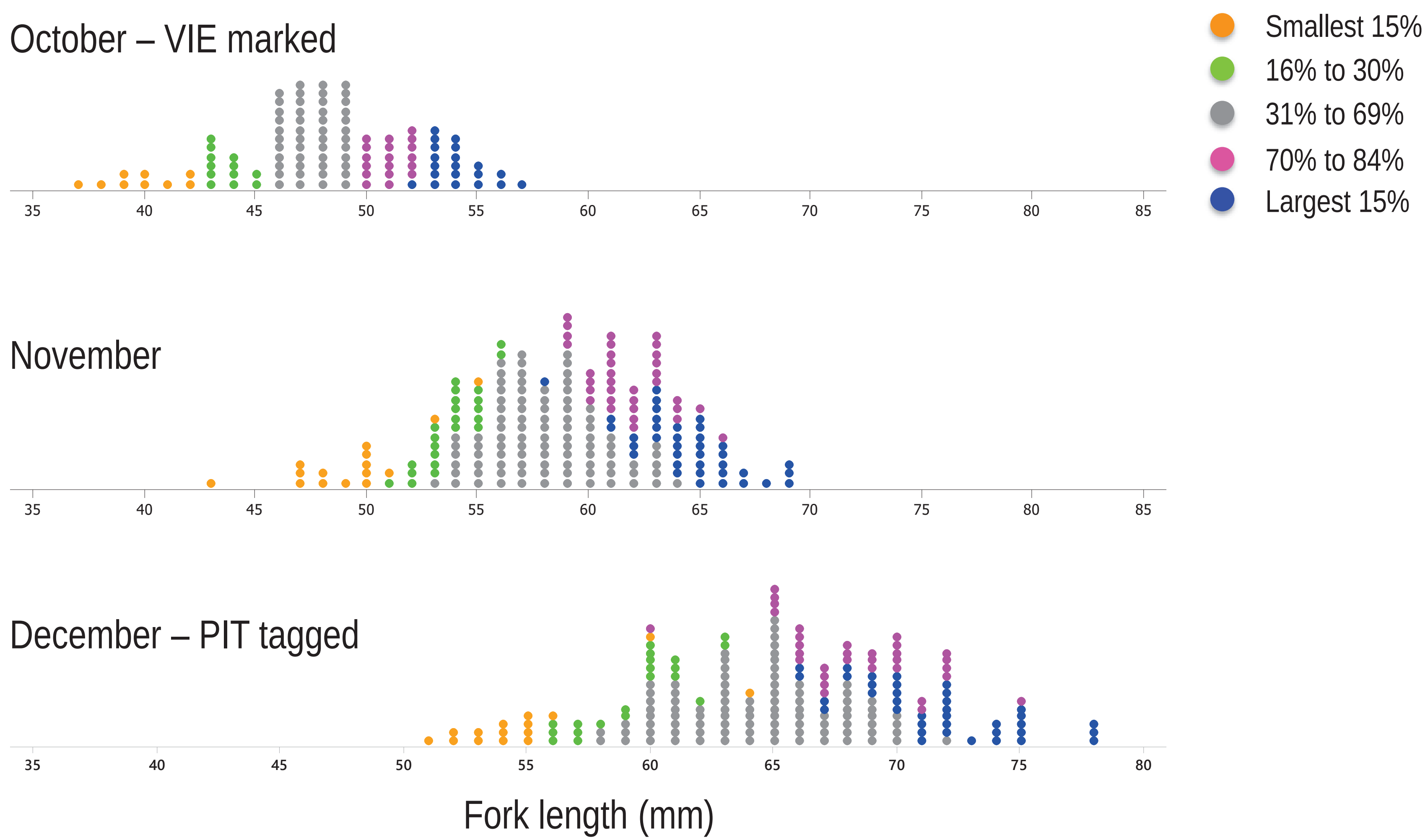
Supplementary Figure S.5. Average monthly FL (mm) for S1 (solid line) and S2 (dashed line) steelhead at Winthrop National Fish Hatchery for release years (RYs) 2010–2014 (month and year are shown on the *x*-axis).



Not all hatcheries can/should implement S2 smolt programs.

Can we design more flexible strategies?

Early growth rate influence on size at smolting



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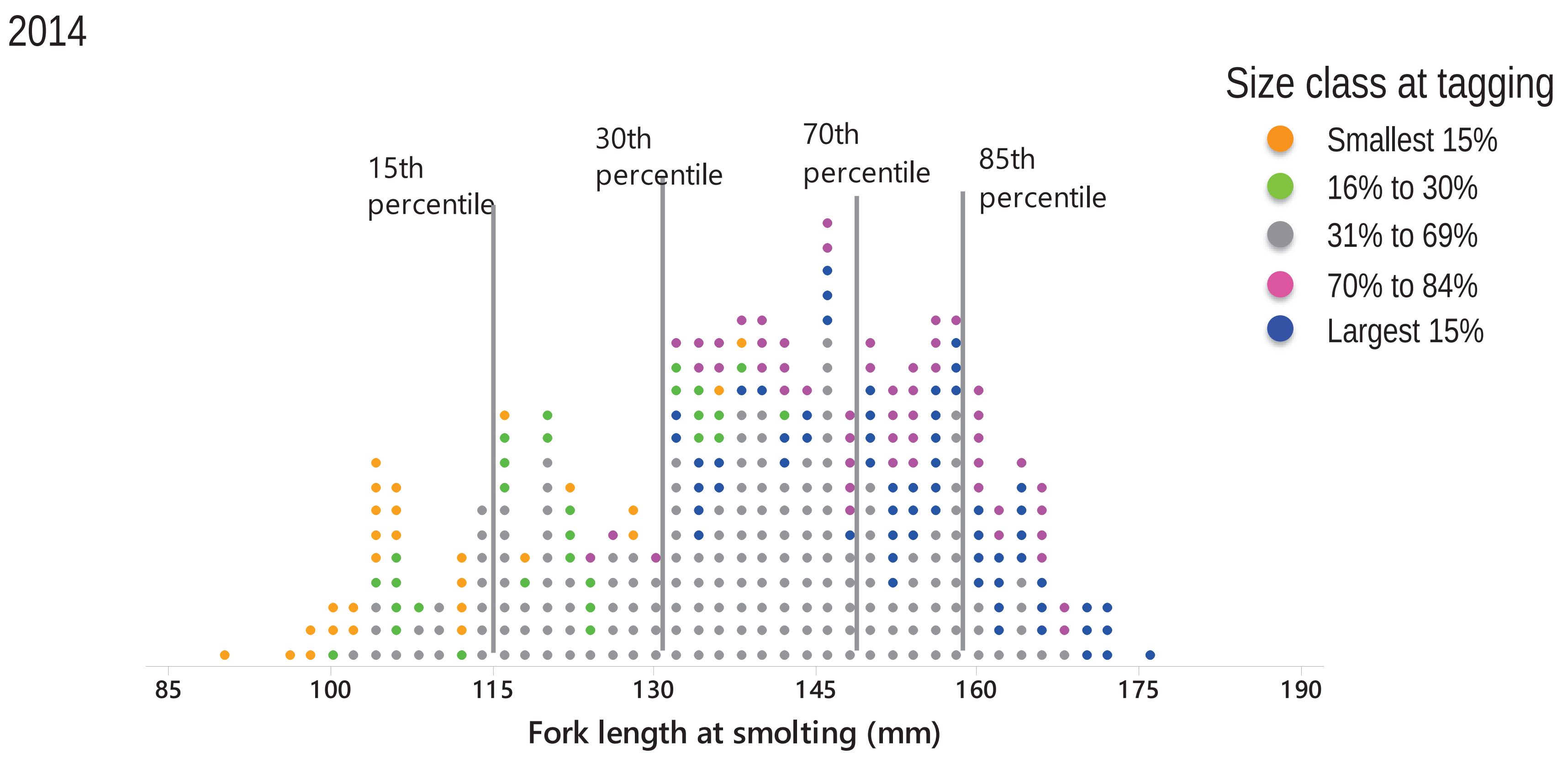
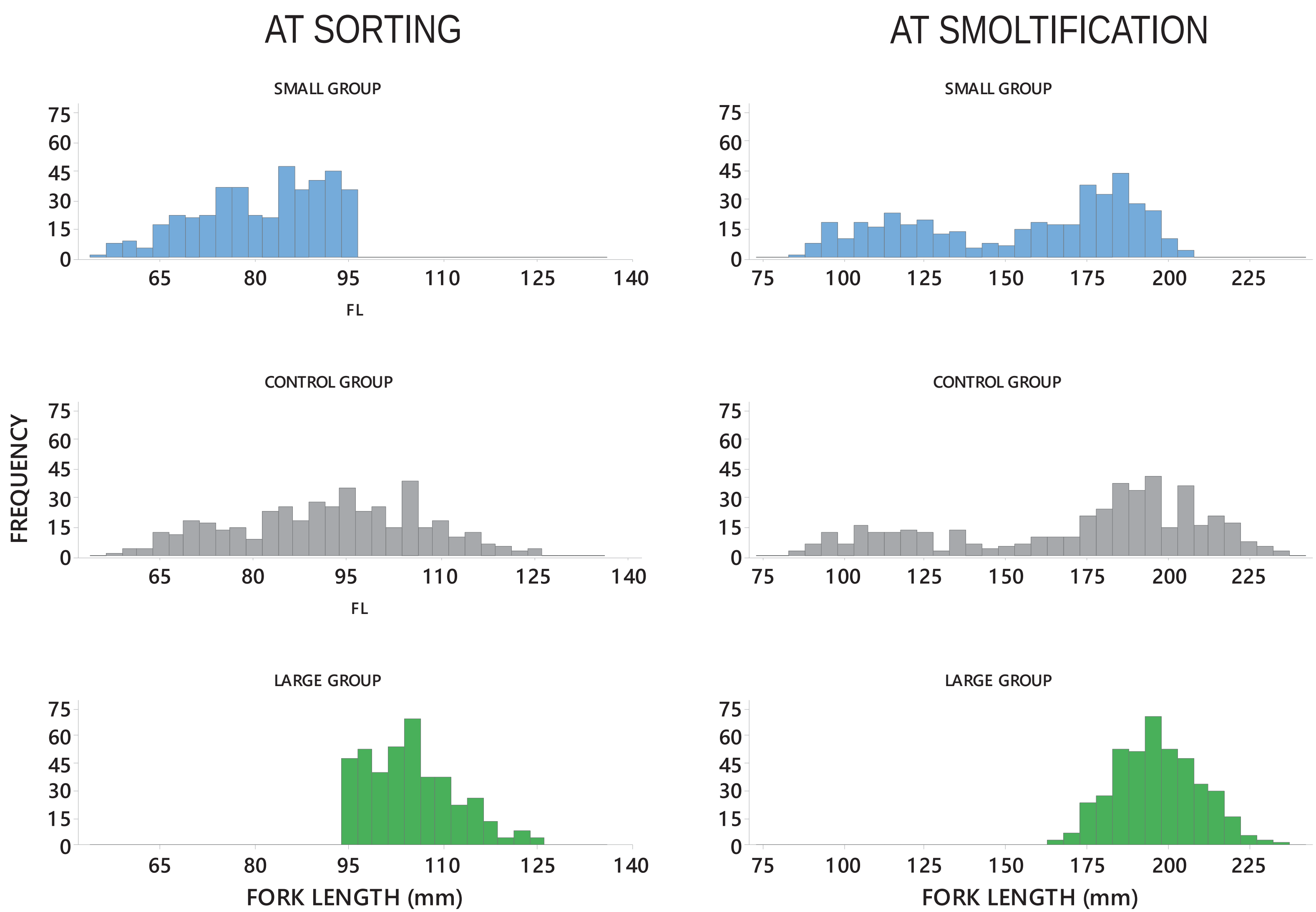
Early growth rate influence on size at smolting



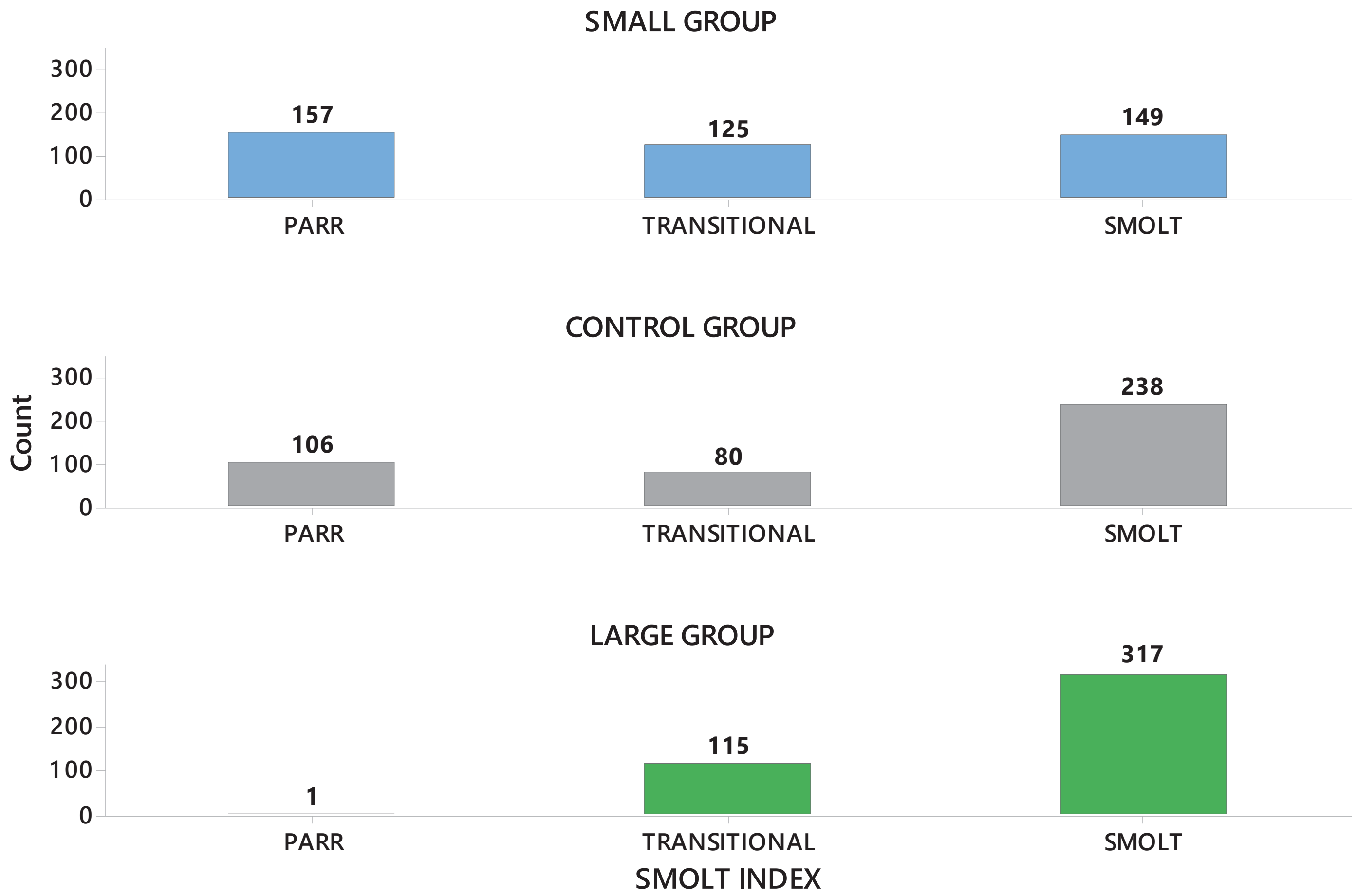
Effects of size-based competition on size variation?

- Mechanism
  - Interference competition may supress the growth of smaller fish and increase size variation
- Size sorting experiment
  - Three treatments (n = 3 tanks per treatment)
    - Small – Below median fork length at tagging
    - Large – Above median fork length at tagging
    - Control – Not sorted by size

Size sorting improve growth of small fish?



Effect of size sorting improve smoltification rate?

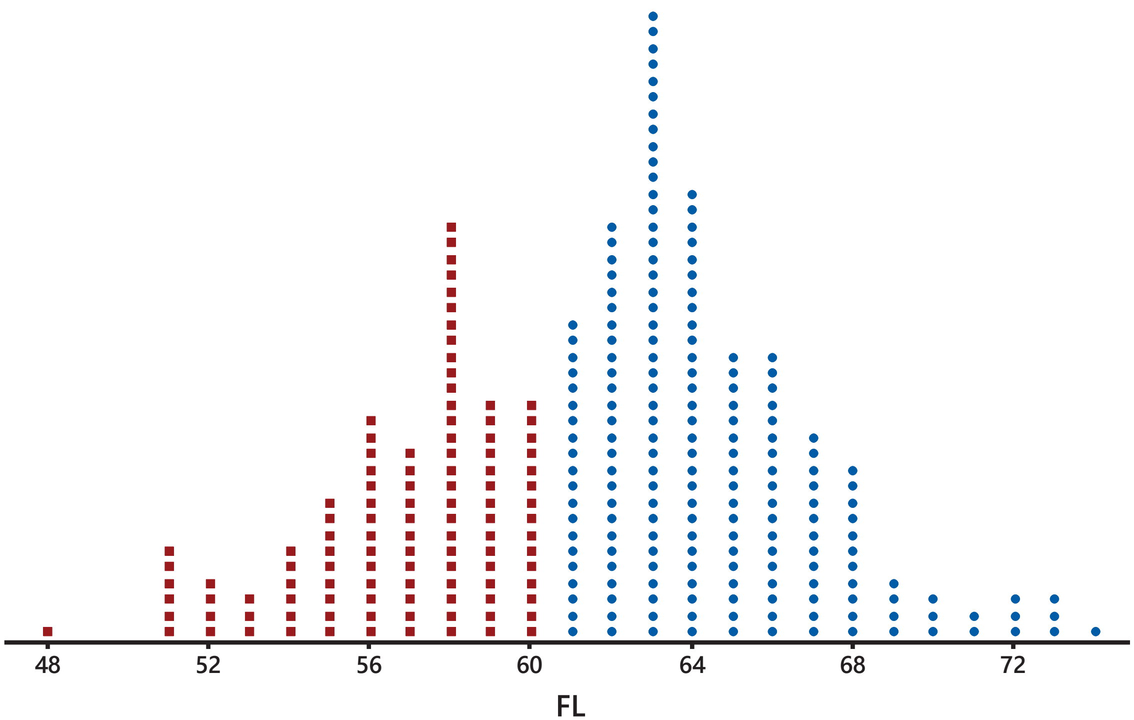


Optimizing smolt production with NOR broodstock

- Three treatments established 8 weeks post-ponding:
  - Control: unsorted + high ration
  - S1: largest 67% of fish ≥ 61mm + high ration
  - S2: smallest 33% of fish ≤60 mm + modulate growth

- Three replicate tanks per treatment

- Target smolt size = 90 g



Acknolwedgements

NOAA Northwest Fisheries Science Center	US Fish and Wildlife Service	Long Live the Kings	Hood Canal Salmon Enahancement Group	Washington Dept. of Fish and Wildlife	University of Washington
Don Van Doornik	Chris Pasley	Rick Endicott	Clayton David	Mark Downen	Jon Dickey
Jeff Atkins	Matt Cooper	Joy Waltermine	Theresa Sjostrom[1]	Bill Evans	Mollie Middleton
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Jeff Hard	Jon Box		Volunteers	Matt Gillum	
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MONITORING AND EVALUATION PLAN FOR PUD HATCHERY PROGRAMS

2017 UPDATE

September 1, 2017

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Prepared for:

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Citation: Hillman, T., T. Kahler, G. Mackey, Andrew Murdoch, K. Murdoch, T. Pearsons, M. Tonseth, and C. Willard. 2017. Monitoring and evaluation plan for PUD hatchery programs: 2017 update. Report to the HCP and PRCC Hatchery Committees, Wenatchee and Ephrata, WA.

TABLE OF CONTENTS

SECTION 1: INTRODUCTION 1

SECTION 2: ADULT PRODUCTIVITY 9
2.1 Natural Replacement Rates of Supplemented Populations 9
2.2 Natural-Origin Recruits of Supplemented Populations 11

SECTION 3: JUVENILE PRODUCTIVITY 13
3.1 Freshwater Juvenile Productivity 13

SECTION 4: NATURAL ENVIRONMENT MONITORING INDICATORS 17
4.1 Hatchery Replacement Rates (HRRs) 17
4.2 Proportion of Hatchery-Origin Spawners (pHOS or PNI) 18
4.3 Run Timing, Spawn Timing, and Spawning Distribution 19
4.4 Stray Rates 22
4.5 Population Genetics 26
4.6 Phenotypic Traits 28

SECTION 5: HATCHERY ENVIRONMENT MONITORING INDICATORS 33
5.1 Release Targets 33

SECTION 6: HARVEST MONITORING INDICATORS 37
6.1 Harvest Rates 37

SECTION 7: REGIONAL OBJECTIVES 39
7.1 Incidence of Disease 39
7.2 Non-Target Taxa of Concern (NTTOC) 40

SECTION 8: ADAPTIVE MANAGEMENT 43

SECTION 9: REFERENCES 45

SECTION 10: GLOSSARY 47

APPENDIX 1: ESTIMATION OF CARRYING CAPACITY 51

APPENDIX 2: HATCHERY REPLACEMENT RATES 79

APPENDIX 3: PNI AND PHOS TARGETS AND SLIDING SCALES 81

APPENDIX 4: SPATIAL DISTRIBUTION OF SPAWNERS OR REDDS 85

APPENDIX 5: WITHIN HATCHERY REARING TARGETS 87

APPENDIX 6: IDENTIFYING AND ANALYZING REFERENCE POPULATIONS 89

LIST OF APPENDICES

Appendix 1: **Estimation of Carrying Capacity**

Appendix 2: **Hatchery Replacement Rates**

Appendix 3: **PNI and pHOS Management Targets and Sliding Scales**

Appendix 4: **Spatial Distribution of Spawners or Redds**

Appendix 5: **Within Hatchery Rearing Targets**

Appendix 6: **Identifying and Analyzing Reference Populations**

SECTION 1: INTRODUCTION

This document is an update of the monitoring and evaluation (M&E) plan of the salmon and steelhead hatchery programs funded by Douglas, Chelan, and Grant County Public Utility Districts (PUDs). Programmatic changes, evaluation of data collection methods, and M&E results from the past several years, along with shifting management paradigms affect M&E needs, all of which have occurred under advancing fish culture and monitoring techniques. As required by the programs, this document is a result of a five-year review intended to expand on and coalesce previous M&E documents (BAMP 1998; Cates et al. 2005; Murdoch and Peven 2005; Hays et al. 2006; Pearsons and Langshaw 2009a, 2009b; Hillman et al. 2013) with inclusion of new information.

Fishery management agencies developed the following general goal statements for hatchery programs, which were adopted by the HCPs Hatchery Committees and PRCC Hatchery Sub-Committee (hereafter, Hatchery Committees):

1. Support the recovery of ESA-listed species by increasing the abundance of the natural adult population, while ensuring appropriate spatial distribution, genetic stock integrity, and adult spawner productivity.
2. Increase the abundance of the natural adult population of unlisted plan species, while ensuring appropriate spatial distribution, genetic stock integrity, and adult spawner productivity. In addition, provide harvest opportunities in years when spawning escapement is sufficient to support harvest.
3. Provide salmon for harvest and increase harvest opportunities, while segregating returning adults from natural tributary spawning populations.

Following the development of Hatchery and Genetic Management Plans (HGMPs), artificial supplementation programs are now characterized into three categories. The first type, integrated conservation programs, are intended to support or restore natural populations. These programs focus on increasing the natural production of targeted fish populations. A fundamental assumption of this strategy is that hatchery fish returning to the spawning grounds are reproductively similar to naturally produced fish. The second type, safety-net programs, are extensions of conservation programs, but are intended to function as reserve capacity for conservation programs in years of low returns. The safety-net provides a demographic and genetic reserve for the natural population. That is, in years of abundant returns they function like segregated programs, and in low return years they can be managed as conservation programs. Lastly harvest augmentation programs are intended to increase harvest opportunities while limiting interactions with wild-origin counterparts.

Monitoring is needed to determine if the hatchery programs are meeting the intended management objectives of conservation, safety-net, or harvest augmentation programs. Objectives for hatchery programs are generally grouped into three categories of performance indicators:

1. In-Hatchery: Is the program meeting the hatchery production objectives?
2. In-Nature: How do fish from the program perform after release?
    a. Conservation Program:

- How does the program affect target population abundance and productivity?
- How does the program affect target population long-term fitness?

b. Safety-Net Program:

- How does the program affect target population long-term fitness?

c. Harvest Augmentation Program:

- Does the program provide harvest opportunities?

3. Risk Assessment: Does the program pose risks to other populations?

Objectives in this plan have been organized in a hierarchy where productivity indicators are the primary metrics used to assess if conservation and safety-net program goals have been met; harvest rates and effects on non-targeted populations are used for harvest programs. In cases where productivity indicators are not available or results are equivocal, monitoring indicators may be used to help evaluate the performance of the program. Evaluations of monitoring indicators may not provide sufficiently powerful conclusions on which to base management actions, although they may provide insight as to why a productivity indicator did or did not meet the program goal. Therefore, the relationship between hatchery programs and indicators can be viewed in a chain-of-causation: management actions within the hatchery programs affect the status of monitoring indicators, which in turn influence productivity indicators (Figure 1).

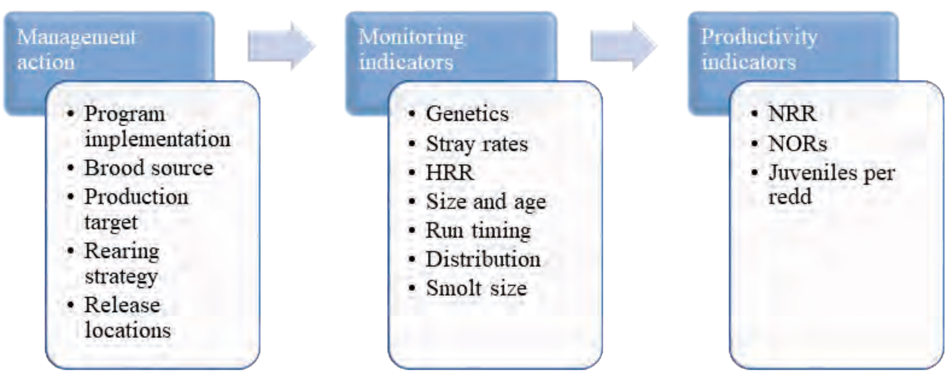

Figure 1. Relationship of indicators to the assessment of supplementation programs. Management actions affect monitoring indicators, which influence productivity indicators. Monitoring indicators may be used to hypothesize the magnitude of influence on productivity.

The primary goal of a conservation program is to contribute to the rebuilding and recovery of naturally reproducing populations within their native habitat. In this plan, natural replacement rates (NRR), recruitment of naturally-produced fish (NOR), and juvenile productivity (juveniles per redd) are important indicators for assessing the success of supplementation. These indicators are difficult to measure precisely and are quite variable in space and time. Therefore, monitoring indicators can be evaluated to help assess if productivity was related to the hatchery programs or other factors (Table 1).

Table 1. Program objectives, indicators, and goals for conservation hatchery programs including productivity and monitoring indicators (also applies to safety-net programs when used to support a conservation program).

				Program goals		
	Objective	**Indicator**	**Target**	**Rebuild natural populations**	**Maintain genetic diversity**	**Opportunity for harvest**
Productivity indicators	Determine if the program has increased the number of naturally spawning adults	Abundance of natural spawners	Increase	✓		✓
		Adult productivity (NRR)	No decrease	✓		
	Determine if the proportion of hatchery fish affects freshwater productivity	Residuals vs. pHOS	No relationship	✓		
		Juveniles per redd vs. pHOS	No relationship	✓		
Monitoring indicators	Determine if run timing and distribution meets objectives	Migration timing	No difference	✓	✓	
		Spawn timing[1]	No difference	✓	✓	
		Redd distribution[2]	No difference	✓	✓	
	Determine if program has affected genetic diversity and population structure	Allele frequency (hatchery vs. wild)	No difference		✓	
		Genetic distance between populations	No difference		✓	
		Effective population size	Increase		✓	
		Age and size at maturity	No difference		✓	
	Determine if hatchery survival meets expectations	HRR	HRR > NRR	✓		
		HRR	HRR ≥ Goal[3]	✓		
	Determine if recipient stray rate of hatchery fish is acceptable	Out of basin	≤ 5%	✓	✓	
		Within basin	≤ 10%	✓	✓	
	Determine if hatchery fish were released at program targets	Size and number	= Target[4]	✓		
	Provide harvest opportunities when appropriate	Harvest	Escapement goals			✓

[1] Hatchery and natural-origin fish should spawn at the same time across the range of elevations within the spawning distribution of each stock.

[2] Hatchery and natural-origin fish should spawn in the same locations. Exceptions are the Carlton and Dryden Summer Chinook programs (see Appendix 4).

[3] HRR targets are identified in Appendix 2.

[4] Number and size targets are identified in Table 3 and Appendix 5.

A flow of information following sequential, logical steps will be employed to evaluate supplementation programs, consistent with the indicators described in Table 1. For example, a hatchery program, at a minimum, must be able to produce more adults per spawner than would occur in the natural environment. Should the program fail this test, hatchery operations should be evaluated to determine if improvements can correct the problem. If a program successfully replaces the required number of adults, it is then evaluated against a reference population or condition, if available, to determine if it has increased the overall number of naturally spawning fish (including both hatchery- and natural-origin adults), increased the number of natural-origin spawners, and to test if productivity of the natural population has changed. When these goals are met, the program is considered successful. When these goals are not met, monitoring indicators may infer why the program is not achieving its goals

If suitable reference populations are not available, other comparisons can be used to help evaluate treatment responses. Evaluation of programs may pursue the following approaches:

- Comparison to reference population(s) that do not contain pre-treatment data.
- Before treatment and after treatment comparisons.
- Comparison to standard(s).
- Comparison to other suitable reference conditions.

Methodologies for selecting reference streams, analyzing data from treatment and reference stream comparisons, and other comparisons are presented in Hillman et al. (2012) (see Appendix 6).

The primary goals of a safety-net program are to provide demographic and genetic reserves for a population that is supplemented by a conservation program (Table 2). Harvest and adult management may be used to control escapement of spawners when appropriate. Monitoring focuses on estimating the number of fish that escape to spawn naturally and stray rates and in-hatchery performance evaluation.

Table 2. Program objectives, indicators, and goals for segregated harvest augmentation hatchery programs including monitoring indicators.

	Objective	Indicator	Target	Program goals: Rebuild natural populations	Program goals: Maintain genetic diversity	Program goals: Opportunity for harvest
Monitoring indicators	Determine if hatchery survival meets expectations	HRR	HRR > NRR			✓
		HRR	HRR ≥ Goal[1]			✓
	Determine if stray rate of hatchery fish is acceptable	Out of basin	≤ 5%		✓	
		Within basin	≤ 10%		✓	
	Determine if hatchery fish were released at program targets	Size and number	= Target[2]			✓
	Provide harvest opportunities when appropriate	Harvest	When greater than escapement goals			✓

[1] HRR targets are identified in Appendix 2.

[2] Number and size targets are identified in Table 3 and Appendix 5.

The primary goal of a harvest augmentation program is to increase harvest opportunities, while segregating adults from natural spawning populations. In this plan, harvest opportunity, survival rates, and stray rates are important indicators for assessing the success of harvest augmentation. These indicators are more readily quantified compared to productivity indicators (Table 2). A flow of information will be employed to evaluate harvest augmentation programs. Since harvest augmentation programs are typically segregated, monitoring indicators will be used to determine the success of a program.

Both monitoring and productivity indicators will be used to evaluate the success of hatchery programs. In the event that the statistical power of tests that involve productivity indicators is insufficient to inform sound management decisions, some of the monitoring indicators may be used to guide management. Figure 2 show the categories of indicators associated with each component of monitoring.

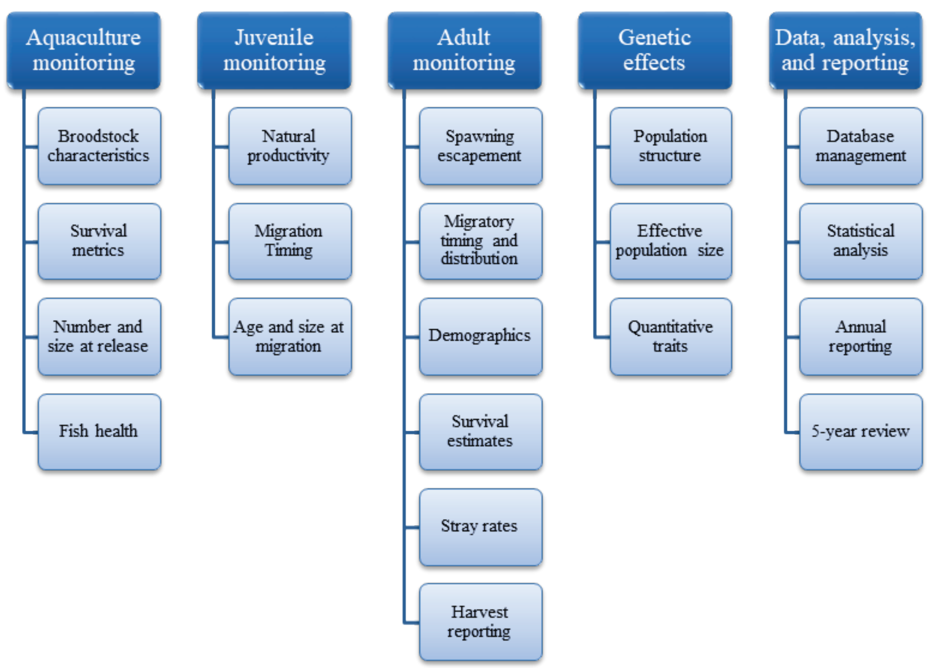

Figure 2. Overview of Monitoring and Evaluation Plan Categories and Components (not including regional objectives).

The overarching goals of conservation, safety-net, and harvest augmentation programs, as described above, are shown in detail in Figure 3. The flow chart (Figure 3) shows the relationship of overarching program goals, the strategies used to meet the goals, the monitoring and evaluation objectives used to evaluate the strategies and determine if goals are being met, and the adaptive

management cycle associated with the programs (see Tables 1 and 2 for the indicators under each objective). The logic depicted in this flow chart shall be used to assess M&E results and apply those results to management decisions. Table 3 presents the current hatchery programs releasing fish in the Upper Columbia Basin.

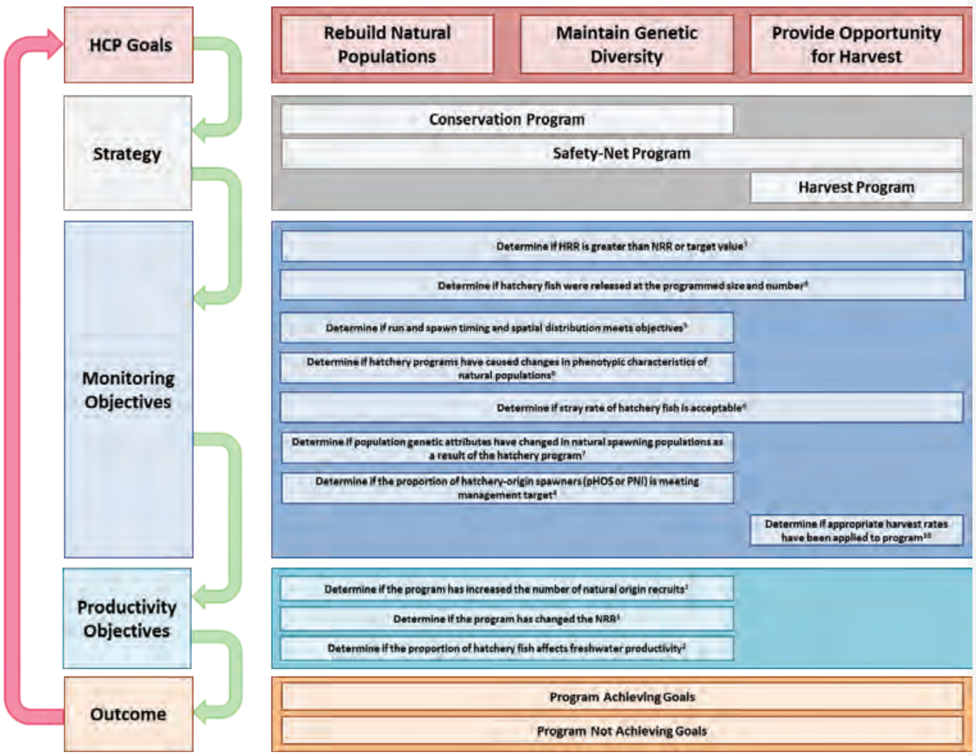

Figure 3. Adaptive management flow chart depicting HCP goals, associated strategies to meet the goals, the monitoring and evaluation objectives (indicated in superscript), and the adaptive management feedback cycle. The strategies, objectives, and outcomes are aligned vertically under the corresponding goals.

Table 3. Hatchery programs in the mid-Columbia River Basin, 2012. Funding entities included Douglas PUD (D), Chelan PUD (C), Grant PUD (G), Bonneville Power Administration (B), Bureau of Reclamation (O), and Army Corps of Engineers (A) and are listed in order of contribution. Total artificial production targets in the mid-Columbia River exceeds 20 million juveniles annually.

Program	Species	Basin	Purpose	Funding Entity	Production
Methow[5]	Spring Chinook [1]	Methow	NNI/Conservation	G, C, D	223,765
Chief Joseph[7]	Spring Chinook	Okanogan	Reintroduction/Harvest	B, G, C, D	900,000
Chiwawa[5]	Spring Chinook [1]	Wenatchee	NNI/Conservation	C	144,026
Nason[5]	Spring Chinook [1]	Wenatchee	NNI/Conservation	G	223,670
Winthrop[7]	Spring Chinook [2]	Methow	Safety-Net	O	400,000
Leavenworth	Spring Chinook [2]	Wenatchee	Harvest	O	1,200,000
Wells[5]	Steelhead [1]	Columbia	Inundation/Safety-Net	D	160,000
Winthrop[7]	Steelhead [1]	Methow	Conservation	O	100,000-200,000
Wells[5]	Steelhead [1]	Methow	Inundation/Safety-Net	D	100,000
Wells/Omak[5, 6]	Steelhead [1]	Okanogan	NNI/Conservation	G	100,000
Wells[5]	Steelhead [1]	Twisp	Inundation/Conservation	D	40,000
Wells[5]	Steelhead [1]	Twisp	NNI/Conservation	D	8,000
Chiwawa[5]	Steelhead [1]	Wenatchee	NNI/Conservation	C	22,000
Chiwawa[5]	Steelhead [1]	Wenatchee	Inundation/Harvest	C	165,000
Chiwawa[5]	Steelhead [1]	Wenatchee	Species trade	C	60,300
Ringold	Steelhead [9]	Columbia	Harvest	Mitchell Act	180,000
Wells[5]	Summer Chinook [2, 3]	Columbia	Inundation/Harvest	D	484,000
Chief Joseph[7]	Summer Chinook [3]	Okanogan	NNI/Cons./Harvest	B, C, D	700,000
Chelan Falls[5]	Summer Chinook [2]	Chelan	Inundation/Harvest	C	400,000
Chelan Falls[5]	Summer Chinook [2]	Chelan	NNI/Conservation	C	176,000
Wells[5]	Summer Chinook [2]	Columbia	Inundation/Harvest	D	320,000
Entiat	Summer Chinook	Entiat	Harvest	O	400,000
Carlton[5]	Summer Chinook	Methow	NNI/Conservation	G	200,000
Chief Joseph[7]	Summer Chinook	Okanogan	NNI/Cons./Harvest	B, G, C, D	1,300,000
Dryden[5]	Summer Chinook	Wenatchee	NNI/Conservation	C, G	500,000
Priest[5]	Fall Chinook[3]	Columbia	Inundation/Harvest	G	5,000,000
Priest[5]	Fall Chinook[3]	Columbia	NNI/Harvest	G	325,543
Priest[5]	Fall Chinook[4]	Columbia	Fry loss/Harvest	G	273,961
Priest[5, 7]	Fall Chinook[3]	Columbia	Harvest	A	1,700,000
Ringold[7]	Fall Chinook[3]	Columbia	Harvest	A	3,500,000
Yakama Nation	Coho	Wenatchee	Reintroduction/Harvest	B, G, C, D	1,000,000
Yakama Nation[8]	Coho	Methow	Reintroduction/Harvest	B, G, C, D	500,000
Skaha	Sockeye	Okanogan	Reintroduction/Harvest	C, G	≤ 5 M eggs

[1] Species listed under the Endangered Species Act.
[2] Segregated program.
[3] Sub-yearling production.
[4] Fry production.
[5] Program covered by this M&E Plan.
[6] Program also partially covered by CCT M&E Plan.
[7] Program affects PUD-funded programs covered by this plan.
[8] Planned to increase to 1,000,000.
[9] Part of the Mitchell Act suite of mitigation programs under the FCRPS BiOp.

SECTION 2: ADULT PRODUCTIVITY

2.1 Natural Replacement Rates of Supplemented Populations[1]

Objective 1: Determine if conservation programs have increased the number of naturally spawning and naturally produced adults of the target population and if the program has reduced the natural replacement rate (NRR) of the supplemented population.

At the core of a conservation program is the objective of increasing the number of spawning adults (i.e., the combined number of naturally produced and hatchery fish) in order to affect a subsequent increase in the number of returning naturally produced fish or natural-origin recruits (NOR). In order for the natural population to remain stable or to increase, the Natural Replacement Rate (NRR), or the ratio of NORs to the parent spawning population, must be at a level where parents are being replaced by their offspring as spawners in the next generation. It is possible to affect an increase in natural-origin spawners through supplementation with a stable or decreasing NRR. However, if the NRR is below replacement (NRR<1.0), termination of the supplementation program will result in a declining natural population should that state of NRR persist. The proportion of the hatchery-origin spawners (pHOS) that will increase natural production without creating adverse effects to the genetic diversity or reproductive success rate of the natural population is unknown, and may be dependent on how individual hatchery programs are operated, as well as available spawning and rearing habitat. Some programs restrict pHOS to reduce the risk to the natural population with the intent of optimizing productivity, concomitantly reducing the overall number of spawners. All other objectives of the M&E Plan either directly support this objective or seek to minimize negative effects of the conservation programs on non-target stocks of concern.

Differences in carrying capacities of supplemented and non-supplemented streams can confound the analysis of the effects of supplementation on total number of spawners returning to the streams. For example, if the supplemented population is at carrying capacity and the non-supplemented population is not, the total number of spawners returning to the non-supplemented population may show an increasing trend over time, while the supplemented population would show no increasing trend. To avoid concluding that the supplementation program has no effect or perhaps a negative effect on total spawners, density corrections should be included in the analyses. Hypotheses that may require density corrections are noted under each monitoring question. Appendix 1 describes methods for estimating carrying capacities.

Monitoring Questions:

Q1.1.1 Has the supplementation program changed the adult productivity (NRRs) of the supplemented populations?[2]

Target Species/Populations:

[1] Supplementation programs may include a safety-net component.

[2] Because adult productivity is affected by the abundance of the population (i.e., productivity decreases with increasing abundance), the goal of supplementation is to increase or maintain productivity, but not decrease it.

- Q1.1.1 applies to all conservation and safety-net stocks.

Statistical Hypotheses 1.1.1[3]:

- $Ho_{1.1.1.1}$: Slope in NRRs before supplementation ≤ slope in NRRs after supplementation.
- $Ho_{1.1.1.2}$: Differences in slopes in NRRs between supplemented and reference populations before supplementation ≤ differences in slopes in NRRs between supplemented and reference populations after supplementation.
- $Ho_{1.1.1.3}$: Mean NRRs before supplementation ≤ mean NRRs after supplementation.
- $Ho_{1.1.1.4}$: Mean ratio scores in NRRs before supplementation ≤ Mean ratio scores in NRRs during supplementation.
- $Ho_{1.1.1.5}$: Mean ratio scores in NRRs (adjusted for density dependence) before supplementation ≤ Mean ratio scores in NRRs (adjusted for density dependence) during supplementation. [This hypothesis adjusts NRRs for density-dependent effects (see Hillman et al. 2012 for details; Appendix 6).]
- $Ho_{1.1.1.6}$: There is no association between the proportion of hatchery-origin spawners (pHOS) and the residuals from the smooth hockey stick stock-recruitment curve; rho = 0. [If there is a significant negative association between pHOS and the residuals, then hatchery fish may be reducing the productivity of the wild population.]

Measured Variables:

- Number of hatchery and naturally produced fish on spawning grounds
- Number of naturally produced fish harvested

Derived Variables:

- Number of naturally produced recruits by brood year for both naturally produced parents and hatchery parents (≥age-3).
- NRRs (calculated as NORs/spawner).
- Stock-recruit models, parameters, and residuals.
- Includes ratio scores of NRRs (requires reference population[s]).
- Includes calculation of ratios NORs (requires reference population).
- Appendix 1: Spawning escapement and carrying capacity information (as applicable)

Spatial/Temporal Scale:

- Calculated annually based on brood year.
- Time series.

Possible Statistical Analysis:

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3 Quality and quantity of data will determine which hypotheses are evaluated. See Hillman et al. 2012 (Appendix 6) for details.

- These analyses shall be performed every 5-years. Use graphic analyses, trend analyses, t-tests, Aspin-Welch tests, and randomization tests to evaluate the statistical hypotheses (see Hillman et al. 2012; Appendix 6). The specific analysis used will depend on the availability of reference conditions.
- Correlation analysis will examine associations between hatchery adult composition and NRRs.
- On a five-year period, correlate productivity with extraneous factors such as ocean productivity indices.

Analytical Rules:

- This is a productivity indicator that will be used to assess the success of the supplementation program.
- Type I Error of 0.05.

2.2 Natural-Origin Recruits of Supplemented Populations

Monitoring Questions:

Q1.2.1: Has the supplementation program changed the abundance of NORs within the supplemented population?

Target Species/Populations:

- Q1.2.1 applies to all supplemented or safety net stocks.

Statistical Hypotheses 1.2.1[4]:

- $Ho_{1.2.1.1}$: Slope in NORs[5] before supplementation ≥ slope in NORs after supplementation.
- $Ho_{1.2.1.2}$: Differences in slopes in NORs between supplemented and reference populations before supplementation ≥ differences in slopes in NORs between supplemented and reference populations after supplementation.
- $Ho_{1.2.1.3}$: Mean NORs before supplementation ≥ mean NORs after supplementation.
- $Ho_{1.2.1.4}$: Mean ratio scores in NORs before supplementation ≥ Mean ratio scores in NORs during supplementation.
- $Ho_{1.2.1.5}$: Mean ratio scores in NORs/Maximum Recruitment before supplementation ≥ Mean ratio scores in NORs/Maximum Recruitment during supplementation. [This hypothesis adjusts NORs for the capacity of the habitat; it tests the fraction of the habitat saturated with NORs (see Hillman et al. 2012 for details).]
- $Ho_{1.2.1.6}$: There is no association between the proportion of hatchery-origin spawners (pHOS) and NORs; rho = 0. [If there is a significant negative association between

4 Quality and quantity of data will determine which hypotheses are evaluated. See Hillman et al. 2012 (Appendix 7) for details.

5 "Slope in NORS" refers to abundance of NORs across time (years).

pHOS and NORs, then hatchery fish may be reducing the reproductive success of the wild population.]

Measured Variables:

- Number of hatchery and naturally produced fish on spawning grounds.
- Number of hatchery and naturally produced fish taken for broodstock.
- Number of hatchery and naturally produced fish taken in harvest (if recruitment is to the Columbia).

Derived Variables:

- NORs (number of naturally produced recruits (total recruits) by brood year for both naturally produced parents and hatchery parents [≥age-3]).
- Stock-recruit models, parameters, and residuals.
- Includes ratio scores of NORs (requires reference population[s]).
- Estimates of carrying capacity (see Appendix 1).

Spatial/Temporal Scale:

- Calculate annually based on brood year.
- Time series.

Possible Statistical Analysis:

- These analyses shall be performed every 5-years. Use graphic analyses, trend analyses, t-tests, Aspin-Welch tests, and randomization tests to evaluate the statistical hypotheses (see Hillman et al. 2012). The specific analysis used will depend on the availability of reference conditions.
- Correlation analysis will examine associations between hatchery adult composition and NORs.
- On a five-year period, correlate NORs with extraneous factors such as ocean productivity indices.

Analytical Rules:

- This is a productivity indicator that will be used to assess the success of the supplementation program.
- Type I Error of 0.05.

SECTION 3: JUVENILE PRODUCTIVITY

3.1 Freshwater Juvenile Productivity

Objective 2: Determine if the proportion of hatchery fish on the spawning grounds affects the freshwater productivity of supplemented stocks.

Out-of-basin effects (e.g., smolt passage through the hydro system, harvest, and ocean productivity, etc.) influence the survival of smolts after they migrate from the tributaries. These effects introduce substantial variability into the adult-to-adult survival rates (NRRs and HRRs) and may mask in-basin effects (e.g., habitat quality, density-dependent mortality, and differential reproductive success of hatchery and naturally produced fish). Therefore, an estimate of freshwater productivity may help inform the performance of hatchery and natural-origin spawners.

The objective of estimating freshwater productivity in the Upper Columbia ESU/DPS is to estimate the survival from egg to a critical juvenile life stage(s) of target stocks. Smolt or juvenile production models generated from the information obtained through these programs will provide a level of predictability with greater sensitivity to in-basin effects than spawner-recruitment models that consider all effects.

Differences in the current carrying capacities of supplemented and non-supplemented streams can confound the effects of supplementation on numbers of juveniles per redd. For example, if the supplemented population is at or above carrying capacity and the non-supplemented population is not, numbers of juveniles per redd in the non-supplemented population may be significantly greater than the number of juveniles per redd in the supplemented population. In addition, pHOS may be correlated with overall spawner abundance. In these cases, it is difficult or impossible to separate density-dependent effects from the influence of pHOS on freshwater productivity. To avoid concluding that the supplementation program has no effect or perhaps a negative effect on juveniles per redd, the capacity of the habitats must be included in the analyses. The Supplementary Hypotheses presented below are designed to address the confounding effects of different densities on the analyses.

Monitoring Questions:

Q2.1.1: Has the supplementation program changed the number of juveniles (smolts, parr, and/or emigrants) per redd within the supplemented population?

Q2.2.1: Does the number of juveniles per redd decrease as the proportion of hatchery spawners increases?[6]

Target Species/Populations:

- Both Q2.1.1 and Q2.2.1 apply to all conservation stocks.

Statistical Hypotheses for 2.1.1[7]:

[6] Information is needed to estimate the effects of density dependence on these questions. Consider spatial distribution of redds.

[7] Quality and quantity of data will determine which hypotheses are evaluated. See Hillman et al. (2012) for details.

- $Ho_{2.1.1.1}$: Slope in juveniles/redd before supplementation ≤ slope in juveniles/redd after supplementation.
- $Ho_{2.1.1.2}$: Differences in slopes in juveniles/redd between supplemented and reference populations before supplementation ≤ differences in slopes in juveniles/redd between supplemented and reference populations after supplementation.
- $Ho_{2.1.1.3}$: Mean juveniles/redd before supplementation ≤ mean juveniles/redd after supplementation.
- $Ho_{2.1.1.4}$: Mean ratio scores in juveniles/redd before supplementation ≤ Mean ratio scores in juveniles/redd during supplementation.
- $Ho_{2.1.1.5}$: Mean ratio scores in juveniles/redd (adjusted for density dependence) before supplementation ≤ Mean ratio scores in juveniles/redd (adjusted for density dependence) during supplementation. [This hypothesis adjusts juveniles/redd for density-dependent effects (see Hillman et al. 2012 for details; Appendix 6).]
- $Ho_{2.1.1.6}$: There is no association between the proportion of hatchery-origin spawners (pHOS) and the residuals from the smooth hockey stick stock-recruitment curve; rho = 0. [If there is a significant negative association between pHOS and the residuals, then hatchery fish may be reducing the productivity of the wild population.]

Statistical Hypotheses for 2.2.1:

- $Ho_{2.2.1.1}$: There is no association between the proportion of hatchery-origin spawners (pHOS) and the residuals from the smooth hockey stick stock-recruitment curve; rho = 0. [If there is a significant negative association between pHOS and the residuals, then hatchery fish may be reducing the productivity of the wild population.]
- $Ho_{2.2.1.2}$: The slope between proportion of hatchery spawners and juveniles/redd is ≥ 0.

Measured Variables:

- Number of hatchery and naturally produced fish on spawning grounds.
- Numbers of redds.
- Number of juveniles (smolts, parr [where appropriate], and emigrants).

Derived Variables:

- Number of juveniles per spawner.
- Number of juveniles per redd.
- Carrying capacity (see Appendix 1).

Spatial/Temporal Scale:

- Calculate annually based on brood year.
- Time series.

Possible Statistical Analysis:

- These analyses shall be performed every five-years. Use graphic analyses, trend analyses, t-tests, Aspin-Welch tests, and randomization tests to evaluate the statistical hypotheses (see Hillman et al. 2012; Appendix 6). The specific analysis used will depend on the availability of reference conditions.
- Correlation analysis will examine associations between hatchery adult composition and juveniles/redd.

Analytical Rules:

- This is a productivity indicator that will be used to assess the success of the supplementation program.
- Type I Error of 0.05.

SECTION 4: NATURAL ENVIRONMENT MONITORING INDICATORS

4.1 Hatchery Replacement Rates (HRRs)

Objective 3: **Determine if the hatchery adult-to-adult survival (i.e., hatchery replacement rate, HRR) is greater than the natural adult-to-adult survival (i.e., natural replacement rate, NRR) and the target hatchery survival rate.**

The survival advantage from the hatchery (i.e., egg-to-smolt) must be sufficient to produce a greater number of returning adults than if broodstock were left to spawn naturally. If a hatchery program cannot produce a greater number of adults than naturally spawning fish, then the program should be modified or discontinued. Production levels were initially developed using historical run sizes and smolt-to-adult survival rates (BAMP 1998). Using the stock specific NRR and agreed upon target values (see Appendix 2), comparisons to actual survival rates will be made to ensure the expected level of survival has been achieved.

Monitoring Questions:

Q3.2.1: Is the adult-to-adult survival rate of hatchery fish (HRR) greater than or equal to the adult-to-adult survival rate (NRR) of naturally produced fish?

Q3.2.2: Is the adult-to-adult survival rate of hatchery fish (HRR) greater than or equal to the Target Value identified in Appendix 2[8]?

Target Species/Populations:

- Q3.2.1 applies to all conservation stocks.
- Q3.2.2 applies to all stocks.

Statistical Hypothesis 3.2.1:

- $Ho_{3.2.1.1}$: $HRR_{\text{Year } x} \geq NRR_{\text{Year } x}$

Statistical Hypothesis 3.2.2:

- $Ho_{3.2.2.1}$: HRR ≥ Target Value identified in Appendix 2

Measured Variables:

- Number of hatchery and naturally produced fish on spawning grounds.
- Number of hatchery and naturally produced fish harvested.
- Number of hatchery and naturally produced fish collected for broodstock.
- Number of broodstock used by brood year (hatchery and naturally produced fish).

Derived Variables:

- Number of hatchery and naturally produced adults by brood year (≥age-3).

[8] Target values may be adjusted by the hatchery committees.

- HRR (number of returning adults per brood year/broodstock)
- NRR (from Objective 1)
- Appendix 2: HRR targets identified in Appendix 2

Spatial/Temporal Scale:

- Calculate annually based on brood year.
- Time series.

Possible Statistical Analysis:

- For Q3.2.1 use graphic analysis and paired-sample quantile tests to compare HRR to NRR
- For Q3.2.2 use graphic analysis and one-sample quantile tests to compare HRR to the target value.
- On a five-year period, correlate HRRs with extraneous factors such as ocean productivity indices.

Analytical Rules:

- This is a monitoring indicator that will be used to support management decisions.
- Type I Error of 0.05.

4.2 Proportion of Hatchery-Origin Spawners (pHOS or PNI)

Objective 4: Determine if the proportion of hatchery-origin spawners (pHOS or PNI) is meeting management target.

Certain hatchery programs have pHOS or PNI targets, while other do not. HGMPs and permits inform the selection of targets, which are identified in Appendix 3.

Monitoring Questions:

Q4.1.1: Is the estimated proportion of hatchery-origin spawners (pHOS) less than or equal to the management target, and/or, is the estimated Percent Natural Influence (PNI) greater than or equal to the management target identified in Appendix 3?

Target Species/Populations:

- Q4.1.1 applies to all conservation and safety-net stocks that have a defined pHOS or PNI target or sliding scale (see Appendix 3).

Statistical Hypothesis 4.1.1:

- $Ho_{4.1.1.1}$: pHOS > target value or $PNI_{\text{Supplemented population}}$ < target value identified in Appendix 3

Measured Variables:

- Number of hatchery and naturally produced fish on spawning grounds

Derived Variables:

- pHOS or PNI
- Appendix 3: PNI and pHOS targets and sliding scales identified in Appendix 3

Spatial/Temporal Scale:

- Calculate annually.
- Analyzed as time series.

Possible Statistical Analysis:

- Use graphic analysis and summary statistics to compare pHOS or PNI to the target value in Appendix 3.

Analytical Rules:

- This is a monitoring indicator that will be used to support management decisions.

4.3 Run Timing, Spawn Timing, and Spawning Distribution

Objective 5: Determine if the run timing, spawn timing, and spawning distribution of the hatchery component is similar to the natural component of the target population or is meeting program-specific objectives.

Strategies for conservation programs typically intend that hatchery and natural-origin fish spawn together and in similar locations. However, in some cases, strategies may differ from this paradigm (e.g., summer Chinook salmon in the Wenatchee and Methow rivers; see Appendix 4). Phenotypic plasticity or selection resulting from the hatchery environment (i.e., domestication) may affect run (migration) timing, spawn timing, and spawning distribution. If conservation programs do not adequately represent the genetic diversity of the natural population, and if phenotypic traits in supplementation fish related to fitness deviate from the naturally produced spawning population, the goals of supplementation may not be achieved. Hatchery adults that migrate and/or spawn at different times or are spatially segregated from natural-origin fish may be subject to reduced fitness. Hatchery adults that spawn at different times or locations than natural-origin fish would be reproductively isolated from the natural population. The extent of such isolation, ranging from no isolation to substantial isolation, may be exploited for management purposes in some cases.

Migration Timing

Monitoring Questions:

Q5.1.1: Is the migration timing of hatchery and natural-origin fish from the same age class similar?

Target Species/Populations:

- Q5.1.1 applies to all conservation stocks.

Statistical Hypotheses 5.1.1:

- $Ho_{5.1.1.1}$: Migration timing $_{\text{Hatchery Age X}}$ = Migration timing $_{\text{Naturally produced Age X}}$

- $Ho_{5.1.1.2}$: The cumulative frequency of migration timing of hatchery-origin fish = the cumulative frequency of migration timing of natural-origin fish.
- $Ho_{5.1.1.3}$: The 10^{th} percentile, 50^{th} percentile (mode), 90^{th} percentile, and mean migration timing of hatchery-origin fish = the 10^{th} percentile, 50^{th} percentile (median), 90^{th} percentile, and mean migration timing of natural-origin fish.

Measured Variables:

- Ages of hatchery and natural-origin fish sampled via PIT tags or stock assessment monitoring.
- Time (Julian date) of arrival at mainstem projects and within tributaries (e.g., traps, PIT arrays) with the intent to identify biologically significant differences.

Derived Variables:

- Mean Julian date for a given age class.

Spatial/Temporal Scale:

- Calculate annually based on return year and age class.
- Time series.

Possible Statistical Analysis:

- Use graphic analyses (cumulative frequency polygons), paired t-tests, Aspin-Welch tests, and randomization tests.

Analytical Rules:

- This is a monitoring indicator that will be used to support management decisions.
- Type I Error of 0.05.

Spawn Timing

Monitoring Questions:

Q5.2.1: Is the timing of spawning similar for conservation hatchery and natural-origin fish?

Target Species/Populations:

- Q5.2.1: Applies to all semelparous species and populations supplemented by conservation programs. Steelhead can only be assessed for natural spawning in situations where hatchery and natural-origin fish can be appropriately marked and detected.

Statistical Hypotheses 5.2.1:

- $Ho_{5.2.1.1}$: The cumulative frequency of spawn timing of hatchery-origin fish = the cumulative frequency of spawn timing of natural-origin fish.
- $Ho_{5.2.1.2}$: The 10^{th} percentile, 50^{th} percentile (mode), 90^{th} percentile, and mean spawn timing of hatchery-origin fish = the 10^{th} percentile, 50^{th} percentile (mode), 90^{th} percentile, and mean spawn timing of natural-origin fish.

- $Ho_{5.2.1.3}$: The relationship between elevation and spawn timing of hatchery-origin fish = the relationship between elevation and spawn timing of natural-origin fish.

Measured Variables:

- Time (Julian date) and elevation (m) of hatchery and natural-origin salmon carcasses or marked steelhead detected on spawning grounds within defined reaches.
- Time (Julian date) of ripeness of hatchery and natural-origin steelhead captured for broodstock.

Derived Variables:

- Mean Julian date.

Spatial/Temporal Scale:

- Calculate annually based on return year.
- Time series.

Possible Statistical Analysis:

- Use graphic analyses (cumulative frequency polygons), paired t-tests, Aspin-Welch tests, and randomization tests.
- Use graphic analyses, ANCOVA, and/or regression analysis to assess relationships between elevation and spawn timing.

Analytical Rules:

- This is a monitoring indicator that will be used to support management decisions.
- Type I Error of 0.05.

Spatial Distribution of Redds

Monitoring Questions:

Q5.3.1: Is the distribution of redds similar for conservation hatchery and natural-origin fish?

Q5.3.2: Is the distribution of redds similar to defined management targets (see Appendix 4)?

Target Species/Populations:

- Q5.3.1 applies to all conservation program stocks.
- Q5.3.2 applies only to conservation program stocks with specific spawning distribution targets (Carlton and Dryden summer Chinook programs; Appendix 4).

Statistical Hypothesis 5.3.1:

- $Ho_{5.3.1.1}$: The distribution of hatchery-origin redds (hatchery females) = the distribution of natural-origin redds (natural-origin females).

Statistical Hypothesis 5.3.2:

- $Ho_{5.3.2.1}$: The distribution of hatchery-origin redds (hatchery females) = the target distribution identified in Appendix 4.

Measured Variables:

- Location (GPS coordinate) of female salmon carcasses observed on spawning grounds. The distribution of hatchery and naturally produced steelhead redds may be evaluated if marking or tagging efforts provide reasonable results.

Derived Variables:

- Location of female salmon carcass at the historic reach scale and at the 0.1 km scale.
- Calculate percent overlap in distribution across available spawning habitat or historical reaches.
- Appendix 4: Management targets for spatial distribution of spawners or redds (as applicable).

Spatial/Temporal Scale:

- Calculate annually based on return year.
- Time series.

Possible Statistical Analysis:

- Use graphic analysis and Yates' Chi-square analysis for both Q5.3.1 and Q5.3.2.

Analytical Rules:

- This is a monitoring indicator that will be used to support management decisions.
- Type I Error of 0.05.

4.4 Stray Rates

<u>Objective 6</u>: Determine if the recipient stray rate of hatchery fish is below the acceptable levels to maintain genetic variation among stocks.

Maintaining locally adapted traits among independent fish populations requires that returning hatchery fish have a high rate of site fidelity to the target population or stream. Hatchery practices (e.g., imprinting on water sources at key life history stages, release methodology, release location, age at return, broodstock used, spawner density, spawning habitat quality and access, and environmental conditions) are the main variables thought to affect stray rates. Regardless of the magnitude of homing of adult returns, if adult hatchery fish do not contribute to the natural population, the program will not meet the basic condition of a supplementation program.

Independent populations are populations that are genetically differentiated from other populations. In some cases, genetic differentiation may be assumed based on phenotypic traits or geographic isolation when molecular genetics analyses are not available. When populations are not independent, straying among them does not pose a risk of genetic homogenization. In addition, stray rates of hatchery-origin fish cannot be expected to be lower than for natural-origin fish. When estimates of stray rates for natural-origin fish are available and if they exceed the 5% among population stray rate or 10% within population stray rate thresholds identified in this plan, analysis

and interpretation of stray rates must take into account the concept that hatchery programs may be held to unattainable standards based on the natural stray rate. Current criteria established by the ICBTRT (2005) and the Upper Columbia Spring Chinook Salmon and Steelhead Recovery Plan (2007) indicate that fish that do stray to other non-target populations should not comprise greater than 5% of the non-target spawning population. Likewise, fish that stray into non-target spawning areas within an independent population should not comprise greater than 10% of the non-target spawning aggregate (see Tables 6.1 and 6.2).

This plan identifies three stray rate metrics; brood-year stray rate, among population return-year stray rate, and within population return-year stray rate. The return-year stray rates have specific targets that are from the ICBTRT (2005) and Upper Columbia Spring Chinook Salmon and Steelhead Recovery Plan (2007), and are linked to extinction risk. That is, hatchery strays from other populations cannot make up more than 5% of the spawning escapement within a non-target, recipient population. In addition, hatchery strays from other spawning aggregations within a population (e.g., Chiwawa spring Chinook) cannot make up more than 10% of the spawning escapement within a non-target, recipient spawning aggregate (e.g., White River). Brood-year stray rate, on the other hand, is not discussed in the Upper Columbia Spring Chinook Salmon and Steelhead Recovery Plan (2007) or ICBTRT (2005) and therefore has no specific target. Nevertheless, it is important to track brood-year stray rates to determine if hatchery operations affect the homing and straying of specific brood years. These data support the return-year stray metrics and are used to inform possible changes in genetic variation among stocks.

Brood-Year Stray Rates

Monitoring Questions:

Q6.1.1: What is the brood-year stray rate of hatchery fish?

Target Species/Populations:

- Q6.1.1 applies to all hatchery stocks.

Statistical Hypothesis 6.1.1:

- $Ho_{6.1.1.1}$: None.

Measured Variables:

- Number of hatchery carcasses found in non-target and target spawning areas or number of returning spawners counted via PIT-tag detection or at weirs in close temporal proximity to spawning areas.
- Number of hatchery fish collected for broodstock.
- Number of hatchery fish taken in fishery.
- Locations of live and dead strays (used to tease out overshoot).

Derived Variables:

- Total number of hatchery carcasses and take in fishery estimated from expansion analysis.
- Percent of the total brood return that strays.

Spatial/Temporal Scale:

- Calculate annually based on brood year.
- Time series.

Possible Statistical Analysis:

- Use graphical analysis to track brood-year stray rates over time.

Analytical Rules:

- This is a monitoring indicator that will be used to support management decisions.

Among-Population Return-Year Stray Rates

Monitoring Questions:

Q6.2.1: Do hatchery strays make up less than 5% of the spawning escapement within their non-target independent populations?

Target Species/Populations:

- Q6.2.1 applies to all hatchery stocks.

Statistical Hypothesis 6.2.1:

- $Ho_{6.2.1.1}$: Stray hatchery fish make up ≥ 5% of the spawning escapement (based on run year) within other independent populations [9]

Measured Variables:

- Number of hatchery carcasses (PIT-tagged steelhead) found in non-target and target spawning areas or number of returning spawners counted via PIT-tag detection or at weirs in close temporal proximity to spawning areas.

Derived Variables:

- Total number of hatchery salmon carcasses (PIT-tagged steelhead, spawners counted at weirs) estimated from expansion analysis.
- Percent of the non-target population that is made up of hatchery strays.

Spatial/Temporal Scale:

- Calculate annually based on return year.
- Time series.

Possible Statistical Analysis:

[9] This stray rate is suggested based on a literature review and recommendations by the ICBTRT (2005) and is identified in the Upper Columbia Spring Chinook Salmon and Steelhead Recovery Plan (2007). It can be re-evaluated as more information on naturally-produced Upper Columbia salmonids becomes available. This will be evaluated on a species and program specific basis and decisions made by the HCP HC and PRCC HSC. It is important to understand the actual spawner composition of the population to determine the potential effect of straying.

- Use graphical analysis and one-sample quantile tests to compare the estimated stray rate with the target (5%) stray rate.

Analytical Rules:

- This is a monitoring indicator that will be used to support management decisions.
- Type I Error of 0.05.

Within-Population Return-Year Stray Rates

Monitoring Questions:

Q6.3.1: Do hatchery strays make up less than 10% of the spawning aggregate within non-target spawning areas within the target population?

Target Species/Populations:

- Q6.3.1 applies to all hatchery stocks.

Statistical Hypothesis 6.3.1:

- $Ho_{6.3.1}$: Stray hatchery fish make up ≥ 10% of spawning escapement (based on run year) within non-target spawning areas within the target population

Measured Variables:

- Number of hatchery carcasses (possibly PIT-tagged steelhead) found in non-target and target spawning aggregates or number of returning spawners counted via PIT-tag detection or at weirs in close temporal proximity to spawning areas.

Derived Variables:

- Total number of hatchery salmon carcasses (possibly PIT-tagged steelhead or spawners counted at weirs) estimated from expansion analysis.
- Percent of the non-target spawning aggregate that is made up of hatchery strays.

Spatial/Temporal Scale:

- Calculate annually based on return year.
- Time series.

Possible Statistical Analysis:

- Use graphical analysis and one-sample quantile tests to compare the estimated stray rate with the target (10%) stray rate.

Analytical Rules:

- This is a monitoring indicator that will be used to support management decisions.
- Type I Error of 0.05.

4.5 Population Genetics

<u>Objective 7</u>: Determine if genetic diversity, population structure, and effective population size have changed in natural spawning populations as a result of the hatchery program.

The genetic component of the M&E Plan specifically addresses the potential for changes in genetic diversity in natural populations as a result of a hatchery program(s). The long-term fitness of populations is assumed to be related to maintaining the genetic diversity of natural populations. However, hatchery programs select a subset of individuals from the population to pass on genetic material to the next generation. This is often a relatively small number of individuals that produce a large number of offspring, and can result in changes in allele frequencies and reductions of effective population size. Therefore, it is important to monitor the genetic status of the natural populations to determine if there are signs of changes in genetic distance among populations, changes in allele frequencies, and to estimate effective population size. Assessing the genetic effects of the hatchery program does not require annual sampling, but does require regular sampling at generational scales. Meeting stray-rate targets (hypotheses tested under Objective 5) should reduce significant changes in population genetics. Stray rates may inform population genetic analyses. Testing statistical hypotheses associated with genetic components (Hypotheses 3.1, 3.2, and 3.3) should be conducted every ten years or two generations.

Allele Frequency

Monitoring Questions:

Q7.1.1: Is the allele frequency of hatchery fish similar to the allele frequency of naturally produced and donor (broodstock) fish?

Target Species/Populations:

- Q7.1.1 applies to all conservation stocks.

Statiscial Hypotheses 7.1.1:

- $Ho_{7.1.1.1}$: Allele frequency $_{\text{Hatchery}}$ = Allele frequency $_{\text{Naturally produced}}$ = Allele frequency $_{\text{Donor pop.}}$
- $Ha_{7.1.1.1}$: Allele frequency $_{\text{Hatchery}}$ ≠ Allele frequency $_{\text{Naturally produced}}$ = Allele frequency $_{\text{Donor pop.}}$ or
- $Ha_{7.1.1.1}$: Allele frequency $_{\text{Hatchery}}$ = Allele frequency $_{\text{Naturally produced}}$ ≠ Allele frequency $_{\text{Donor pop.}}$ or
- $Ha_{7.1.1.1}$: Allele frequency $_{\text{Hatchery}}$ ≠ Allele frequency $_{\text{Naturally produced}}$ ≠ Allele frequency $_{\text{Donor pop.}}$

Measured Variables:

- SNP genotypes

Derived Variables:

- Allele frequency

Spatial/Temporal Scale:

- Analyze as a time series, initially comparing pre- and post-hatchery samples and thereafter every 10 years.
- Compare samples within drainages.

Possible Statistical Analysis:

- Population differentiation tests, analysis of molecular variance (AMOVA), and relative genetic distances.

Analytical Rules:

- This is a monitoring indicator that will be used to support management decisions.
- Type I Error of 0.05.

Genetic Distance Between Populations

Monitoring Questions:

Q7.2.1: Does the genetic distance among subpopulations within a supplemented population remain the same over time?

Target Species/Populations:

- Q7.2.1 applies to all conservation and safety-net stocks.

Statistical Hypothesis 7.2.1:

- $Ho_{7.2.1.1}$: Genetic distance between subpopulations $_{\text{Year x}}$ = Genetic distance between subpopulations $_{\text{Year y}}$

Measured Variables:

- SNP genotypes

Derived Variables:

- Allele frequencies

Spatial/Temporal Scale:

- Analyze as a time series, initially comparing pre- and post-hatchery samples and thereafter every 10 years.
- Compare samples among spawning aggregates.

Possible Statistical Analysis:

- Population differentiation tests, AMOVA, and relative genetic distances.

Analytical Rules:

- This is a monitoring indicator that will be used to support management decisions.
- Type I Error of 0.05.

Effective Spawning Population

Monitoring Questions:

Q7.3.1: Is the ratio of effective population size (N_e) to spawning population size (N) constant over time?

Target Species/Populations:

- Q7.3.1 applies to all supplemented stocks.

Statistical Hypothesis 3.3:

- $Ho_{7.3.1.1}$: $(N_e/N)_{t0} = (N_e/N)_{t1}$ for each population

Measured Variables:

- SNP genotypes

Derived Variables:

- Allele frequencies

Spatial/Temporal Scale:

- Analyze as a time series, initially comparing pre- and post-hatchery samples and thereafter every 10 years.

Possible Statistical Analysis:

- Population differentiation tests, relative genetic distances, statistics to calculate effective population size (e.g., harmonic means).

Analytical Rules:

- This is a monitoring indicator that will be used to support management decisions.
- Type I Error of 0.05.

4.6 Phenotypic Traits

Objective 8: Determine if hatchery programs have caused changes in phenotypic characteristics of natural populations.

Fitness, or the ability of individuals to survive and pass on their genes to the next generation in a given environment, includes genetic, physiological, and behavioral components.[10] Maintaining the long-term fitness of supplemented populations requires a comprehensive evaluation of genetic and phenotypic characteristics. Evaluation of some phenotypic traits (i.e., run timing, spawn timing, spawning location, and stray rates) is addressed under Objective 5. Objective 8 assess the potential effects of domestication, including size at maturity, age at maturity, sex ratio, and fecundity. Age and size at maturity shall be assessed for both fish arriving in the Columbia system, and those recovered on the spawning grounds. Size (or age) selective mortality during migration through the Columbia system, such as through fisheries, could alter the age and size of fish on the spawning grounds.

[10] These metrics are difficult to measure, and phenotypic expression of these traits may be all we can measure and evaluate.

Age at Maturity

Monitoring Questions:

Q8.1.1: Is the age at maturity of hatchery and natural-origin fish similar at the time they enter the Columbia River and when they spawn?

Target Species/Populations:

- Q8.1.1 applies to all conservation program stocks.

Statistical Hypotheses 8.1.1:

- $Ho_{8.1.1.1}$: Age at Maturity $_{\text{Hatchery produced spawners Gender X}}$ = Age at Maturity $_{\text{Naturally produced spawners Gender X}}$
- $Ho_{8.1.1.2}$: Age at Maturity $_{\text{All hatchery produced adults Gender X}}$ = Age at Maturity $_{\text{All naturally produced adults Gender X}}$

Measured Variables:

- Total and salt (ocean) age of hatchery and natural-origin salmon carcasses collected on spawning grounds.
- Total and salt age of broodstock.
- Total and salt age of fish at stock assessment locations (e.g., Dryden, Tumwater, Wells, Priest Rapids).
- Whenever possible, age at maturity will be measured at weirs or dams near the spawning stream to avoid the size-related carcass recovery bias on spawning grounds (carcass sampling).
- Assess age of fish, including harvested fish.

Derived Variables:

- Total age and saltwater age
- Age of fish entering the Columbia River.

Spatial/Temporal Scale:

- Calculate annually based on brood year.
- Time series.

Possible Statistical Analysis:

- Use graphic analysis and Yates' Chi-square.

Analytical Rules:

- This is a monitoring indicator that will be used to support management decisions.
- Type I Error of 0.05.

Size at Maturity

Monitoring Questions:

Q8.2.1: Is the size (length) at maturity of a given age and sex of hatchery fish similar to the size at maturity of a given age and sex of natural-origin fish?

Target Species/Populations:

- Q8.2.1 applies to all conservation and safety-net stocks.

Statistical Hypothesis 8.2.1:

- $Ho_{8.2.1.1}$: Size (length) at Maturity $_{\text{Hatchery Age X and Gender Y}}$ = Size (length) at Maturity $_{\text{Naturally produced Age X and Gender Y}}$
- $Ho_{8.2.1.2}$: Size (length) at Maturity $_{\text{All hatchery adults Gender X}}$ = Size (length) at Maturity $_{\text{All naturally produced adults Gender X}}$

Measured Variables:

- Size (length), age, and gender of hatchery and natural-origin salmon carcasses collected on spawning grounds.
- Size (length), age, and gender of broodstock.
- Size (length), age, and gender of fish at stock assessment locations (e.g., Priest Rapids, Dryden, Tumwater, Wells, Twisp Weir).
- Whenever possible, size at maturity will be measured at weirs or dams near the spawning stream to avoid the size-related carcass recovery bias on spawning grounds (carcass sampling).

Derived Variables:

- Total age and saltwater age

Spatial/Temporal Scale:

- Calculate annually based on brood year.
- Time series.

Possible Statistical Analysis:

- Use graphic analysis and three-way ANOVA by origin, gender, and age

Analytical Rules:

- This is a monitoring indicator that will be used to support management decisions.
- Type I Error of 0.05.

Fecundity at Size[11]

Monitoring Questions:

Q8.3.1: Is the fecundity vs. size relationship of hatchery and natural-origin fish similar?

[11] May not apply to all programs.

Q8.3.2: Is the gonadal mass vs. size relationship of hatchery and natural-origin fish similar?

Target Species/Populations:

- Both Q8.3.1 and Q8.3.2 apply to all conservation stocks using both natural- and hatchery-origin broodstock.

Statistical Hypothesis 8.3.1:

- $Ho_{8.3.1.1}$: Slope of Fecundity vs. Size $_{\text{Hatchery}}$ = Slope of Fecundity vs. Size $_{\text{Naturally produced}}$

Statistical Hypothesis 8.3.2:

- $Ho_{8.3.2.1}$: Gonadal Mass vs. Size $_{\text{Hatchery}}$ = Gonadal Mass vs. Size $_{\text{Naturally produced}}$

Measured Variables:

- Length, weight, and age (covariate) of hatchery and natural-origin broodstock after eggs have been removed.
- Number and weight of eggs

Derived Variables:

- Total age and saltwater age.
- Mean weight per egg.

Spatial/Temporal Scale:

- Calculate annually based on brood year.
- Time series.

Possible Statistical Analysis:

- Use graphic analysis, regression, t-test, and ANCOVA.

Analytical Rules:

- This is a monitoring indicator that will be used to support management decisions.
- Type I Error of 0.05.

Sex Ratio

Monitoring Questions:

Q8.4.1: Is the sex ratio of hatchery and natural-origin fish similar?

Target Species/Populations:

- Q8.4.1 applies to all conservation stocks.

Statistical Hypothesis 8.4.1:

- $Ho_{8.4.1.1}$: Sex Ratio $_{\text{Hatchery}}$ = Sex Ratio $_{\text{Naturally produced}}$

Measured Variables:

- Age and sex of hatchery and natural-origin salmon carcasses collected on spawning grounds or sampled at dams or weirs.
- Whenever possible sex ratio will be measured at weirs or dams near the spawning stream to avoid the size-related carcass recovery bias on spawning grounds (carcass sampling or ultrasound on live fish).

Derived Variables:

- Ratio of sexes based on brood year returns

Spatial/Temporal Scale:

- Calculate annually based on brood year.
- Time series.

Possible Statistical Analysis:

- Use graphic analysis and Yates'Chi-square.

Analytical Rules:

- This is a monitoring indicator that will be used to support management decisions.
- Type I Error of 0.05.

SECTION 5: HATCHERY ENVIRONMENT MONITORING INDICATORS

5.1 Release Targets

<u>Objective 9</u>: Determine if hatchery fish were released at the programmed size and number.

The HCP outlines the number and size of fish that are to be released to meet NNI and inundation compensation levels. The size of the fish at release may be altered according to an adaptive management process in the Hatchery Committee(s), and the number of fish can be altered by survival study results and adjustment of hatchery production for population dynamics. Size of fish at release can affect survival, sex ratios, age at return, stray rate, and fecundity. In addition, the variation in size at release may affect performance of the fish.

The coefficient of variation (CV) will be evaluated to ascertain if program performance is related to variation in size at release. Note also that variation in a population is a natural condition and striving to control this variation could result in directional or stabilizing artificial selection that could have unforeseen long-term consequences. Attaining uniform or multi-modal growth in a hatchery environment may not be adaptive for fitness in the wild. Therefore, pursuit of a CV target should be seen as an informative exercise, but is not in itself indicative of success or failure of a hatchery program. Furthermore, growth regimes may prove to be important in affecting adult returns and age structure. Although many factors can influence both the size and number of fish released, past hatchery cultural experience with these stocks should assist in meeting program production levels. Appendix 5 presents the target size at release and CVs for the programs. These targets shall be assessed annually to ensure they are optimized to inform management decisions.

Size at Release of Hatchery Fish

Monitoring Questions:

Q9.1.1: Is the size (fish per pound; fpp) of hatchery fish released equal to the program goal identified in Appendix 5?

Target Species/Populations:

- Q9.1.1 applies to all hatchery stocks.

Statistical Hypothesis 9.1.1:

- $Ho_{9.1.1.1}$: Hatchery fish $_{\text{fpp at release}}$ = Programmed $_{\text{fpp at release}}$ (see Appendix 5)

Measured Variables:

- Fork length and weights of random samples of hatchery juveniles at release.

Derived Variables:

- Mean length (FL), mean weight, and fish per pound
- Appendix 5: Rearing targets

Spatial/Temporal Scale:

- Calculate annually.
- Time series.

Possible Statistical Analysis:

- Use graphic analysis and descriptive statistics to compare the estimated fpp of hatchery fish at time of release with the program goal.

Analytical Rules:

- This is a monitoring indicator that will be used to support management decisions.

Coefficient of Variation (CV) of Hatchery Fish Released

Monitoring Questions:

Q9.2.1: Is the CV of hatchery fish released equal to the program target identified in Appendix 5?

Target Species/Populations:

- Q9.2.1 applies to all hatchery stocks.

Statistical Hypothesis 9.2.1:

- $Ho_{9.2.1.1}$: Hatchery fish $CV_{\text{at release}}$ = Programmed CV in Appendix 5

Measured Variables:

- Length and weights of random samples of hatchery smolts.

Derived Variables:

- Coefficient of Variation: $cv = (1 + 1/4n) \times (s/x)$ (where s = standard deviation, x = estimated mean, n = sample size)
- Appendix 5: Rearing targets

Spatial/Temporal Scale:

- Calculate annually.
- Time series.

Possible Statistical Analysis:

- Use graphic analysis and descriptive statistics to compare the estimated CV of size of hatchery fish released with the program goal.

Analytical Rules:

- This is a monitoring indicator that will be used to support management decisions.

Condition Factor (K) of Hatchery Fish Released

Monitoring Questions:

Q9.3.1: Is the K of hatchery fish released equal to the program target identified in Appendix 5?

Target Species/Populations:

- Q9.3.1 applies to all hatchery stocks.

Statistical Hypothesis 9.3.1:

- $Ho_{9.3.1.1}$: Hatchery fish $K_{\text{at release}}$ = Programmed K identified in Appendix 5

Measured Variables:

- Monthly individual lengths and weights of random samples of hatchery juveniles.

Derived Variables:

- Condition Factor: $K = W/L^3 \times 10^5$

Spatial/Temporal Scale:

- Calculate annually.
- Time series.

Possible Statistical Analysis:

- Use graphic analysis and descriptive statistics to compare the estimated K of released hatchery fish with the program goal.

Analytical Rules:

- This is a monitoring indicator that will be used to support management decisions.
- Type I Error of 0.05.

Number of Hatchery Fish Released

Monitoring Questions:

Q9.4.1: Is the number of hatchery fish released equal to the program goal identified in Appendix 5?

Target Species/Populations:

- Q9.4.1 applies to all hatchery stocks.

Statistical Hypothesis 9.4.1:

- $Ho_{9.4.1.1}$: Hatchery Fish Number = Programmed Number identified in Appendix 5

Measured Variables:

- Numbers of smolts released from the hatchery.

Derived Variables:

- Appendix 5: Rearing targets

Spatial/Temporal Scale:

- Calculate annually.

- Time series.

Possible Statistical Analysis:

- Use graphic analysis and one-sample quantile tests to compare the estimated number of hatchery fish released with the program goal.

Analytical Rules:

- This is a monitoring indicator that will be used to support management decisions.
- Type I Error of 0.05.

SECTION 6: HARVEST MONITORING INDICATORS

6.1 Harvest Rates

Objective 10: Determine if appropriate harvest rates have been applied to conservation, safety-net, and segregated harvest programs to meet the HCP/SSSA goal of providing harvest opportunities while also contributing to population management and minimizing risk to natural populations.

Harvest will be applied to different types of programs in an effort to achieve the management objectives of those programs. Programs designed to augment harvest should routinely contribute to harvest at a rate that greatly reduces the incidence of straying to natural spawning grounds, but also allows the program to be sustained. Safety-net programs may be harvested as part of an adult management strategy to minimize excessive escapement of hatchery-origin fish to spawning grounds. Similarly, conservation programs may undergo harvest to manage returning adults, but the emphasis for these programs should be to achieve escapement goals. In all cases, harvest effort should not have the unintended consequence of removing excessive numbers of conservation or natural-origin fish. In years when the expected returns of hatchery adults are above the level required to meet program goals (i.e., supplementation of spawning populations and/or brood stock requirements), surplus fish may be available for harvest. The M&E Plan specifically addresses harvest and harvest opportunities upstream of Priest Rapids Dam. Harvest or removal of surplus hatchery fish from the spawning grounds may assist in reducing potential adverse ecological and genetic impacts to natural populations (e.g., loss of genetic variation within and between populations, loss of fitness, reduced effective population size, and density-dependent effects).

Monitoring Questions:

Q10.1.1: Conservation Programs: Is the harvest on conservation hatchery fish at an appropriate level to manage natural spawning of conservation hatchery fish but low enough to sustain the hatchery program?

Q10.1.2: Safety-Net Programs: Is the harvest on conservation hatchery fish at an appropriate level to manage natural spawning of safety-net hatchery fish but low enough to sustain the hatchery program?

Q10.1.3: Is the harvest on hatchery fish produced from harvest-augmentation programs high enough to manage natural spawning but low enough to sustain the hatchery program?

Q10.1.4: Is the escapement of fish from conservation and safety-net programs in excess of broodstock and natural production[12] needs to provide opportunities for terminal harvest?

Target Species/Populations:

- Q10.1.1 applies to conservation programs.
- Q10.1.2 applies to safety-net programs.

[12] The current best estimates of carrying capacity (maximum recruits) will be used, as available.

- Q10.1.3 applies harvest augmentation programs.
- Q10.1.4 applies to conservation and safety-net programs.

Statistical Hypothesis 10.1.1:

- $Ho_{10.1.1.1}$: Harvest rate ≤ Maximum level to meet program goals

Statistical Hypothesis 10.1.2:

- $Ho_{10.1.2.1}$: Harvest rate ≤ Maximum level to meet program goals

Statistical Hypothesis 10.1.3:

- $Ho_{10.1.3.1}$: Escapement ≤ Maximum level to meet supplementation goals

Statistical Hypothesis 10.1.4:

- $Ho_{10.1.4.1}$: Harvest rate ≤ Maximum level to meet program goals

Measured Variables:

- Numbers of hatchery fish taken in harvest.
- Numbers of natural-origin fish taken in harvest.

Derived Variables:

- Total harvest by fishery estimated from expansion analysis.

Spatial/Temporal Scale:

- Calculated annually.
- Time series.

Possible Statistical Analysis:

- Use graphic analysis and one-sample quantile tests to compare the estimated harvest of hatchery fish with the program goal.

Analytical Rules:

- This is a monitoring indicator that will be used to support management decisions.
- Type I Error of 0.05.

SECTION 7: REGIONAL OBJECTIVES

Hatchery programs have the potential to increase diseases that typically occur at low levels in the natural environment (Objective 9). In addition, hatchery fish can reduce the abundance, size, or distribution of non-target taxa through ecological interactions (Objective 10). In this section, we address incidence of disease and non-target taxa of concern.

7.1 Incidence of Disease

Objective 11: Determine if the incidence of disease has increased in the natural and hatchery populations.

The hatchery environment has the potential to amplify diseases that are typically found at low levels in the natural environment. Amplification could occur within the hatchery population (i.e., vertical and horizontal transmission) or indirectly from the hatchery effluent or commingling between infected and non-infected fish (i.e., horizontal transmission). Potential impacts to natural populations have not been extensively studied, but should be considered for programs in which the hatchery fish are expected to commingle with natural fish. This is particularly important for supplementation type programs. Specifically, the causative agent of bacterial kidney disease (BKD), *Renibacterium salmoninarum* (Rs), could be monitored at selected acclimation ponds, both in the water and fish, in which the risk and potential for transmission from the hatchery is highest. Although it is technologically possible to measure the amount of Rs in water or Rs DNA in smolts and adults non-lethally sampled, the biological meaning of these data are uncertain. Currently, the only metric available for M & E purposes is measuring the antigen level from kidney/spleen samples (i.e., ELISA, PCR). When available, non-lethal sampling may replace or be used in concert with lethal sampling.

Implementation of this objective will be conducted in a coordinated approach within the hatchery and natural environment. BKD management within the hatchery population (e.g., broodstock or juveniles) has the potential to reduce the prevalence of disease through various actions (e.g., culling or reduced rearing densities). BKD management must also take into account and support other relevant objectives of the M & E program (e.g., Hatchery Return Rate [HRR], number of smolts released). Hence, the goal of BKD management is to decrease the prevalence of disease and maintain hatchery production objectives (i.e., number and HRR).

As previously discussed, disease transmission from hatchery to naturally produced fish may occur at various life stages and locations. Of these, horizontal transmission from hatchery effluent, vertical transmission on the spawning grounds, and horizontal transmission in the migration corridor have been identified as disease interactions that could be examined under this objective, although others may also be relevant. Experimental designs addressing this objective may require technology not yet available, although in some instances samples may be collected, but not analyzed until a link can be established between bacteria levels in samples and disease prevalence.

Developing a complete set of questions and hypotheses statements for this objective may not be practical at this time, because there is currently no BKD Management Plan. However, while developing experimental designs for this objective, it may be feasible to incorporate both hatchery and natural environment monitoring under a single study design. Integration of the different

aspects of the objective would likely result in a more robust approach into understanding the effectiveness of disease management strategies.

Proposed Tasks:

T1: Assemble fish health data for fish used as brood (e.g., ELISA results).

T2: Conduct data exploration exercise to identify potential relationships between pathogen profiles and likely causative variables (e.g., rearing conditions and management actions).

T3: Develop hypotheses for potential testing to meet objective.

7.2 Non-Target Taxa of Concern (NTTOC)

Objective 12: Determine if the release of hatchery fish affects non-target taxa of concern (NTTOC) within acceptable limits.

Commented [TH1]: The text below is new.

Hatchery programs have the potential to affect non-target taxa through various types of interactions (e.g., competition and predation). These interactions can reduce the distribution, size, and abundance of non-target species. The non-target taxa of concern (NTTOC) ecological risk assessment was developed as a regional objective that would addressed ecological interactions on non-target taxa.

In 2008, the Wells HCP, Rocky Reach HCP, Rock Island HCP Hatchery Committees, and the Priest Rapids Hatchery Sub-Committee agreed to an approach to evaluate the potential effects of hatchery programs on NTTOC. The committees originally planned to convene a panel of experts to conduct a preliminary evaluation of the potential effects of Plan supplemented species on NTTOC. At the 15 October 2008 Hatchery Committees meeting, the members agreed to convene an expert panel to conduct a preliminary evaluation of potential effects of supplemented Plan Species on non-target taxa using an approach similar to that used in the Yakima Basin (Pearsons and Hopley 1999; Ham and Pearsons, 2001). The Committees agreed to convene the panel in spring or early summer 2009, and focus this initial effort on HCP Plan Species and the two non-Plan Species, westslope cutthroat trout and lamprey. The Committees identified species interactions, containment objectives for non-target species, and fisheries professionals who possessed the expertise to contribute as panel members. However, this expert panel was never assembled. Instead, the Committees directed the Hatchery Evaluation Technical Team (HETT) to pursue assessment of the hatchery programs potential effects on NTTOC.

The HETT evaluated methods to conduct a risk assessment on NTTOC, and proposed using a combined modeling and a Delphi panel approach, whereby the modeling results would be compared and correlated with the Delphi panel results. The HETT identified the PCD Risk 1 model (Busack et al., 2005; Pearsons and Busack, 2012) to conduct the modeling evaluation. The PCD Risk 1 model is a data intensive, individual-based stochastic model. The HETT determined that the assembled data to be used as inputs for the PCD Risk 1 model would also serve to provide expert panelists the necessary data for them to conduct risk assessments. Hence, the HETT embarked on an extensive effort to gather, organize, and extract the required data from existing datasets, literature, and biologists familiar with the programs and/or particular NTTOC. Ultimately the input data were assembled in a relational database that allowed the data to be output in user-friendly formats for modeling or Delphi panel use. The database also served to hold the modeling results, which could be extracted and summarized as needed.

A report titled *Ecological Risk Assessment of Upper-Columbia Hatchery Programs on Non-Target Taxa of Concern* was drafted in 2013 and finalized in 2014, which included the modeling results to date. The results in the report represent a very extensive effort to model the risk of all the upper Columbia hatchery programs for the identified NTTOC for which data and model runs were available. Should new information become available, the Committees agreed to assess the suitability of the data as it relates to conducting future NTTOC evaluations as a regional objective.

Attachment E

SECTION 8: ADAPTIVE MANAGEMENT

Commented [TH2]: The text below is new.

One of the challenges of evaluating PUD hatchery programs is that hatchery programs are modified resulting in hatchery treatments that are uneven throughout the duration of the hatchery program. Modifications occur as a result of recalculating hatchery release numbers every 10 years and also through adaptive management. To solve this evaluation challenge, we propose to conduct two scales of analysis. First, the entire duration of the program will be analyzed using the entire data set. This evaluation will analyze whether the overall adaptively managed program achieved objectives. Second, where appropriate, analyses will be compared across periods or programs to determine if major program changes have resulted in hypothesized changes to key response variables. We acknowledged that partitioning data into shorter periods will likely result in reduced statistical power so only the biggest changes will be evaluated. In the future, the hatchery committees will develop a table or figure that identifies major program changes in fish culture or M&E.

In the past, hatchery programs have been evaluated at the hatchery program scale (e.g., Nason Creek, Carlton summer Chinook). In some cases, it may be worthwhile to evaluate supplementation programs at different spatial scales. For example, the Nason Creek spring Chinook salmon program can be evaluated at the scale of Nason Creek, the combined effects of spring Chinook hatchery programs in the Wenatchee basin at the Wenatchee basin scale, and then all of the spring Chinook programs in the upper Columbia at the upper Columbia basin scale.

Comparisons of supplemented populations (treatments) to in-basin reference populations are the best way to evaluate whether treatments have caused changes to variables such as natural-origin recruits or productivity. Many suitable out-of-basin references are available (see Appendix 6), but these references do not control for unique factors that may be happening in the upper Columbia or areas outside the upper Columbia. For example, large fires that occur in the Upper Columbia may not occur at similar times in areas outside of this area. Candidate in-basin reference populations are not ideal for spring Chinook salmon because they are small and are above a lake (e.g., Little Wenatchee River) or they have had a long history of hatchery stocking (e.g., Entiat River). Every population of upper Columbia summer and fall Chinook is supplemented so in-basin references are not currently available. Without a suitable number of in-basin reference populations that are similar in size and distribution to treated populations, it will be difficult to unambiguously assess hatchery effects on certain variables. Although not ideal, the only way to increase in-basin reference comparisons is to strategically reduce the number of places where hatchery fish are released such as was done for the Entiat River.

Previous stocking history will lessen the value of reference populations; however, they can still be of value. For instance, the Committees can still test whether NORs are increased under supplementation compared to periods when other populations are not supplemented (i.e., a reverse BACI analysis).

SECTION 9: REFERENCES

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SECTION 10: GLOSSARY

Adult-to-Adult survival (Ratio)	The number of parent broodstock relative to the number of returning adults.
Age at maturity	The age of fish at the time of spawning (hatchery or naturally).
Augmentation	A hatchery strategy where fish are released for the sole purpose of providing harvest opportunities.
Broodstock	Adult salmon and steelhead collected for hatchery fish egg harvest and fertilization.
Donor population	The source population for supplementation programs before hatchery fish spawned naturally.
Effective population size (Ne)	The number of reproducing individuals in an ideal population (i.e., Ne = N) that would lose genetic variation due to genetic drift or inbreeding at the same rate as the number of reproducing adults in the real population under consideration (Hallerman 2003).
ESA	Endangered Species Act passed in 1973. The ESA-listed species refers to fish species added to the ESA list of endangered or threatened species and are covered by the ESA.
Expected value	The number of smolts or adults derived from survival rates agreed to in the Biological Assessment and Management Plan (BAMP 1998).
Extraction rate	The proportion of the spawning population collected for broodstock.
Genetic diversity	All the genetic variation within a species of interest, including both within and between population components.
Genetic stock structure	A type of assortative mating, in which the gene pool of a species is composed of a group of subpopulations, or stocks, that mate panmictically within themselves.
Genetic variation	All the variation due to different alleles and genes in an individual, population, or species.
HCP	Habitat Conservation Plan is a plan that enables an individual or organization to obtain a Section 10 Permit which outlines what will be done to “minimize and mitigate” the impact of the permitted take on a listed species.

HCP-HC	Habitat Conservation Plan Hatchery Committee is the committee that directs actions under the hatchery program section of the HCP's for Chelan and Douglas PUDs.
HRR	Hatchery Replacement Rate is the ratio of the number of returning hatchery adults relative to the number of adults taken as broodstock, both hatchery and naturally produced fish (i.e., adult-to-adult replacement rate).
Long-term fitness	Long-term fitness is the ability of a population to self-perpetuate over successive generation.
Naturally produced	Progeny of fish that spawned in the natural environment, regardless of the origin of the parents.
Mean Ratio	The ratio between a treatment and control population, with the mean taken across a time period, such as years. Used in analysis in Before-After-Control-Impact studies.
Ne	Effective population size.
Non-target taxa of concern (NTTOC)	Species, stocks, or components of a stock with high value (e.g., stewardship or utilization) that may suffer negative effects because of a hatchery program.
NRR	Natural replacement rate is the ratio of the number of returning naturally produced adults relative to the number of adults that naturally spawned, both hatchery and naturally produced.
NTTOC	Non-target taxa of concern.
pHOS	Proportion of Hatchery Origin Spawners.
PNI	Proportionate Natural Influence.
pNOB	Proportion of Natural Origin Broodstock.
PRCC HSC	Priest Rapids Coordinating Committee Hatchery Subcommittee.
Productivity	The capacity in which juvenile fish or adults can be produced.
Reference population	A population in which no directed artificial propagation is currently directed, although may have occurred in the past. Reference populations are used to monitor the natural variability in survival rates and out of basin impacts on survival.
Smolt-to-adult survival rate (SAR)	Smolt-to-adult survival rate is a measure of the number of adults that return from a given smolt population.
Segregated	A type of hatchery program in which returning adults are spatially or temporally isolated from other populations.

Size at maturity	The length or weight of a fish at a point in time during the year in which spawning will occur.
Smolts per redd	The total number of smolts produced from a stream divided by the total number of redds from which they were produced.
SNP or single-nucleotide polymorphism	A single-nucleotide polymorphism is a variation in a single nucleotide that occurs at a specific position in the genome, where each variation is present to some appreciable degree within a population.
Spawning Escapement	The number of adult fish that survive to spawn.
Stray rate	The rate at which fish spawn outside of natal rivers or the stream in which they were released.
Supplementation	A hatchery strategy where the main purpose is to increase the relative abundance of natural spawning fish without reducing the long-term fitness of the population.
Target population	A specific population in which management actions are directed (e.g., artificial propagation, harvest, or conservation).

Attachment E

APPENDIX 1: ESTIMATION OF CARRYING CAPACITY

Commented [TH3]: This section is new.

In the ecological literature, carrying capacity is often defined as the maximum population size that can be supported indefinitely by the environment (Cain et al. 2014). Said another way, carrying capacity is the maximum number or biomass of a species that a given habitat can support. This maximal environment load is often referred to as “habitat capacity” and is identified with the letter “C.” In contrast, the carrying capacity parameter “K” in population models (e.g., logistic equation, Beverton-Holt model, hockey stick model, and the Ricker model) defines a maximum equilibrium population size. Maximum equilibrium population size is generated from density dependent mechanisms that reduce population growth rates as population size increases (negative density dependence). This is referred to as compensation. Population size fluctuates about the maximum equilibrium size because of variability in vital rates that are unrelated to density (density independent factors) and measurement error. Maximum equilibrium population size is often referred to as “population capacity.” The two capacities (habitat capacity and population capacity) are related but not identical and therefore should not be confused. Habitat capacity will usually be greater than population capacity.

Estimation of carrying capacity is important because hatchery managers use it to inform supplementation programs, harvest managers use it to set appropriate harvest and escapement levels, modelers use it in life-cycle models to predict the effects of different recovery scenarios, and restoration practitioners use it to guide restoration actions. The purpose of this paper is to describe methods that can be used to estimate carrying capacity for stocks within the Upper Columbia River basin. We apply these methods to Wenatchee and Chiwawa River spring Chinook salmon.[13] Data used in this exercise are shown in Tables 1 and 2 and come from Hillman et al. (2017). We begin by identifying simple methods used to detect density dependence. We then describe the use of population models to estimate population capacity. We also discuss the use of habitat models and quantile regression to estimate habitat capacity. We end by comparing results of different methods and offering recommendations for estimating carrying capacity.

Table 1. Numbers of redds, adult spawners (estimated from redd surveys), eggs (estimated as the number of redds times average brood-year fecundity), summer parr (estimated using snorkel surveys), and yearling smolts (estimates using a rotary screw trap) by brood year for spring Chinook salmon in the Chiwawa River watershed. Smolts represent the number of yearling Chinook produced entirely within the Chiwawa River watershed. Date are from Hillman et al. (2017). NS = not sampled.

Brood year	Numbers of Chiwawa spring Chinook				
	Redds	Spawners	Eggs	Parr	Smolts
1991	104	242	478,400	45,483	42525
1992	302	676	1,570,098	79,113	39723
1993	106	233	556,394	55,056	8662
1994	82	184	485,686	55,241	16472
1995	13	33	66,248	5,815	3830

[13] Technically, Wenatchee River spring Chinook are one population. Chiwawa River spring Chinook are a subgroup of the Wenatchee spring Chinook population.

Brood year	Numbers of Chiwawa spring Chinook				
	Redds	Spawners	Eggs	Parr	Smolts
1996	23	58	106,835	16,066	15475
1997	82	182	374,740	68,415	28,334
1998	41	91	218,325	41,629	23,068
1999	34	94	166,090	NS	10,661
2000	128	346	642,944	114,617	40,831
2001	1,078	1,725	4,984,672	134,874	86,482
2002	345	707	1,605,630	91,278	90,948
2003	111	270	648,684	45,177	16,755
2004	241	851	1,156,559	49,631	72,080
2005	332	599	1,436,564	79,902	69,064
2006	297	529	1,284,228	60,752	45,050
2007	283	1,296	1,256,803	82,351	25,809
2008	689	1,158	3,163,888	106,705	35,023
2009	421	1,347	1,925,233	128,220	30,959
2010	502	1,094	2,165,628	141,510	47,511
2011	492	2,032	2,157,420	103,940	37,185
2012	880	1,478	3,716,240	149,563	34,334
2013	714	1,378	3,367,224	121,240	39,396
2014	485	999	1,961,825	111,224	37,170
2015	543	967	2,631,921	140,172	

Table 2. Numbers of redds, adult spawners (estimated from redd surveys), eggs (estimated as the number of redds times average brood-year fecundity), and yearling smolts (estimates using a rotary screw trap) by brood year for spring Chinook salmon in the Wenatchee River basin. Smolts represent the number of yearling Chinook produced entirely within the Wenatchee River basin. Date are from Hillman et al. (2017). NS = not sampled.

Brood year	Numbers of Wenatchee spring Chinook			
	Redds	Spawners	Eggs	Smolts*
2000	350	830	1,758,050	76,643
2001	2,109	3,217	8,674,624	243,516
2002	1,139	1,965	5,300,906	165,116
2003	323	673	1,887,612	70,738
2004	574	1,686	2,663,445	55,619
2005	830	1,484	3,587,083	302,116
2006	588	1,000	2,542,512	85,558
2007	466	2,035	2,069,506	60,219
2008	1,411	2,278	6,479,312	82,137
2009	733	2,299	NS	NS

Brood year	Numbers of Wenatchee spring Chinook			
	Redds	Spawners	Eggs	Smolts*
2010	968	1,921	NS	NS
2011	872	3,139	3,823,720	89,917
2012	1,704	2,720	7,195,992	67,973
2013	1,159	2,133	5,512,204	58,595
2014	885	1,600	3,894,000	36,752

* From 2000-2010 the smolt trap operated near the Town of Monitor; from 2013 to present the trap operated near the Town of Cashmere.

Evidence of Density Dependence

To calculate population capacity, the size of the population or stock must be influenced to a large degree by density-dependent factors. That is, population growth is affected by mechanisms whose effectiveness increases as population size increases. As population density increases, factors such as competition, predation, and disease (and parasites) cause birth rates to decrease, death rates to increase, and dispersal to increase. When densities decrease, the opposite occurs; birth rates increase and death and emigration rates decrease. In general, when the density of the population becomes high enough, density-dependent factors decrease population size because food or space are in short supply (Chapman 1966). In the ecological literature, this is referred to as “population regulation.”

A simple way to determine if density-dependent factors regulate population size is to plot population growth rate (or appropriate surrogate) against population size. If population regulation is occurring, the relationship between population size and population growth rate decreases exponentially (decreases linearly if data are log-transformed). Surrogates for population growth rate include survival rates, natality (birth rates), productivity, recruits, individual growth rates, and movement. Figure 1 shows the relationship between productivity (parr/spawner and smolts/spawner) and spawning escapement for Wenatchee River and Chiwawa River spring Chinook. One could use redd counts as a surrogate for spawning abundance. Because most female spring Chinook construct only one redd (Murdoch et al. 2009), redd counts reflect the number of female spawners in the population. In this report, we use number of spawners (spawning escapement) because most management decisions are based on spawning escapement.

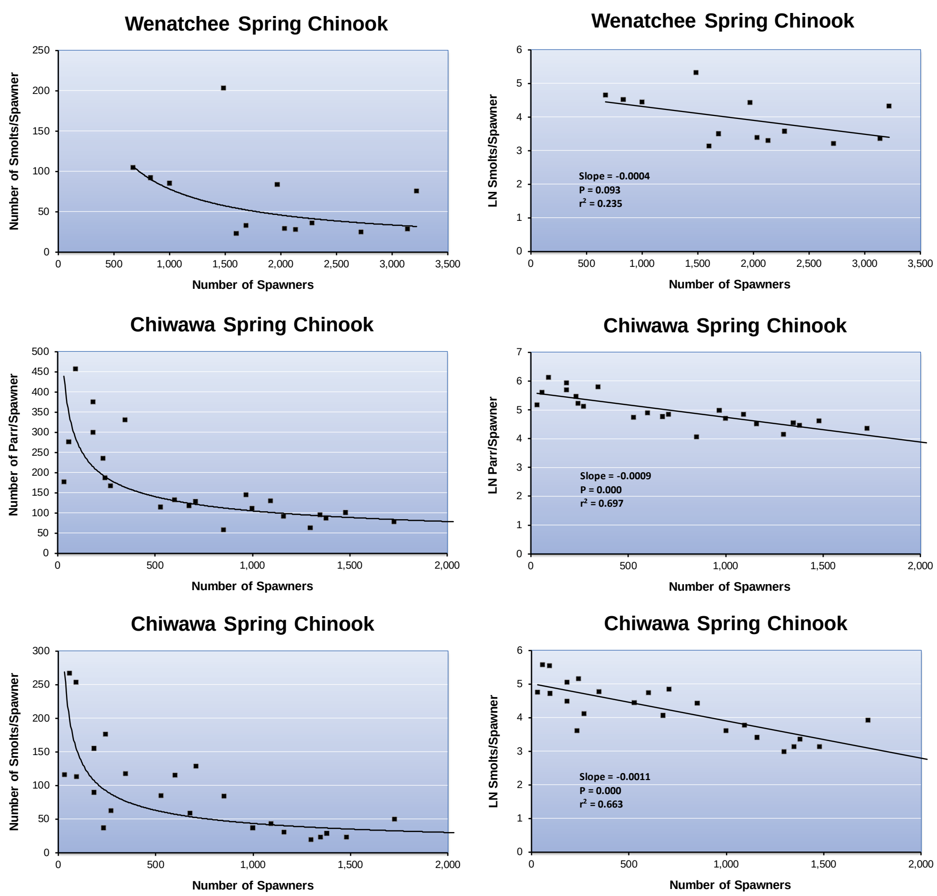

Figure 1. Relationship between spawner abundance and smolts/spawner for Wenatchee spring Chinook (top figures), spawner abundance and parr/spawner for Chiwawa spring Chinook (middle figures), and spawner abundance and smolts/spawner for Chiwawa spring Chinook (bottom figures). Figures on the right show natural log transformed productivity data.

The negative relationship between spawner abundance and juvenile productivity indicates the presence of density dependence in Chiwawa spring Chinook. Although there is a hint of density dependence in the Wenatchee River productivity data, the relationship was not significant statistically. This in part may be related to changes in sampling over the 13-year period. The negative relationship was significant for both summer parr and yearling smolts in the Chiwawa River watershed. We caution, however, that there may be a bias in the simple regression analysis presented in the figures. That is, the dependent (productivity) and independent (abundance) variables are not independent and this can produce a negative bias in regression estimates of slope. Nevertheless, the decline in juvenile productivity with increasing spawner abundance indicates the

presence of density dependence. Given the presence of density dependence, we should be able to estimate population capacity.

Estimating Carrying Capacity

Several different methods can be used to estimate population capacity. For example, time series analyses, including the logistic or Gompertz functions, or stock-recruitment models can be used to estimate population capacity. Common stock-recruitment models include Ricker, Beverton-Holt, and smooth hockey stick models. These models incorporate environmental variability and can be used to estimate the size of the spawning population needed to produce the maximum number of recruits. Habitat capacity, on the other hand, can be estimated using fish-habitat models. In general, these models estimate habitat capacity as the product of habitat area and fish/habitat relationships. These range from simple models such as percent habitat saturation models to more complex models including habitat suitability, quantile regression forest models, dynamic food-web models, and bioenergetic or net rate of energy intake models. In this report, we explore the use of stock-recruitment models to estimate population capacity. We apply quantile regression to stock-recruitment models to estimate habitat capacity and compare those results to a habitat model, the quantile regression forest model.

Population Capacity

To estimate population capacity, we evaluated the fit of three different stock-recruitment models to Chiwawa and Wenatchee River spring Chinook data: Ricker, Beverton-Holt, and smooth hockey stick models. In using these models, we assume:

- *Density-dependent mortality*—For some time period before recruitment, the brood instantaneous mortality rate is proportional to the number of parent spawners (Ricker 1954).
- *Lognormal variation*—At any particular spawning stock size, the variation in recruitment is log-normally distributed about its average, and acts multiplicatively (Quinn and Deriso 1999).
- *Measurement error*—Error in spawning stock size estimates (measurement error) is small relative to the range of spawning stock sizes observed (Hilborn and Walters 1992). Variation in realized recruitment at any particular spawning stock size (process error) dominates recruitment measurement error.
- *Stationarity*—The average stock-recruitment relationship is constant over time (Hilborn and Walters 1992). That is, environmental conditions randomly affect survival independent of stock size or time.

In general, the methods we used to fit the models to the data followed those outlined in Hilborn and Walters (1992) and Froese (2008). The Ricker model, which assumes that the number of recruits increases to a maximum and then declines as the number of spawners increases, takes the form:

$$\boldsymbol{E(R) = \alpha S e^{-\beta S}}$$

where E(R) is the expected recruitment, S is spawner abundance, α is the number of recruits per spawner at low spawning levels, and β describes how quickly the recruits per spawner drop as the number of spawners increases. We estimated population capacity (K) as:

$$\boldsymbol{K = \left(\frac{\alpha}{\beta}\right) e^{-1}}$$

and the number of spawners (SP) needed to produce the maximum number of recruits as:

$$SP = \frac{\mathbf{1}}{\boldsymbol{\beta}}$$

The Beverton-Holt model assumes that the number of recruits increases constantly toward an asymptote as the number of spawners increases. After the asymptote is reached, the number of recruits neither increases nor decreases. The asymptote represents the maximum number of recruits the system can support (i.e., population capacity for the system; K). The Beverton-Holt curve takes the form:

$$\boldsymbol{E(R) = \frac{(\alpha S)}{(\beta + S)}}$$

where E(R) and S are as above, α is the maximum number of recruits produced (i.e., α = K), and β is the number of spawners needed to produce (on average) recruits equal to one-half the maximum number of recruits. The number of spawners needed to produce the maximum number of recruits is ∞ in the Beverton-Holt model.

Like the Beverton-Holt model, the smooth hockey stick model assumes that the number of recruits increases toward an asymptote (population capacity; K) as the number of spawners increases. After the carrying capacity is reached, the number of recruits neither increases nor decreases. The carrying capacity represents the maximum equilibrium number of recruits the system can support. This curve takes the form (Froese 2008):

$$\boldsymbol{E(R) = R_{\infty}\left(1 - e^{-\left(\frac{\alpha}{R\infty}\right)S}\right)}$$

where E(R) and S are as above, α is the slope at the origin of the spawner-recruitment curve, and R_{∞} is the carrying capacity of recruits (i.e., $R_{\infty} = K$). There is no direct estimate of SP in the smooth hockey stick model. Therefore, we estimated SP as the number of spawners needed to produce 0.95(K).

We used non-linear regression to fit the three models to spawner-recruitment data. Before fitting the models, we transformed recruitment data using natural logs. We estimated bias and uncertainty measures (95% CI) for the model parameters using bootstrap procedures, which assumed that the {R, S} sample represented or approximated the population. The number of bootstrap samples was 3,000. We computed and stored the non-linear regression results for each bootstrap sample. We then calculated the bootstrap 95% CI by arranging the 3,000 bootstrap parameter values in sorted order and selected the 2.5 and 97.5 percentiles from the list.

We used Akaike's Information Criterion for small sample size (AIC_c) to determine which model(s) best explained the relationship between spawners and recruitment in the supplemented and reference populations. AIC_c was estimated as:

$$\boldsymbol{AIC_c = -2log\big(\pounds(\theta|data)\big) + 2K + \left(\frac{2K(K+1)}{n-K-1}\right)}$$

where *log(£(θ|data))* is the maximum likelihood estimate, *K* is the number of estimable parameters (structural parameters plus the residual variance parameter), and *n* is the sample size (Burnham and Anderson 2002). We used least-squares methods to estimate *log(£(θ|data))*, which was calculated as $log(\sigma^2)$, where σ^2 = residual sum of squares divided by the sample size ($\sigma^2 = RSS/n$). AIC_c assessed model fit in relation to model complexity (number of parameters). The model with the smallest AIC_c value represented the "best approximating" model within the model set. Remaining models were ranked relative to the best model using AIC_c difference scores (ΔAIC_c), Akaike weights (w_i), and evidence ratios. Models with ΔAIC_c values less than 2 indicated that there is substantial support for these models as being the best-fitting models within the set (Burnham and Anderson 2002). Models with values greater than 2 had less support. Akaike weights are probabilities estimating the strength of the evidence supporting a particular model as being the best model within the model set. Models with small w_i values are less plausible as competing models (Burnham and Anderson 2002). If no single model could be specified as the best model, a "best subset" of competing models was identified using (1) AIC_c differences to indicate the level of empirical support each model had as being the best model, (2) evidence ratios based on Akaike weights to indicate the relative probability that any model is the best model, and (3) coefficients of determination (R^2) assessing the explanatory power of each model.

<u>Chiwawa River Spring Chinook Parr</u>

We successfully fit the three stock-recruitment curves to the Chiwawa spring Chinook parr data (Figure 2).

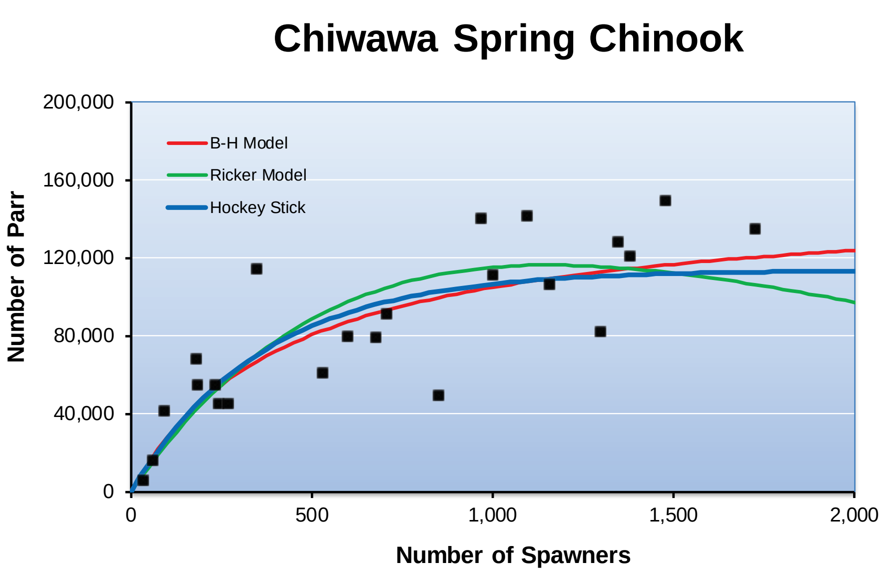

Figure 2. Relationship between numbers of spring Chinook parr and numbers of spawners in the Chiwawa River watershed, 1992-2016 (no sampling occurred in 2000). Figure shows the fit of the Beverton-Holt, Ricker, and smooth hockey stick models to the data.

For summer parr, the use of AIC_c indicated that the Beverton-Holt model best approximated the information in the productivity data. The estimated structural parameters for this model were:

$$Parr = \frac{(150{,}902 \times Spawners)}{(438 + Spawners)}$$

where the bootstrap estimated standard errors for the two parameters were 21,142 and 145, respectively. The adjusted $R^2 = 0.812$.

The second-best model was the smooth hockey stick model, which was 0.245 AIC_c units from the best model. The estimated parameters for this model were:

$$LN(Parr) = 11.6 + LN\left(1 - e^{-\left(\frac{312.9}{113{,}801}\right)Spawners}\right)$$

where the bootstrap estimated standard errors of the two parameters were 0.097 and 57.578, respectively, and the $R^2 = 0.810$.

The AIC_c difference scores, Akaike weights, and evidence ratios indicated that there was substantial support for both the Beverton-Holt and smooth hockey stick models. There was less support for the Ricker model, which was > 2 AIC_c units from the best models. This was further supported by the fact that, relative to the best models, the Ricker model had an evidence ratio greater than 3.

Depending on the stock-recruitment model used, population capacity ranged from 113,801 to 150,902 parr (Table 3). The Beverton-Holt model estimated the highest capacity, while the smooth hockey stick model estimated the lowest. The number of spawners needed to produce the population capacity of parr ranged from 1,089 to 1,163 (Table 3).

Table 3. Estimates of Beverton-Holt, smooth hockey stick, and Ricker model parameters, parr capacity (K), parr productivity (parr per spawner), and the number of spawners needed to produce the maximum number of parr for Chiwawa River spring Chinook.

Model	Parameter		Population capacity (K)	Intrinsic productivity	Spawners
	A	B			
Beverton-Holt	150,902.145	437.655	150,902	345	∞
Smooth Hockey Stick	11.642	312.913	113,801	313	1,089
Ricker	272.696	0.0009	116,650	273	1,163

It is important to note that the population capacity estimates are based on the number of parr counted in the Chiwawa River watershed during August. There are spring Chinook fry and parr that move out of the Chiwawa River watershed during spring and early summer (Hillman et al. 2017). It is unknown if these fish leave because of density-dependent pressures, they are flushed out during high flows, it is a life-history characteristic, or a combination of these. Regardless of the mechanism or reason, some of these fish may survive and rear in the Wenatchee or Columbia rivers. These emigrants are not included in the capacity estimates shown in Table 3.

The capacity estimates for spring Chinook parr apply only to the Chiwawa River watershed, a watershed within the Wenatchee River basin. Estimating parr capacity for the entire Wenatchee River basin using stock-recruitment models is difficult because there is no long-term time series of parr data for the entire basin. However, we can extrapolate parr capacity estimates from the

Chiwawa River watershed to the entire Wenatchee River basin using intrinsic potential (IP). Multiplying the parr capacity per intrinsic potential within the Chiwawa River watershed by the total intrinsic potential within the Wenatchee River basin yields an estimate of parr capacity for the Wenatchee River basin (Table 4). The Interior Columbia Basin Technical Recovery Team estimated IP based on wetted width, valley width (confinement), and gradient (see Cooney and Holzer 2006). They used sedimentation and temperature to refine IP for each 200-m long reach. We used the total stream area (km^2) weighted by intrinsic potential and temperature limited to extrapolate parr capacity to the entire Wenatchee River basin.

Table 4. Estimates of Wenatchee River basin parr capacity based on intrinsic potential (IP). The amount of IP within the Chiwawa River watershed is 0.481 km^2; the total amount of IP within the Wenatchee River basin is 1.798 km^2.

Model	Chiwawa parr capacity	Chiwawa parr/IP	Wenatchee parr capacity
Beverton-Holt	150,902	313,726	564,079
Smooth Hockey Stick	113,801	236,593	425,395
Ricker	116,650	242,516	436,043

Using this simple method, we estimate the Wenatchee River basin supports about 425,395-564,079 parr depending on which model is used. An important assumption of this simple method is that each unit of IP supports the same number of parr. This is clearly not true given that the quality of habitat within each unit of IP can vary greatly. That is, one unit of IP may contain more habitat structure (e.g., wood and cover) than another unit of IP. Importantly, the ratio of parr to IP comes from the Chiwawa River watershed, which contains some of the highest quality habitat within the Wenatchee River basin. Therefore, the estimated total parr capacity for the entire Wenatchee River basin is likely biased high. If habitat conditions throughout the Wenatchee River basin are enhanced to conditions similar to those in the Chiwawa River watershed, we may expect parr abundance to approach those estimated with this simple method.

Chiwawa River Spring Chinook Smolts

We successfully fit the three stock-recruitment curves to the Chiwawa spring Chinook smolt data (Figure 3).

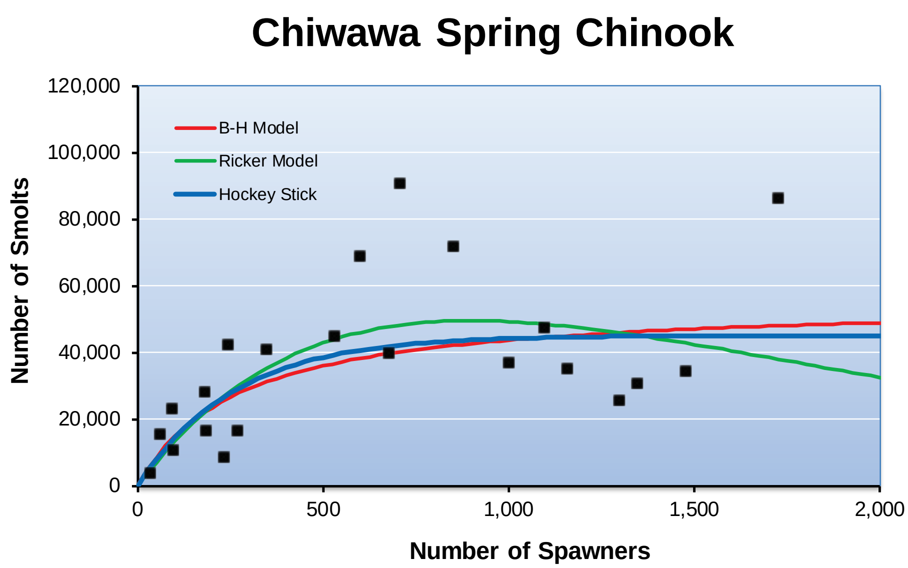

Figure 3. Relationship between numbers of spring Chinook smolts and numbers of spawners in the Chiwawa River watershed, 1992-2015. Figure shows the fit of the Beverton-Holt, Ricker, and smooth hockey stick models to the data.

For yearling smolts produced entirely within the Chiwawa River watershed, the use of AIC_c indicated that the smooth hockey stick model best approximated the information in the productivity data. The estimated structural parameters for this model were:

$$LN(Smolts) = 10.7 + LN\left(1 - e^{-\left(\frac{174.1}{45,161}\right)Spawners}\right)$$

where the bootstrap estimated standard errors for the two parameters were 0.13 and 41.29, respectively. The adjusted $R^2 = 0.569$.

The second-best model was the Ricker model, which was 0.234 AIC_c units from the best model. The estimated parameters for this model were:

$$Smolts = 149.45 \times Spawners(\mathrm{e}^{-0.00111 \times Spawners})$$

where the bootstrap estimated standard errors of the two parameters were 26.23 and 0.00018, respectively, and the $R^2 = 0.573$.

The third-best model was the Beverton-Holt model, which was 0.725 AIC_c units from the best model. The estimated parameters for this model were:

$$Smolts = \frac{(55,702 \times Spawners)}{(273 + Spawners)}$$

where the bootstrap estimated standard errors of the two parameters were 10,421.9 and 123.0, respectively, and the $R^2 = 0.560$.

The AIC_c difference scores, Akaike weights, and evidence ratios indicated that there was substantial support for all three models. Relative to the best model, the other two models had evidence ratios less than 1.5.

Depending on the stock-recruitment model used, population capacity ranged from 45,161 to 55,702 smolts (Table 5). The Beverton-Holt model estimated the highest capacity, while the smooth hockey stick model estimated the lowest. The number of spawners needed to produce the population capacity of smolts ranged from 777 to 901 (Table 5).

Table 5. Estimates of Beverton-Holt, smooth hockey stick, and Ricker model parameters, smolt capacity (K), smolt productivity (smolts per spawner), and the number of spawners needed to produce the maximum number of smolts for Chiwawa River spring Chinook.

Model	Parameter		Population capacity (K)	Intrinsic productivity	Spawners
	A	B			
Smooth hockey stick	10.718	174.077	45,161	174	777
Ricker	149.452	0.00111	49,532	149	901
Beverton-Holt	55,702.281	273.910	55,702	203	∞

It is important to note that the population capacity estimates are based on the number of smolts produced entirely within the Chiwawa River watershed. As noted earlier, there are spring Chinook fry and parr that move out of the Chiwawa River watershed during spring, early summer, and fall (Hillman et al. 2017). Fall emigration is common and occurs even when densities of juveniles are very low, indicating that fall emigration is a life-history characteristic. Regardless of why the fish emigrate as fry and parr, some of these fish survive and rear in the Wenatchee or Columbia rivers. Some survive to smolt (unpublished WDFW data), but are not included in the smolt capacity estimates shown in Table 5.

As with parr, the capacity estimates for spring Chinook smolts apply only to the Chiwawa River watershed. As before, we can extrapolate smolt capacity estimates from the Chiwawa River watershed to the entire Wenatchee River basin using intrinsic potential (IP). In this case, we multiply the smolt capacity per intrinsic potential within the Chiwawa River watershed by the total intrinsic potential within the Wenatchee River basin. This yields an estimate of smolt capacity for the Wenatchee River basin (Table 6).

Table 6. Estimates of Wenatchee River basin smolt capacity based on intrinsic potential (IP). The amount of IP within the Chiwawa River watershed is 0.481 km^2; the total amount of IP within the Wenatchee River basin is 1.798 km^2.

Model	Chiwawa smolt capacity	Chiwawa smolts/IP	Wenatchee smolt capacity
Beverton-Holt	55,702	115,805	208,218
Smooth Hockey Stick	45,161	93,891	168,816
Ricker	49,532	102,976	185,152

Using this simple method, we estimate the population capacity for the Wenatchee River basin at 168,816-208,218 smolts depending on which model is used. Based on smolt trapping in the lower Wenatchee River over a 13-year period, total smolt abundance has ranged from 36,752 to 302,116 smolts (average = 107,300 smolts) (Table 2).[14] Thus, recent (2000-2014) smolt production appears to be below capacity estimates for most years but higher in some years.

An important assumption of this simple method is that each unit of IP supports the same number of smolts. As we noted earlier, this is not the case given that the quality of habitat within each unit of IP can vary greatly. Nevertheless, the ratio of smolts to IP comes from the Chiwawa River watershed, which contains some of the highest quality habitat within the Wenatchee River basin. Therefore, the estimated total smolt capacity for the entire Wenatchee River basin is likely biased high. If habitat conditions throughout the Wenatchee River basin are enhanced to conditions similar to those in the Chiwawa River watershed, we may expect smolt abundance to approach those estimated with this simple method.

Wenatchee River Spring Chinook Smolts

Rather than extrapolate results from the Chiwawa River watershed to the entire Wenatchee River basin, we can fit stock-recruitment models to the smolt data collected in the lower Wenatchee River and estimate population capacity directly from the population models. We successfully fit the three stock-recruitment curves to the Chiwawa spring Chinook smolt data; although, the models explained little of the variation in the stock-recruitment data ($R^2 < 0.05$) (Figure 3).

[14] It is important to point out that the trapping location has changed over time. During the period 2000-2008 and 2011-2012, the trap was located near the Town of Monitor. During the period 2013-present, the trap was located near the Town of Cashmere.

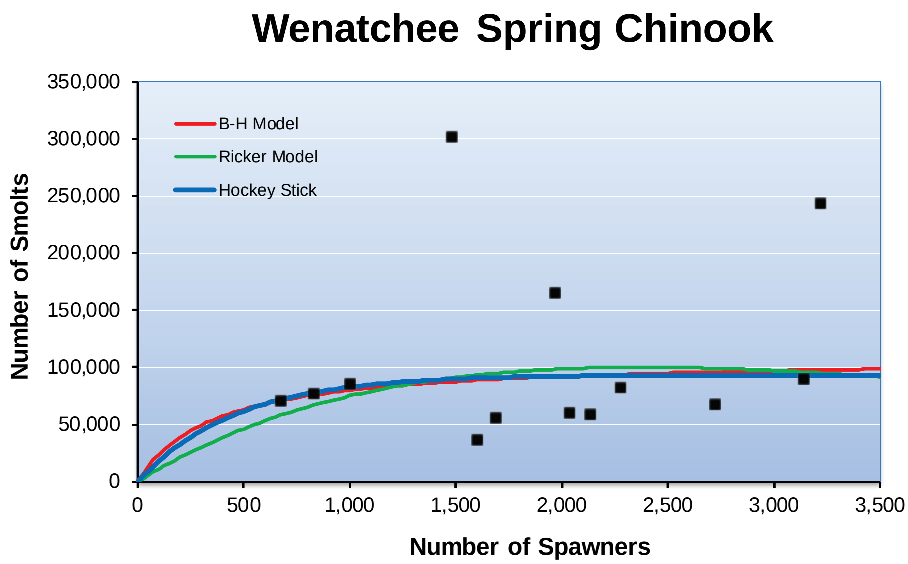

Figure 4. Relationship between numbers of spring Chinook smolts and numbers of spawners in the Wenatchee River basin, 2000-2014 (no data were collected in 2009 or 2010). Figure shows the fit of the Beverton-Holt, Ricker, and smooth hockey stick models to the data.

For yearling smolts produced within the Wenatchee River basin, the use of AIC_c indicated that the Beverton-Holt model best approximated the information in the productivity data. The estimated structural parameters for this model were:

$$Smolts = \frac{(108{,}696 \times Spawners)}{(359 + Spawners)}$$

where the bootstrap estimated standard errors for the two parameters were 49,948 and 836, respectively. The adjusted $R^2 = 0.026$.

The second-best model was the smooth hockey stick model, which was 0.112 AIC_c units from the best model. The estimated parameters for this model were:

$$LN(Smolts) = 11.4 + LN\left(1 - e^{-\left(\frac{20.72}{93{,}560}\right)Spawners}\right)$$

where the bootstrap estimated standard errors of the two parameters were 30.74 and 225.43, respectively, and the $R^2 = 0.017$.

The third-best model was the Ricker model, which was 0.0.808 AIC_c units from the best model. The estimated parameters for this model were:

$$Smolts = 114.10 \times Spawners(\mathrm{e}^{-0.00042 \times Spawners})$$

where the bootstrap estimated standard errors of the two parameters were 56.16 and 0.00021, respectively, and the $R^2 = 0.001$.

The AIC_c difference scores, Akaike weights, and evidence ratios indicated that there was substantial support for all three models. Relative to the best model, the other two models had evidence ratios less than 2.0.

Depending on the stock-recruitment model used, population capacity for the Wenatchee River basin ranged from 93,560 to 108,696 smolts (Table 7). The Beverton-Holt model estimated the highest capacity, while the smooth hockey stick model estimated the lowest. The number of spawners needed to produce the population capacity of smolts ranged from 1,389-2,381 (Table 7).

Table 7. Estimates of Beverton-Holt, smooth hockey stick, and Ricker model parameters, smolt capacity (K), smolt productivity (smolts per spawner), and the number of spawners needed to produce the maximum number of smolts for Wenatchee River spring Chinook.

Model	Parameter		Population capacity (K)	Intrinsic productivity	Spawners
	A	B			
Smooth hockey stick	11.446	201.724	93,560	202	1,389
Ricker	114.104	0.00042	99,944	114	2,381
Beverton-Holt	108,696.009	358.616	108,696	303	∞

The population capacity estimates reported here are based on the number of smolts produced within the Wenatchee River basin. It is likely that some juvenile spring Chinook rear in the Columbia River and survive to smolt. Those fish are not included in these estimates of capacity.

Habitat Capacity

Habitat capacity can be estimated using fish-habitat models and creative modeling of stock-recruitment data. As we noted earlier, there are several different fish-habitat models that can be used to estimate habitat capacity. In this paper, we explore the use of two different methods, quantile regression applied to stock-recruitment functions and the Quantile Regression Random Forest model. The former relies on simple stock and recruitment data, while the latter requires estimates of habitat quality and quantity, and functional relationships between maximum fish density and habitat conditions.

Quantile Regression Analysis of Stock-Recruitment Data

To estimate population capacity, we used non-linear regression techniques to fit stock-recruitment functions to the data. These techniques approximate the conditional mean of the recruitment data given the range of stock sizes. As such, the functions (curves) estimated from the analyses lie near the center of the distribution of data resulting in data points above and below the curve. Although this technique is useful for estimating population capacity, it is not appropriate for estimating habitat capacity. The fact that there are actual recruitment data above the estimated population capacity indicates that habitat capacity must be greater than the population capacity, or that measurement error is high. The former explanation is more likely than the latter.

One way to possibly estimate habitat capacity with stock-recruitment data is to fit stock-recruitment functions to the juvenile spring Chinook data using quantile regression techniques. Quantile regression estimates quantiles of the recruitment data given the range of stock sizes. Thus,

we can use quantile regression to fit a stock-recruitment function to, say, the upper 90% or 95% of the recruitment distribution. In other words, we fit a stock-recruitment function to the upper limits of the recruitment data given the range of stock sizes. In this case, the resulting stock-recruitment curve is above most of the recruitment data and therefore few data points lie above the curve. Calculation of capacity from these functions should more closely represent habitat capacity, provided there is an adequate range of stock sizes. Quantile regression gives results similar to those obtained from calculating reference intervals (RI).

In this exercise, we calculated the upper 90% RI for the Beverton-Holt and Ricker functions. We assume the 90% RI will closely represent the habitat capacity for juvenile spring Chinook. We calculated the 90% RI only for the Beverton-Holt and Ricker models, because these functions can be transformed into linear function (see Hilborn and Walters 1992). RIs are easier to calculate on linear functions than non-linear functions. We were unable to transform the smooth hockey stick model into a linear function and therefore we did not calculate RIs for this function.

Chiwawa River Spring Chinook Parr—We calculated 90% RIs for Chiwawa Chinook parr data for both the Ricker and Beverton-Holt models (Figure 5). The estimated parameters for the 90% RI for the Ricker model were:

$$\log\left(\frac{Parr}{Spawners}\right) = 6.152 - \frac{6.152}{5{,}984.436}(Spawners)$$

This resulted in an estimated habitat capacity of 168,071 parr, which is about 1.4 times greater than the population capacity estimated with the Ricker model.

The estimated parameters for the 90% RI for the Beverton-Holt model were:

$$\frac{Spawners}{Parr} = \frac{196.91}{181{,}818} + \frac{1}{181{,}818}(Spawners)$$

This function resulted in an estimated habitat capacity of 181,818 parr, which was about 1.2 times greater than the population capacity estimated with the Beverton-Holt model.

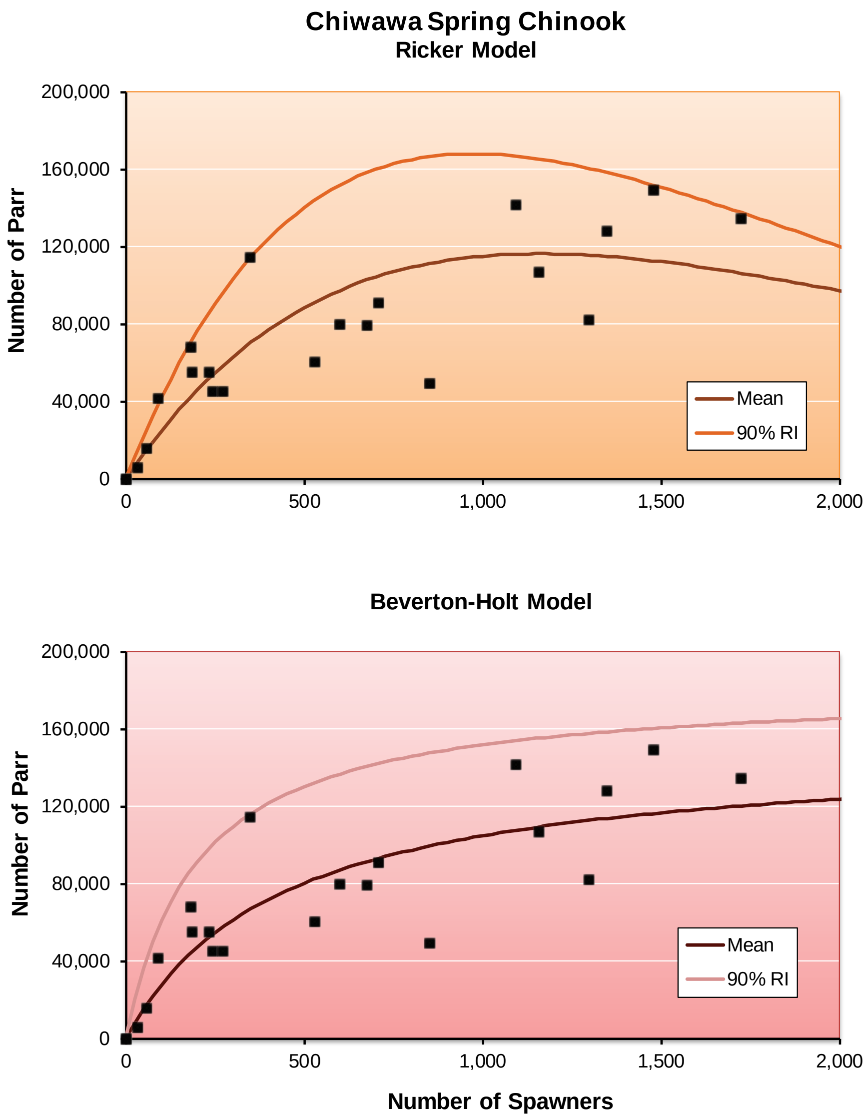

Figure 5. Relationship between numbers of spring Chinook parr and numbers of spawners in the Chiwawa River watershed, 1992-2016. Upper figure shows the fit of the Ricker model and its 90% reference interval to the data; lower figure shows the fit of the Beverton-Holt model and its 90% reference interval.

If we extrapolate the habitat capacity estimates for Chiwawa spring Chinook parr to the entire Wenatchee River basin (using the IP method described earlier), we estimate the habitat capacity for the Wenatchee River basin to be 628,256 parr from the Ricker model and 679,645 parr from the Beverton-Holt model.

Chiwawa River Spring Chinook Smolts—As with parr, we calculated 90% RIs for Chiwawa Chinook smolt data for both the Ricker and Beverton-Holt models (Figure 6). The estimated parameters for the 90% RI for the Ricker model were:

$$\log\left(\frac{Smolts}{Spawners}\right) = 5.687 - \frac{5.687}{4{,}687.964}(Spawners)$$

This resulted in an estimated habitat capacity of 89,425 smolts, which is about 1.8 times greater than the population capacity estimated with the Ricker model.

The estimated parameters for the 90% RI for the Beverton-Holt model were:

$$\frac{Spawners}{Smolts} = \frac{102.129}{64{,}516} + \frac{1}{64{,}516}(Spawners)$$

This function resulted in an estimated habitat capacity of 64,516 smolts, which was about 1.2 times greater than the population capacity estimated with the Beverton-Holt model.

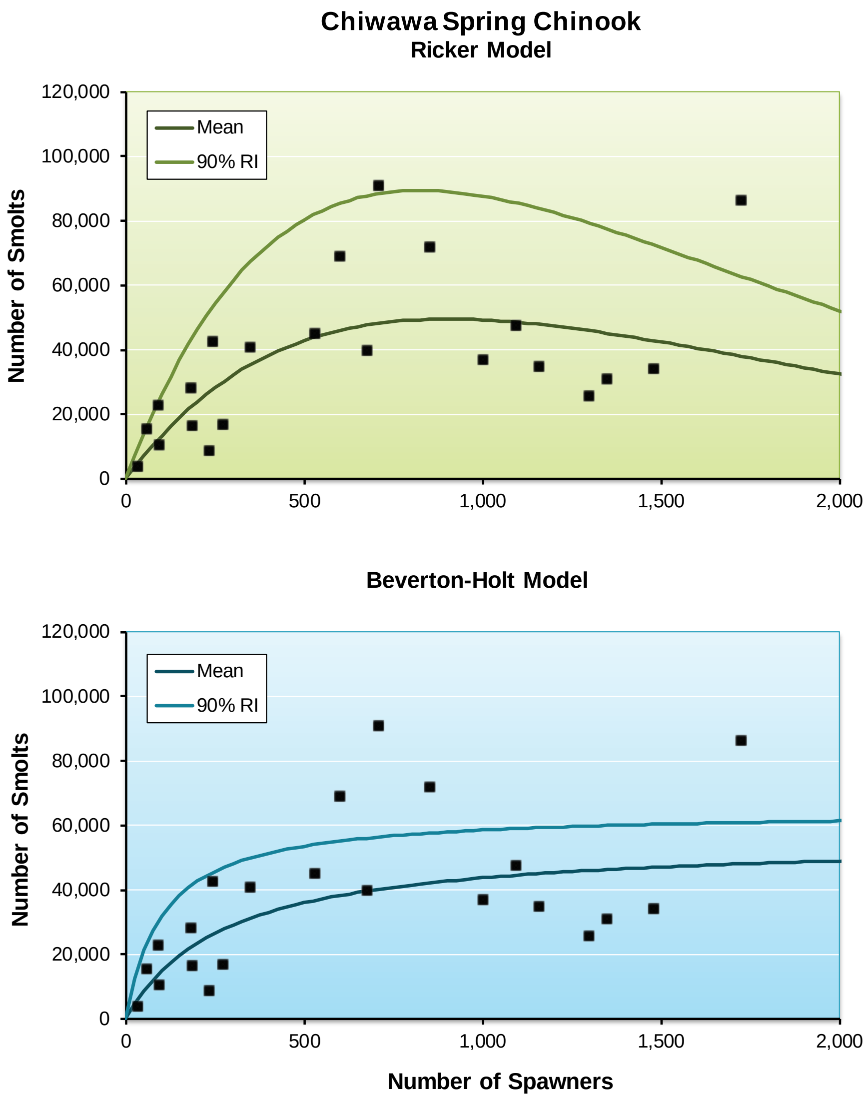

Figure 6. Relationship between numbers of spring Chinook smolts and numbers of spawners in the Chiwawa River watershed, 1992-2015. Upper figure shows the fit of the Ricker model and its 90% reference interval to the data; lower figure shows the fit of the Beverton-Holt model and its 90% reference interval.

If we extrapolate the habitat capacity estimates for Chiwawa spring Chinook smolts to the entire Wenatchee River basin (using the IP method described earlier), we estimate the habitat capacity

for the Wenatchee River basin to be 334,276 smolts based on the Ricker model and 241,164 smolts from the Beverton-Holt model.

Wenatchee River Spring Chinook Smolts—We calculated 90% RIs for Wenatchee River Chinook smolt data for both the Ricker and Beverton-Holt models (Figure 7). The estimated parameters for the 90% RI for the Ricker model were:

$$\log\left(\frac{Smolts}{Spawners}\right) = 5.320 - \frac{5.320}{16{,}642.420}(Spawners)$$

This resulted in an estimated habitat capacity of 235,131 smolts, which is about 2.4 times greater than the population capacity estimated with the Ricker model.

The estimated parameters for the 90% RI for the Beverton-Holt model were:

$$\frac{Spawners}{Smolts} = \frac{357.593}{186{,}567} + \frac{1}{186{,}567}(Spawners)$$

This function resulted in an estimated habitat capacity of 186,567 smolts, which was about 1.7 times greater than the population capacity estimated with the Beverton-Holt model.

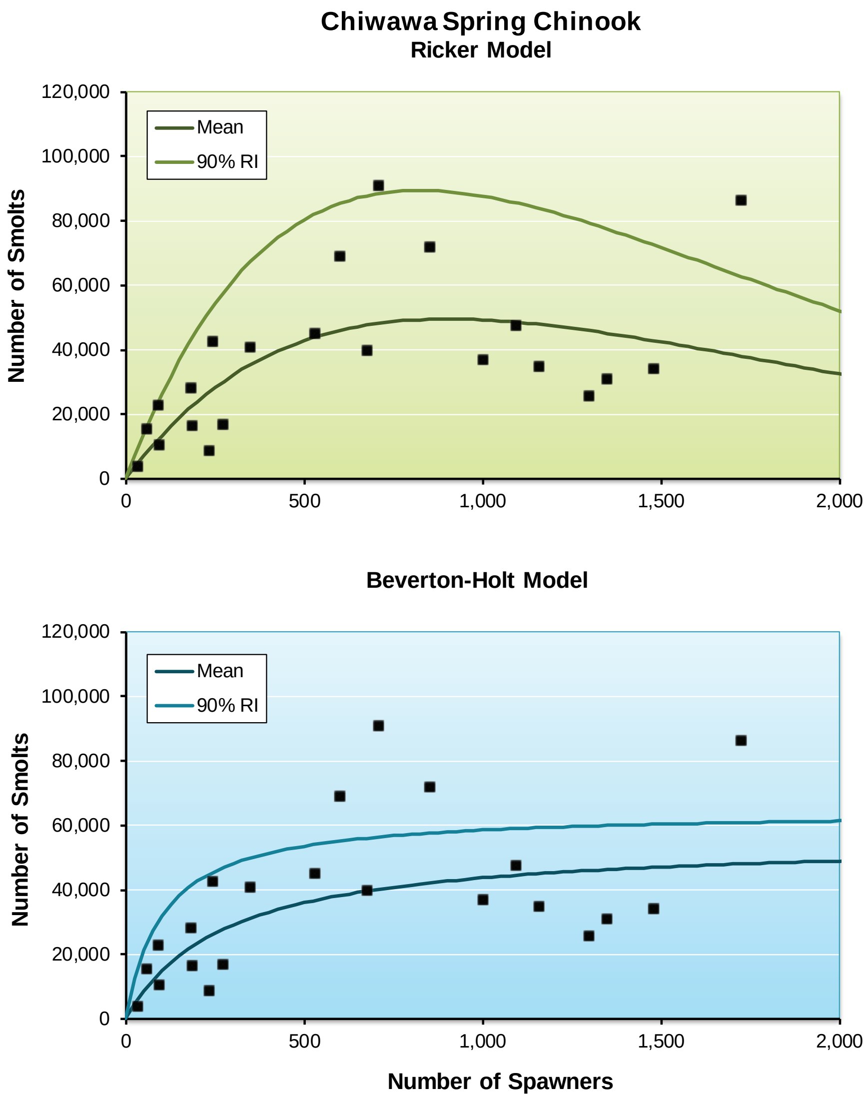

Figure 7. Relationship between numbers of spring Chinook smolts and numbers of spawners in the Wenatchee River basin, 2000-2015 (no data were collected in 2009 or 2010). Upper figure shows the fit of the Ricker model and its 90% reference interval to the data; lower figure shows the fit of the Beverton-Holt model and its 90% reference interval.

Quantile Regression Random Forest Model

Researchers with the Integrated Status and Effectiveness Monitoring Program (ISEMP) developed a model that estimates Chinook parr habitat capacity based on fish-habitat relationships (ISEMP/CHaMP 2015). Based on extensive sampling throughout the Columbia River basin, these researchers developed relationships between maximum densities of Chinook parr (summer estimates) and various habitat variables. Quantile regression forest (QRF) models use these relationships to estimate carrying capacities for juvenile Chinook. Very simply, QRF analysis develops non-linear relationships between fish density and different habitat variables. In this case, however, QRF analysis predicts the 90% quantile of fish density rather than the mean or median density. The researchers assume that the 90% quantile represents habitat capacity. This is important because the numbers of fish counted in some field sampling sites may not have been at maximum capacity. That is, it is likely that not all sites sampled were fully "seeded" with Chinook salmon. Thus, using the mean or median (50% quantile) would not represent habitat capacity, but some level below habitat capacity.

Researchers fit the QRF model to parr density data and 12 habitat variables that were collected from 227 sites within the distribution of Chinook throughout the Columbia River basin (within CHaMP/ISEMP watersheds). These variables were selected to represent a variety of types of habitat variables (e.g., substrate, riparian, complexity, temperature, etc.), contain the most "fish information," and be as uncorrelated as possible (ISEMP/CHaMP 2015). The 12 habitat variables and their relative importance are shown in Figure 8.

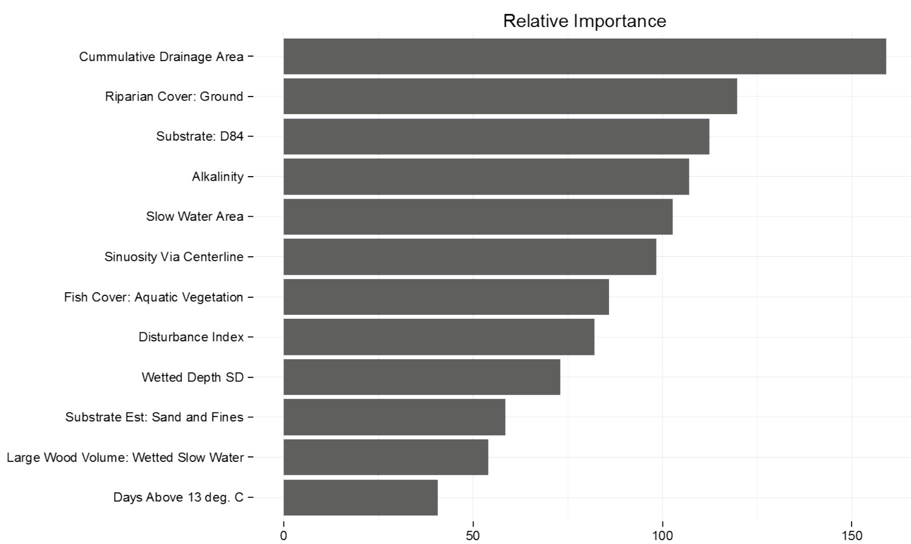

Figure 8. Relative importance of habitat variables included in juvenile Chinook salmon quantile regression forest models (Figure is from ISEMP/CHaMP 2015).

As a way of testing the model, ISEMP researchers used their QRF model to estimate Chinook parr capacities in different watersheds, including the Chiwawa River watershed, and compared their

estimates to those generated from fish population data using stock-recruitment modeling. Figure 9 shows the relationship between the QRF model results and population model results for the Chiwawa River watershed. The red curve was generated using the QRF model and the blue curve was generated using the Beverton-Holt model. At the time of this analysis, the Beverton-Holt model was fit to 21 years of parr data, not the 24 years of data used in the analyses above.

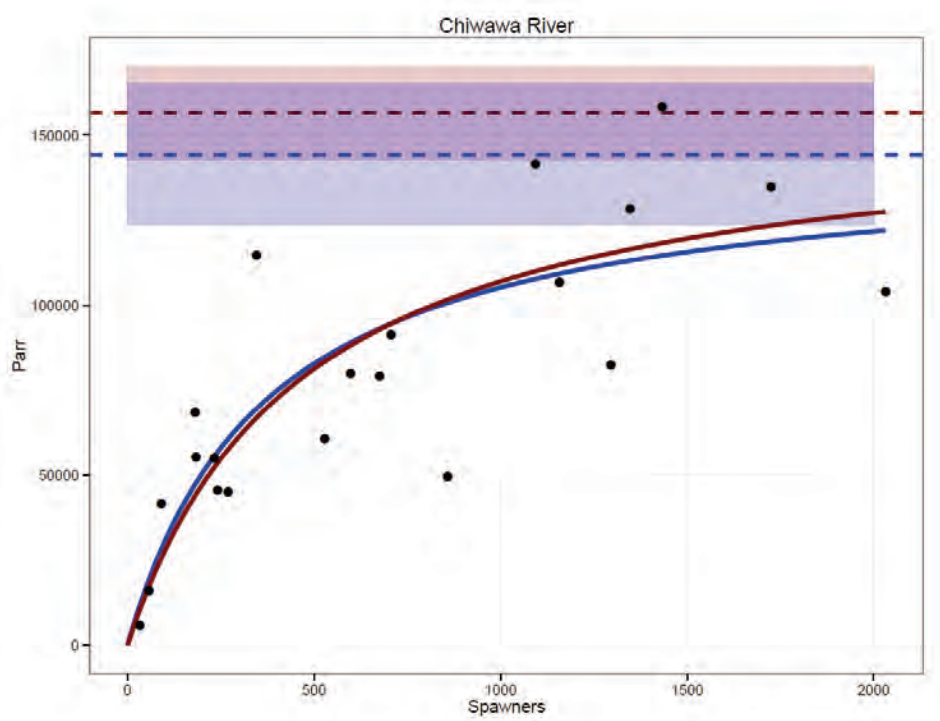

Figure 9. Comparison of productivity curves for Chiwawa spring Chinook parr generated from the QRF model (red line) and Beverton-Holt model (blue line). Dashed horizontal lines represent carrying capacity estimates. Shading about the capacity estimates represent the 95% confidence bounds. Figure is from ISEMP/CHaMP (2015).

The comparison shows that although the curves are very similar, the carrying capacity estimates (dashed horizontal lines) differed, with the habitat capacity generated from the QRF model being larger than the population capacity generated from the population data. That is, the QRF model estimated a habitat capacity of about 164,000 spring Chinook parr, while the population model estimated a population capacity of about 145,000 parr. Including more recent parr data in the Beverton-Holt model indicates that the population capacity estimate is about 151,000 parr for the Chiwawa River watershed. The 90% RI for the Beverton-Holt model estimated a habitat capacity of about 182,000, which is 1.1 times greater than the estimate from the QRF model. Note that the 90% RI for the Ricker model estimated a habitat capacity of about 168,000, which is close to the QRF model estimate.

Comparing Results

We estimated capacities for both spring Chinook parr and smolts for the Chiwawa River watershed and the entire Wenatchee River basin using different analytical tools. In this section, we compare the results from the different approaches.

Parr Capacity

Depending on the population model used, population capacity estimates for the Chiwawa River watershed ranged from 113,801 to 150,902 parr (Table 8). Not surprisingly, the Beverton-Holt model generally predicts the highest capacity estimates, while the smooth hockey stick model predicts the lowest. As expected, the population capacity estimates for Chiwawa parr were less than the habitat capacity estimates for parr. Habitat capacity estimates were about 1.2 to 1.5 times greater than the population capacity estimates (Table 8). Importantly, the fish-habitat model (QRF model) calculated a habitat capacity estimate that was close to that estimated from calculating 90% RI for the population models. Extrapolating Chiwawa capacity estimates to the entire Wenatchee River basin resulted in population capacities of 425,395 to 564,079 parr and habitat capacity estimates of 613,040 to 679,645 parr (Table 8).

Table 8. Comparison of spring Chinook parr capacity estimates for the Chiwawa River watershed and the Wenatchee River basin. Population capacities were estimated directly from the stock-recruitment functions; habitat capacities were estimated by calculating 90% reference intervals (using quantile regression; QR) for the stock-recruitment models and using a fish-habitat model (Quantile Regression Forest Model; QRF). Capacities for the Wenatchee River basin were estimated by extrapolating Chiwawa capacities using intrinsic potential.

Capacity type	Model	Chiwawa parr capacity	Wenatchee parr capacity
Population capacity	Beverton-Holt	150,902	564,079
	Smooth Hockey Stick	113,801	425,395
	Ricker	116,650	436,043
Habitat capacity	QR Beverton-Holt	181,818	679,645
	QR Ricker	168,071	628,256
	QRF Model	164,000	613,040

The number of spawners needed to achieve parr capacity also varied depending on the population model used (Table 9). For the Chiwawa River watershed, maximum spawners needed to achieve population capacity for parr ranged from 1,089 to 1,163 adults. Extrapolating Chiwawa results to the entire Wenatchee River basin resulted in maximum spawner estimates of 4,070 to 4,347 adults. We were able to estimate habitat capacity only with the Ricker model (Table 9). Using quantile regression to calculate the 90% RI for the Ricker model resulted in a maximum spawner abundance of 973 adults, which is less than the number needed to achieve population capacity. This is because the 90% RI for the Ricker function estimates a higher intrinsic productivity, which shifts the "hump" of the curve to the left resulting in a higher capacity estimate but a lower maximum spawner estimate (see Figure 5).

Table 9. Comparison of the number of spawners needed to achieve parr capacities in the Chiwawa River watershed and the Wenatchee River basin. For the Chiwawa River watershed, maximum spawners were estimated directly from the stock-recruitment functions. Maximum spawners for the entire Wenatchee River basin were estimated as the product of the extrapolated parr numbers times the ratio of maximum spawners to parr capacity for Chiwawa spring Chinook. Because of the nature of the Beverton-Holt model, no maximum spawners can be calculated from that model.

Capacity type	Model	Spawners need to achieve parr capacity	
		Chiwawa	Wenatchee
Population capacity	Smooth Hockey Stick	1,089	4,070
	Ricker	1,163	4,347
Habitat capacity	QR Ricker	973	3,636

Smolt Capacity

As with parr estimates, population capacity estimates for smolts varied depending on the population model used. For Chiwawa spring Chinook smolts, population capacities ranged from 45,161 to 55,702 smolts, with the smooth hockey stick providing the lowest estimate and the Beverton-Holt model providing the highest (Table 10). The population capacity estimates were about 55 to 86% of the habitat capacity estimates. Extrapolating Chiwawa capacity estimates to the entire Wenatchee River basin resulted in population capacities of 168,816 to 208,218 smolts and habitat capacity estimates of 241,164 to 334,276 smolts (Table 10). These were greater than those estimated using smolt and spawner data for the entire Wenatchee River basin. Fitting population models to smolt and spawner data for the entire basin resulted in population capacities of 93,560 to 108,696 smolts and habitat capacities of 186,567 to 235,131 smolts (Table 10).

Table 10. Comparison of spring Chinook smolt capacity estimates for the Chiwawa River watershed and the Wenatchee River basin. Population capacities were estimated directly from the stock-recruitment functions; habitat capacities were estimated by calculating 90% reference intervals (using quantile regression; QR) for the stock-recruitment models. Capacities for the Wenatchee River basin were estimated by extrapolating Chiwawa capacities using intrinsic potential and by fitting population models to the smolt and spawner data for the entire basin.

Capacity type	Model	Chiwawa smolt capacity	Wenatchee smolt capacity	
			Chiwawa extrapolation	Wenatchee data
Population capacity	Beverton-Holt	55,702	208,218	108,696
	Smooth Hockey Stick	45,161	168,816	93,560
	Ricker	49,532	185,152	99,944
Habitat capacity	QR Beverton-Holt	64,516	241,164	186,567
	QR Ricker	89,425	334,276	235,131

The number of spawners needed to achieve smolt capacity varied depending on the population model used (Table 11). For the Chiwawa River watershed, maximum spawners needed to achieve

population capacity for smolts ranged from 777 to 901 adults. Note that the maximum number of adults needed to achieve population capacity for smolts is less than those needed to achieve population capacity for parr. Extrapolating Chiwawa results to the entire Wenatchee River basin resulted in maximum spawner estimates of 2,904 to 3,368 adults. These estimates are considerably higher than those estimated from fitting population models to Wenatchee River basin data. The latter estimated maximum spawners ranging from 1,389 to 2,381 adults. We were able to estimate habitat capacity only with the Ricker model (Table 11). Using quantile regression to calculate the 90% RI for the Ricker model resulted in a maximum spawner abundance of 824 adults for the Chiwawa River watershed and 3,129 adults for the entire Wenatchee River basin. Extrapolating Chiwawa results to the entire Wenatchee River basin resulted in a maximum spawner estimate of 3,080, which is close to the estimate generated by fitting the model to Wenatchee River basin data.

Table 11. Comparison of the number of spawners needed to achieve smolt capacities in the Chiwawa River watershed and the Wenatchee River basin. Maximum spawners were estimated directly from the stock-recruitment functions. Maximum spawners for the entire Wenatchee River basin were also estimated as the product of the extrapolated smolt numbers times the ratio of maximum spawners to smolt capacity for Chiwawa spring Chinook. Because of the nature of the Beverton-Holt model, no maximum spawners can be calculated from that model.

Capacity type	Model	Spawners need to achieve smolt capacity		
		Chiwawa	Wenatchee	
			Chiwawa extrapolation	Wenatchee data
Population capacity	Smooth Hockey Stick	777	2,904	1,389
	Ricker	901	3,368	2,381
Habitat capacity	QR Ricker	824	3,080	3,129

As an additional exercise, we calculated smolt capacities and maximum spawners generated from fitting population models to smolt and spawner data in the Chiwawa River, Nason Creek, and White River watersheds, and compared the sum of those estimates to the Wenatchee River basin estimates. Only the Ricker model could be fit to the White River and Nason Creek data (see Hillman et al. 2017). Estimated population capacities from the Ricker model were 49,532 smolts in the Chiwawa, 4,412 smolts in Nason Creek, and 4,659 smolts in the White River, resulting in a cumulative population capacity of 58,603 smolts (1,550 spawners are needed to achieve this cumulative smolt capacity). The cumulative population capacity estimate is nearly 60% of the total population capacity calculated from fitting the Ricker model to the entire Wenatchee River basin data. If these estimates are correct, this means that about 40% of the current Wenatchee River basin smolt capacity is outside the Chiwawa River, Nason Creek, and White River watersheds. Hillman et al. (2017) report that over the period 1989 to 2016, on average, 76% of spring Chinook spawning occurs in the three watersheds. Thus, a large percentage of smolt capacity is generated outside the major spawning areas. We believe this highlights the importance of the mainstem Wenatchee River as a rearing area for juvenile spring Chinook.

Recommendations

Based on the simple analyses conducted in this report, we offer the following recommendations:

1. Where sufficient stock and recruitment data are available, and the data have sufficient contrast, then use population (stock-recruitment) modeling as the primary method to calculate population capacity and the number of spawners needed to achieve capacity for each spawning aggregate or population of interest. Select the best fitting stock-recruitment model based upon AIC_c, unless other factors suggest otherwise, such as evidence for a biological mechanism. A biological mechanism supporting a Ricker function, for example, would be that there is a stock-dependent effect on the mortality of eggs and juveniles (i.e., mortality is proportional to the initial cohort size). When AIC_c values are not appreciably different, then select the model that is most useful (e.g., Ricker and smooth hockey stick models are easier to work with than the Beverton-Holt model).
2. Adult-to-adult data are the most relevant because they account for all life stages and delayed effects in freshwater (e.g., small size at migration), but they are also the most variable (i.e., low R^2). Therefore, adult-to-juvenile data (e.g., parr, yearling smolts, total migrants) are likely the most useful for determining freshwater population capacity. Where data are available, pre-spawn adult to spawning adult survival can also be assessed using population models to evaluate density dependence and pre-spawn adult capacity.
3. The population models used to estimate population capacity should also be used in reference streams so one can make comparisons of carrying capacities and density-corrected productivities. Unless there are good reasons for selecting a different juvenile life-stage, the default should be to use yearling smolts because they represent the capacity of the tributaries to produce yearlings and it is also a clear identification and quantification of a migrant life-stage.
4. In the absence of fish-habitat models, quantile regression can be used to estimate habitat capacity by calculating reference intervals for the population models. The percentage of the reference interval should be set using the error in the estimation of the recruits and the level of desire to exclude anomalous data. For example, if the 95% confidence interval is approximately 10% of the recruitment estimate, then the reference interval should be set at 90% (e.g., RI = 100% - C.I.%).
5. Where sufficiency conditions in (1) are not met, use habitat-based expansion of density at capacity for the most ecologically similar population. For example, use Twisp capacity estimates for habitat-based expansions in the Methow. The habitat expansion metric should be "total stream area weighted by intrinsic potential and temperature limited," unless there are good reasons for a different expansion. The primary idea is to exclude areas that are known to not produce fish because of passage, temperature, or other limitations.
6. Capacity estimates should be described within the context of the information that was used to derive estimates. For example, spawner distribution of hatchery-origin fish could influence estimates of capacity if they are within poor habitat. However, the capacity estimates do reflect the historic and current hatchery practices. It is unknown how the capacity estimates would change if a different hatchery program that produced different spawning distributions was to be implemented. However, if those data do become available, then capacity estimates can be revised. Similarly, significant enhancements (e.g.,

improved passage) or degradations (e.g., fire) in habitat can also change capacity and can be incorporated into future estimates of capacity.

7. Regardless of the method used to estimate capacity, always describe the limitations of the data and assumptions of the models. Note where assumptions are violated and how these violations could affect the results of the analysis.

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APPENDIX 2: HATCHERY REPLACEMENT RATES

Based on ideas developed by the HETT, in February 2016, the HCP Hatchery Committees and PRCC Hatchery Subcommittee agreed to the following rules and HRR targets:

1. Use the estimated 40% HRR Target during 5-year statistical evaluation periods.
2. Use varying degrees of action depending on the numbers of years that annual HRR deviates from Target.
   a. Green Light (below Target for ≤ 2 years).
   b. Red Light (below Target for > 2 years).
3. Each program will have its own HRR target with the following exceptions.
   a. Nason Creek spring Chinook will use the Chiwawa Target (there are currently no data to calculate a target for Nason Creek spring Chinook).
   b. Methow and Chewuch spring Chinook will use the greater of their two Targets (they are MetComp stock and evaluated similarly).

Table 1. Release numbers and 5-year hatchery replacement rates (HRR) targets for Upper Columbia River Hatchery Programs.

Species	Owner	Program (Hatchery)	Basin (Purpose)	Smolts released[1]	5-Year HRR[2]
Steelhead	CPUD	Eastbank (Chiwawa)	Wenatchee (Conservation)	123,650	6.9
Steelhead	CPUD	Eastbank (Chiwawa)	Wenatchee (Safety Net)	123,650	6.9
Steelhead	DPUD	Wells (Wells)	Columbia (Safety Net)	160,000	26.5
Steelhead	DPUD	Wells (Wells)	Methow (Safety Net)	100,000	26.5
Steelhead	DPUD	Wells (Wells)	Twisp (Conservation)	48,000	26.5
Steelhead	GPUD	Wells (Omak)	Okanogan (Conservation)	100,000	7.3 [3]
SUM Chinook	CPUD	Eastbank (Chelan Falls)	Chelan (Conservation)	176,000	5.7
SUM Chinook	CPUD	Eastbank (Chelan Falls)	Chelan (Harvest)	400,000	5.7
SUM Chinook	CPUD, GPUD	Eastbank (Dryden)	Wenatchee (Conservation)	500,000	5.7
SUM Chinook	DPUD	Wells (Wells)	Columbia (Harvest)	320,000	3.0
SUM Chinook	GPUD	Eastbank (Carlton)	Methow (Conservation)	200,000	3.0
SUM Chinook	CCT	Chief Joseph	Okanogan (Harvest)	1,100,000	8.6
SPR Chinook	CPUD	Eastbank (Chiwawa)	Wenatchee (Conservation)	144,026	6.7

SPR Chinook	CPUD, DPUD, GPUD	Wells (Methow)	Methow (Conservation)	193,765	3.8
SPR Chinook	DPUD, GPUD	Wells (Twisp)	Methow (Conservation)	30,000	2.7
SPR Chinook	GPUD	Eastbank (Nason)	Wenatchee (Conservation)	223,670	6.7

[1] Release goal established by HCPs and adjusted by HC.
[2] Derived from Annual Reports.
[3] Harvest not included.

APPENDIX 3: PNI and pHOS Targets and Sliding Scales

Select CPUD, DPUD, and GPUD funded hatchery mitigation programs have PNI management targets, while others do not. Table 1 summarizes management strategies by species and population. Detailed information can be found in the sections that follow. Descriptions provided in the following sections are taken directly from HGMPs and/or issued and draft permits.

Table 1. Summary of management strategies by species and population.

Species	Population	Management Strategy	Comments
Spring Chinook	Wenatchee	Sliding Scale of PNI management	Details can be found in Section 2.0
	Methow	Two—population sliding scale PNI management	Details can be found in Section 3.0
	Okanogan	None Currently	Details can be found in Section 4.0
Steelhead	Wenatchee	Two-zone management.	Details can be found in 5.0
	Methow	In-development	Details forthcoming; Section 6.0
	Okanogan	None Currently	Details can be found in Section 7.0
Summer Chinook	Wenatchee	None Currently	Details can be found in Section 9.0
	Methow	None Currently	Details can be found in Section 10.0
	Okanogan	0.67; pHOS 0.30	Details can be found in Section 11.0
	Upper Columbia River	None Currently	Details can be found in Section 12.0
Fall Chinook	Hanford Reach	0.67	Details can be found in Section 13.0

2.0 Wenatchee Spring Chinook

Wenatchee spring Chinook will be managed according to the sliding scale identified in the Wenatchee Spring Chinook Management Plan (2010) and Permit Numbers 18118 and 18121. The sliding scale is based upon the estimated number of natural origin spring Chinook over Tumwater Dam. As more information becomes available the sliding scale may be adjusted as a result of gaining a better understanding of the pre-spawn mortality rate and carrying capacity.

Table 2. Sliding scale of PNI goals based on natural origin spring Chinook run size expected to the Wenatchee River basin. Percentiles are based on adult returns observed between 1999 and 2008.

Percentile	NOR Run Size				PNI
	Chiwawa	Nason Creek	White	Wenatchee River (above TWD)	
>75th	>372	>350	>87	>910	≥ 0.80
50% - 75%	278-372	259-349	68-86	631-909	≥ 0.67
25% - 50%	209-277	176-258	41-67	525-630	≥ 0.50
10%-25%	176-208	80-175	20-40	400-524	≥ 0.40

<10th	<175	<80	<20	<400	Any PNI

3.0 Methow/ Chewuch Spring Chinook

The following sliding scale (Table 3) is presented in the April 14, 2016 draft Methow Hatchery Spring Chinook Section 10-Draft. It is anticipated that no further changes will be made to the sliding scale prior to issuance of the final permits.

Table 3. PUD PNI sliding scale calculations for a range of natural run sizes.

Natural Origin Returns	PUD pHOS	WNFH pHOS	PUD pNOB	2-Pop PNI	PUD PNI (equation)
<300	Ensure minimum of 500 total spawners				
300	0.40	0.2	0.75	0.67	0.67
500	0.40	0.2	0.80	0.68	0.76
900	0.30	0.15	1.00	0.78	0.80
1500	0.25	0.1	1.00	0.8	0.80
2000	0.25	0.1	1.00	0.8	0.80
2500	0.25	0.1	1.00	0.8	0.80

4.0 Okanogan Spring Chinook

The Okanogan spring Chinook program is a re-introduction effort implemented as a non-essential experimental population under ESA Section 10j to re-introduce spring Chinook into the Okanogan River. As a non-essential experimental population targeting re-introduction and establishment of a local population of spring Chinook, the Okanogan spring Chinook program will not conduct adult management actions to reduce the proportion of 10j hatchery fish on the spawning grounds or conduct broodstocking efforts in the Okanogan for a 10-year period (2014 – 2023), as such, no PNI or pHOS objectives have been identified for this program in this 10-year period.

CJH Program segregated production released into the mainstem Columbia River are non-listed Leavenworth stock released reared/acclimated/released at CJH. Although no PNI or pHOS targets are identified for the Okanogan 10j population, minimizing strays from the CJH segregated spring Chinook program is a program objective, as such, returning segregated program fish will be subject to directed harvest and aggressive adult surplusing at CJH to minimize straying to the Okanogan River Basin as well as other extant upper Columbia River spring Chinook populations. Stray targets for the segregated program are 5% or less stray rate (i.e. spawning contribution to other upper Columbia River spring Chinook populations).

5.0 Wenatchee Steelhead

Interim escapement goal for Wenatchee River steelhead will be 1,500 spawners with an additional goal of attaining an average PNI of 0.67 for the Wenatchee River basin population as a whole. To achieve the stated goal, the Wenatchee steelhead program will use a two-zone management approach wherein the upper basin (above TWD) will be managed for recovery using an integrated recovery program, a separate spawning escapement goal, and a PNI standard to achieve the overall basin goal of an average PNI over time of 0.67 (Table 4). Areas below TWD will be managed to minimize hatchery supplementation with a pHOS goal of < 0.10.

Steelhead returning upstream of TWD will be managed as an integrated recovery program with a pNOB goal of 1.0. The above TWD escapement goal will be 1,094 spawners. Working within this framework, pNOB will be maximized above TWD while pHOS will be minimized.

Table 4. Wenatchee steelhead two-zone management and PNI targets.

Location	Run Escapement Goal	pNOB Conservation Program	pNOB Safety Net Program	pHOS	PNI
Above TWD	1,094	1.0	0.0	Varies	Varies
Below TWD	406	N/A	N/A	< 0.10	< 0.67
Basin Total	1,500	N/A	N/A	Minimal	Average = 0.67

6.0 Methow Steelhead

Methow steelhead PNI targets are currently in development.

7.0 Okanogan Steelhead

Current program has no PNI goal. CTCR submitted an Okanogan steelhead HGMP to NOAA Fisheries on February 4, 2014. Within the HGMP provisions were included to allow a greater collection of natural-origin broodstock and multiple adult management strategies to address over-escapement of hatchery-origin steelhead to the spawning grounds. The HGMP also identified a near-term (1-4 years) and a long-term PNI objectives of 0.50 and > 0.67, respectively. Once NOAA has completed the consultation and issued a new permit, providing the opportunity to increase the proportion of natural-origin fish in the broodstock and additional adult management strategies, the program will adopt the PNI objectives and this Appendix can be amended accordingly.

8.0 Wells Columbia Mainstem Safety-net Steelhead

The Safety-Net Mainstem Columbia component released below Wells Dam will be managed primarily at the Wells Hatchery volunteer channel. The objective of the adult management of the Safety-Net Mainstem Columbia component is to prevent runs of this component from moving into natural spawning areas. This will be accomplished through in-river harvest and removal of volunteers at the Wells Hatchery outfall. There are no PNI goals for this component.

9.0 Wenatchee Summer Chinook

No PNI goals are established.

10.0 Methow Summer Chinook

No PNI goals are established.

11.0 Okanogan Summer Chinook

Okanogan summer/fall Chinook will be managed to achieve a 5-year rolling average PNI of 0.67 and pHOS of 0.30. Strategies to achieve that PNI target include up to 100% pNOB, aggressive removal of hatchery-origin Chinook in selective fisheries, at the Okanogan weir, and during surplusing at CJH ladder. Reduction in the number of juveniles released in the Okanogan River Basin (integrated program) is also a management option, should adult management actions be unable to control the proportion of hatchery fish on the spawning grounds to achieve that PNI target.

CJH segregated summer/fall Chinook program rears/acclimates/releases smolts into the mainstem Columbia River at CJH. Broodstock are 100% hatchery-origin, as such no PNI target for this production component. Stray rate (i.e. contribution to upper Columbia summer/fall Chinook populations) is 5% or less. Adult management on returning adults from the segregated program include fisheries, removal at the Okanogan weir, and removal at the CJH ladder.

12.0 Upper Columbia Summer Chinook (Chelan Falls and Wells)

No PNI goals are established. Chelan Falls and Wells FH summer Chinook programs are segregated harvest programs designed to provide opportunity for harvest. Adult returns are not intended to spawn naturally; therefore, there is no escapement goal for natural spawning areas. Adult returns will be managed to meet program objectives. Chelan Falls and Wells Hatchery summer Chinook are available for harvest in the ocean and Columbia River commercial, tribal, and recreational fisheries.

13.0 Priest Rapids Fall Chinook

The Hanford Reach fall Chinook population is intentionally supplemented by Grant PUD at the Priest Rapids Hatchery and the ACOE at the Priest Rapids and Ringold Springs hatcheries. Managers desire to achieve a population level PNI that includes all hatchery programs of $\geq$0.67. Grant PUD and the HSC do not have control over operation or expansion of the ACOE program and therefore will strive to operate the Priest Rapids Hatchery fall Chinook program in a way that does its fair share of achieving a population level PNI of 0.67.

APPENDIX 4: SPATIAL DISTRIBUTION OF SPAWNERS OR REDDS

Strategies for conservation programs typically intend that hatchery and naturally produced fish spawn together and in similar locations. However, in some cases, strategies may differ from this paradigm. In Table 1, conservation programs that have a spatial distribution management plan that deviates from similar to the natural spawning spatial distributions are presented. Otherwise, conservation programs are intended to have a spawning distribution similar to the natural origin spawning spatial distributions, as described by M&E Objective 5.3.

Table 1. Management targets for the spatial distribution of hatchery-origin redds for conservation programs that deviate from Objective 5.3.

Program	Target	Rational	Source
Carlton Summer Chinook	The observed spawning distribution of hatchery origin Methow summer Chinook from 2005-2010 represents the base-line spawner distribution for evaluating the performance of the hatchery program (i.e., M&E plan check-ins). It is acknowledged that this distribution is lower in the River than the spawning distribution of natural origin summer Chinook salmon.	Based upon an assessment of summer Chinook and ESA-listed spring Chinook abundance and spawner distribution, it was determined that an increase in summer Chinook spawning abundance in the upper most range of natural origin summer Chinook distribution or potentially above the current range may pose an unknown and potentially adverse impact to ESA listed spring Chinook. Due to the concern for spring Chinook, the HSC has endorsed an acclimation site in the Methow Basin that is lower in the basin than may be required to attain exact replication of natural and hatchery origin summer Chinook spawner distribution.	SOA 2011-02 Priest Rapids Coordinating Committee Hatchery Subcommittee Statement of Agreement on Monitoring & Evaluation (M&E) Objective for Spawning Distribution of Hatchery-Origin Summer Chinook
Dryden Summer Chinook	The observed spawning distribution of hatchery origin Wenatchee summer Chinook from 2008-2013 (previous 5 years to the current M&E check-in cycle) represents the base-line spawner distribution for evaluating the performance of the	The primary site endorsed by the HSC for Grant PUD overwinter acclimation of summer Chinook is the Dryden Pond, and is the current acclimation and release site for the existing summer Chinook supplementation program	Adapted from SOA 2011-02 Priest Rapids Coordinating Committee Hatchery Subcommittee Statement of Agreement on Monitoring & Evaluation (M&E) Objective for Spawning Distribution of Hatchery-Origin Summer Chinook

	hatchery program (i.e., M&E plan check-ins).	funded and owned by Chelan PUD. Because current data indicates that spawning distribution of hatchery summer Chinook from the existing program is lower in the Wenatchee River than natural origin spawners, expectations are that acclimation of Grant PUD's summer Chinook at Dryden Pond would continue to return hatchery origin summer Chinook that result in different spawning distributions for hatchery and natural summer Chinook.	

APPENDIX 5: WITHIN HATCHERY REARING TARGETS

Rearing Targets for Upper Columbia River Hatchery Programs. K-factor or fork length targets will be determined based on data from the pending "Five-Year Report."

Table 1. Numbers, fish per pound (fpp), coefficient of variation (CV), and condition factor (K) targets at release of Upper Columbia River Hatchery Programs.

Hatchery	Species	Life Stage	Basin	Release number	FPP	CV	K-factor
Methow	Spring Chinook	Yearling	Methow	193,765[1]	15	<10	TBD
Methow	Spring Chinook	Yearling	Twisp	30,000	15	<10	TBD
Chief Joseph	Spring Chinook	Yearling	Columbia	700,000	15	<10	TBD
Chief Joseph	Spring Chinook	Yearling	Okanogan	200,000	15	<10	TBD
Chiwawa	Spring Chinook	Yearling	Wenatchee	144,026	18	<10	TBD
Nason	Spring Chinook	Yearling	Wenatchee	223,670[3]	18-24	<10	TBD
Winthrop	Spring Chinook	Yearling	Methow	400,000	17	<10	TBD
Leavenworth	Spring Chinook	Yearling	Wenatchee	1.2 M	17	<10	TBD
Wells	Steelhead	Yearling	Columbia	160,000	6	<10	TBD
Wells	Steelhead	Yearling	Methow	100,000	6	<10	TBD
Wells	Steelhead	Yearling	Twisp	48,000	6	<10	TBD
Wells	Steelhead	Yearling	Omak	~100,000[4]	5-8	<10	TBD
Wells	Steelhead	Yearling	Okanogan	~100,000[4]	5-8	<10	TBD
Winthrop	Steelhead	Two year	Methow	200,000	4-6	<10	TBD
Chiwawa	Steelhead	Yearling	Wenatchee	247,300[5]	6	9.0	TBD
Wells	Summer Chinook	Subyearling	Columbia	480,000	50[6]	<7	TBD
Wells	Summer Chinook	Yearling	Columbia	320,000	10	<7	TBD
Chief Joseph	Summer Chinook	Subyearling	Columbia	400,000	50	<7	TBD
Chief Joseph	Summer Chinook	Subyearling	Okanogan	300,000	50	<7	TBD
Chelan Falls	Summer Chinook	Yearling	Chelan	576,000	13	9.0	TBD
Entiat	Summer Chinook	Yearling	Entiat	400,000	17	<10	TBD
Carlton	Summer Chinook	Yearling	Methow	200,000	13-17	<12	TBD
Chief Joseph	Summer Chinook	Yearling	Columbia	500,000	10	<7	TBD
Chief Joseph	Summer Chinook	Yearling	Okanogan	799,998[7]	10	<7	TBD
Dryden	Summer Chinook	Yearling	Wenatchee	500,001	18	9.0	TBD
Priest	Fall Chinook	Subyearling	Columbia	7.3 M[8]	50	<10	TBD
Ringold	Fall Chinook	Subyearling	Columbia	3.5 M	50	<10	TBD

[1] The total release includes the release of 108,249 into the Methow River at the Methow Fish Hatchery, 25,000 into the Methow River at the Goat Wall site, and 60,516 into the Chewuch River at the Chewuch Acclimation Facility.

[2] These fish come from Winthrop National Fish Hatchery (MetComp) eyed eggs.

[3] The total release includes 125,000 conservation fish and 98,670 safety net fish.

[4] The combined Okanogan and Omak steelhead release number is 100,000.

[5] The total release includes 66,771 fish into Nason Creek, 53,170 into the Chiwawa River, 102,359 into the Wenatchee River, and 25,000 into Blackbird Pond.

[6] The Wells subyearling Chinook are not reared to achieve a specific size target. The fish are released on a date to optimize survival and are grown to the largest size possible before release.

[7] The total release is divided equally among the Omak, Riverside, and Similkameen Acclimation Ponds.

[8] The total release consists of 5.6 m fall Chinook for the Grant PUD program and 1.7 M fall Chinook for the Army Corps of Engineers program.

APPENDIX 6: IDENTIFYING AND ANALYZING REFERENCE POPULATIONS

An important goal of supplementation is to increase spawning abundance and natural-origin recruitment of the supplemented population, and not reduce the productivity of the supplemented population. Indeed, a successful supplementation program must increase spawning abundance and natural-origin recruitment to levels above those that would have occurred without supplementation. There are several methods that can be used to test the effects of supplementation programs on these population metrics. One important method is to compare the performance of population metrics (e.g., spawning abundance, natural-origin recruitment, and productivity) in the supplemented population to those in un-supplemented (reference) populations. By comparing supplemented populations to reference populations, one can determine if the supplementation programs benefit, harm, or have no effect on the supplemented populations. These comparisons, however, are only valid if the performance of the reference populations is similar to the performance of the supplemented population prior to the period of supplementation. If the performance of the two populations differs significantly before any supplementation occurs, then any results from comparing the two populations after supplementation will be suspect. It is therefore important to select reference populations that are as similar as possible to the supplemented populations.

One of the goals of the Conceptual Approach to Monitoring and Evaluating the Chelan County PUD Hatchery Programs (Murdoch and Peven 2005) is to use reference populations to analyze the potential effects of hatchery supplementation programs on natural-origin salmon and steelhead spawner abundance and productivity[15]. Murdoch and Peven (2005) identified specific objectives to evaluate the performance of the program. For example, Objective 1 determines if the supplementation programs have increased the number of naturally spawning and naturally produced adults of the target population (supplemented population) relative to a reference population. Objective 7 determines if the proportion of hatchery fish on the spawning grounds affects the freshwater productivity (e.g., number of juveniles per redd) of supplemented streams when compared to reference streams. The relevant questions tested under each objective are as follows:

Objective 1:

- Is the annual change in the number of natural-origin recruits produced from the supplemented populations greater than or equal to the annual change in natural-origin recruits in an un-supplemented population?
- Is the change in natural replacement rates within the supplemented population greater than or equal to the change in natural replacement rates in an un-supplemented population?

Objective 7:

[15] Productivity is defined as adult recruits per spawner, where recruits are the number of adults produced from a given brood year (i.e., spawners plus adults harvested).

- Is the change in numbers of juveniles (smolts, parr, or emigrants) per redd in the supplemented population greater than or equal to that in an un-supplemented population?[16]

In this paper, we describe methods used to identify suitable reference streams and statistical techniques that can be used to compare reference populations with supplemented populations. Although we apply the methods described in this paper to Chiwawa spring Chinook salmon (hereafter referred to as Chinook), the methods should also apply to steelhead and other supplemented salmon stocks in the Upper Columbia Basin.

Identification of Reference Populations

Reference populations are an important component of an effectiveness monitoring design because they provide the standard by which treatment conditions are compared (ISRP and ISAB 2005; Murdoch and Peven 2005; Galbreath et al. 2008). Selecting appropriate reference areas and maintaining them over long periods of time is needed to establish the effectiveness of supplementation programs.

We developed a three-step process for identifying suitable reference populations (Figure 1). Each step serves as a filter. That is, potential reference populations are evaluated based on specific criteria under each step. Populations that pass through each step are considered suitable reference populations for a specific supplemented population.

[16] In this paper, we only address adult recruits, not juvenile recruits. This is because we were unable to find suitable reference populations for analysis of juveniles. However, the methods described in this paper would also apply to juveniles.

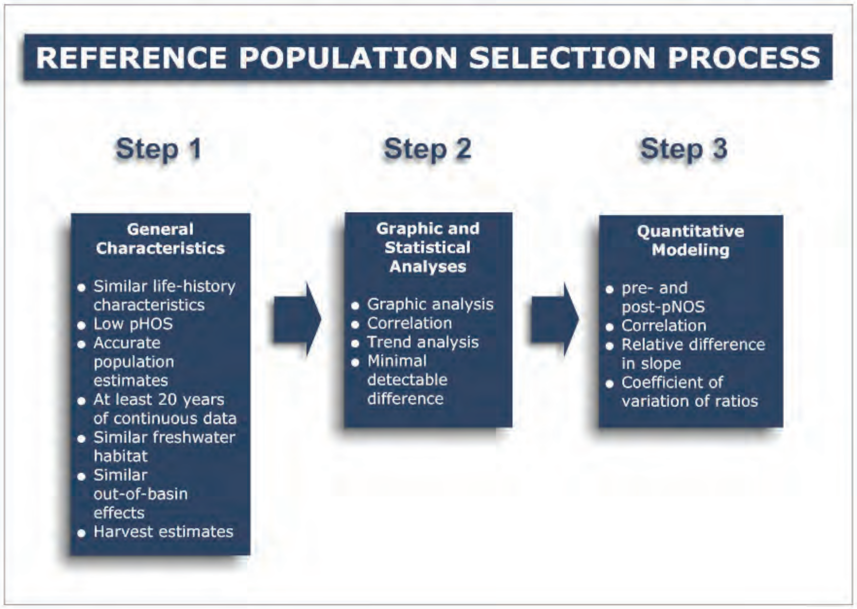


Figure 1. Criteria evaluated during each step in the process of identifying suitable reference populations.

Step 1: General Characteristics

Under step 1, potential reference populations are evaluated based on several general criteria. When compared to the supplemented population, potential reference populations should have:

- Similar life-history characteristics (e.g., run timing, migration characteristics, etc.).
- No or few hatchery fish in the reference area (pHOS < 10%).
- Accurate abundance estimates.
- Long time series of natural-origin abundance and productivity estimates (at least 20 years of continuous data).
- Similar trends in freshwater habitat.
- Similar out-of-basin effects (i.e., similar migration and ocean survivals).
- Harvest estimates for adjusting escapement estimates.

We used these criteria to begin the process of selecting suitable reference populations for the Chiwawa spring Chinook program. We began by identifying stream-type Chinook populations within the Columbia Basin. Galbreath et al. (2008; their Table 1) identified stream-type Chinook populations within the Columbia River Basin that may serve as suitable reference populations for hatchery programs. Supplementing their work with data from the NOAA Fisheries Salmon Population Summary Database, we identified 18 candidate stream-type Chinook populations that may serve as reference populations for the Chiwawa supplementation program (Table 1).

Table 1. Populations of stream-type Chinook salmon and their comparison to Chiwawa spring Chinook.

Population	Similar life-history	No or few hatchery fish	Accurate abundance estimates	Long time series (at least 20 years)	Similar freshwater habitat impairments	Similar out-of-basin effects	Comments
Deschutes River	Yes	Yes	Yes	Yes	No	No	
John Day mainstem	Yes	Yes	Yes	Yes	No	No	
Middle Fk John Day	Yes	Yes	Yes	Yes	No	No	
North Fk John Day	Yes	Yes	Yes	Yes	No	No	
Granite Creek	Yes	Yes	Yes	Yes	No	No	
Wenaha River	Yes	No	Yes	Yes	Yes	No	Hatchery strays (>10%)
Minam River	Yes	No	Yes	Yes	Yes	No	Hatchery strays (>10%)
Slate Creek	Yes	Yes	Yes	No	No	No	
Secesh River	Yes	Yes	Yes	Yes	Yes	No	
Middle Fk Salmon River	Yes	Yes	Yes	No	No	No	Fair productivity est.
Big Creek	Yes	Yes	Yes	Yes	No	No	
Camas Creek	Yes	Yes	Yes	Yes	No	No	Fair productivity est.
Loon Creek	Yes	Yes	Yes	Yes	No	No	Fair productivity est.
Sulphur Creek	Yes	Yes	Yes	Yes	No	No	
Bear Valley Creek	Yes	Yes	Yes	Yes	No	No	
Marsh Creek	Yes	Yes	Yes	Yes	Yes	No	
North Fk Salmon River	Yes	Yes	No	No	Yes	No	
Lemhi River	Yes	Yes	Yes	Yes	No	No	
East Fk Salmon River	Yes	No	Yes	Yes	No	No	Hatchery strays (>10%)
Valley Creek	Yes	No	Yes	Yes	No	No	Hatchery strays (>10%)
Chamberlain Creek	Yes	Yes	Yes	No	Yes	No	
Naches River	Yes	Yes	Yes	Yes	Yes	No	
Little Wenatchee River	Yes	No	Yes	Yes	Yes	Yes	Hatchery strays (>10%)
Entiat River	Yes	No	Yes	Yes	No	No	Hatchery release ending

We then assessed the accuracy and length of the series of abundance estimates. We assumed that abundance estimates generated from expanded redd counts or adjusted weir counts would compare well with estimates in the Chiwawa Basin, which were based on expanded redd counts. In addition, we looked for populations that had an abundance data series that extended from at least 1981 to present. Based on this analysis, we identified 18 populations with abundance estimates that could be compared to those from the Chiwawa Basin (Table 1).

Next, we determined if the potential reference populations came from watersheds with habitat conditions similar to those in the Chiwawa Basin. For this exercise, we searched recovery plans and draft recovery plans to identify tributary factors that limit Chinook abundance, productivity, and survival within the reference populations. We compared these factors with those limiting

Chinook salmon in the Chiwawa Basin. Based on this analysis, we identified eight populations with habitat impairments similar to those in the Chiwawa Basin (Table 1).

Finally, we examined the potential reference populations to see if they experienced out-of-basin effects similar to spring Chinook from the Chiwawa Basin. In this case, we compared the number of mainstem dams that each potential reference population passes during migration. Six of the potential reference populations pass less than six mainstem dams; the other populations pass eight mainstem dams (Table 1). Only the Little Wenatchee population passes seven dams, similar to the Chiwawa population.

In sum, there were no reference populations that matched the Chiwawa spring Chinook population on all the criteria identified above. Differential out-of-basin effects and freshwater habitat conditions prevented most reference populations from matching with Chiwawa spring Chinook. However, some of the potential reference populations were similar to the Chiwawa population on several criteria and warranted further investigation. We selected the following populations for further investigation: Sesech River, Marsh Creek, Naches River, Little Wenatchee, and Entiat River.

We included the Little Wenatchee because it is within the Wenatchee River basin and experiences similar out-of-basin effects and has the same climatic and environmental conditions as the Chiwawa. A confounding effect with the Little Wenatchee is that Chiwawa hatchery fish have strayed into the Little Wenatchee. However, straying of Chiwawa hatchery fish should decrease with the change in source water to the Chiwawa acclimation ponds in 2006. We also included the Entiat River because it is an adjacent basin to the Chiwawa and experiences similar climatic and environmental conditions. The spring Chinook hatchery program that has operated in the Entiat since 1975 has been discontinued. Therefore, this population offers a unique opportunity to compare the Chiwawa population to a population in which the hatchery program has been discontinued.

Step 2: Graphic and Statistical Analysis

Graphic Analysis

Although we were unable to find potential reference populations that matched with the Chiwawa population on all criteria considered under Step 1, spawner abundance, natural-origin recruits (NORs), and productivity of some of the potential reference populations may nevertheless track closely with the Chiwawa population. If the time series of abundance, NORs, and productivity of a potential reference population tracks closely with the abundance, NORs, and productivity of the Chiwawa population, the reference population may provide a reasonable reference condition for testing the effects of supplementation on the Chiwawa population.

Under Step 2, we used graphing techniques to examine the relationship of abundance, NORs, and productivity between the Chiwawa population and the five reference populations (Sesech River, Marsh Creek, Naches River, Little Wenatchee, and Entiat River). We compiled spawner abundance, NORs, and productivity data from local biologists and the NOAA Fisheries Salmon Population Summary Database. We then compared time series plots of spawner abundance, NORs, and productivity data of potential reference populations with the Chiwawa population (Figures 2, 3, and 4; plots on the left side of figures). The time series only included the period 1981 to 1992, which represented the period before supplementation of the Chiwawa population (pre-treatment period). We also plotted the relationship between the abundance, NORs, and productivity of each

potential reference population to the Chiwawa population (Figures 2, 3, and 4; plots on right side of figures). These plots show whether the reference populations closely tracked the Chiwawa population. As a point of reference, data points that fall along the dashed line would represent a perfect relationship between the two populations (i.e., both populations have identical abundance, NORs, and productivity estimates). While a perfect relationship between two independent populations is unrealistic, a strong linear relationship between the two populations indicates populations with similar trends.

Based on analysis of spawner abundance, the Naches River time series tracked more closely with the abundance of Chiwawa spring Chinook than did the other potential reference populations. The poor relationship with the other potential reference streams was largely because of the relatively high abundance of Chiwawa spring Chinook during the mid-1980s. As with spawner abundance, analyses of NORs indicated a close relationship between the Naches and Chiwawa populations. The other potential reference populations tracked poorly with the Chiwawa. The analyses of productivity indicated close relationships between potential reference populations and the Chiwawa population. The Naches, Sesech, and Little Wenatchee populations tracked the closest with the Chiwawa population.

When analyzing the potential effects of a supplementation program on fish performance, it is common to transform the data to meet various assumptions of statistical analysis. The most common transformation used to adjust abundance, NORs, and productivity data is the natural logarithm (LN or $\log_e$). We therefore transformed the spawner abundance, NORs, and productivity data using LN and re-plotted the relationships between the potential reference populations and the Chiwawa population (Figures 5, 6, and 7). We added 1 to each observation before taking its logarithm to avoid taking the logarithm of 0, which is undefined (note that the LN of 1 is 0).

By transforming spawner abundance, NORs, and productivity data, most of the potential reference populations tracked more closely with the Chiwawa population. The Naches, Entiat, and Little Wenatchee abundance data tracked the closest with the Chiwawa abundance data (Figure 5). For NORs, Marsh Creek and the Little Wenatchee populations tracked the closest with the Chiwawa (Figure 6). For productivity, the Naches, Sesech, and Little Wenatchee tracked the closest with the Chiwawa (Figure 7).

Attachment E

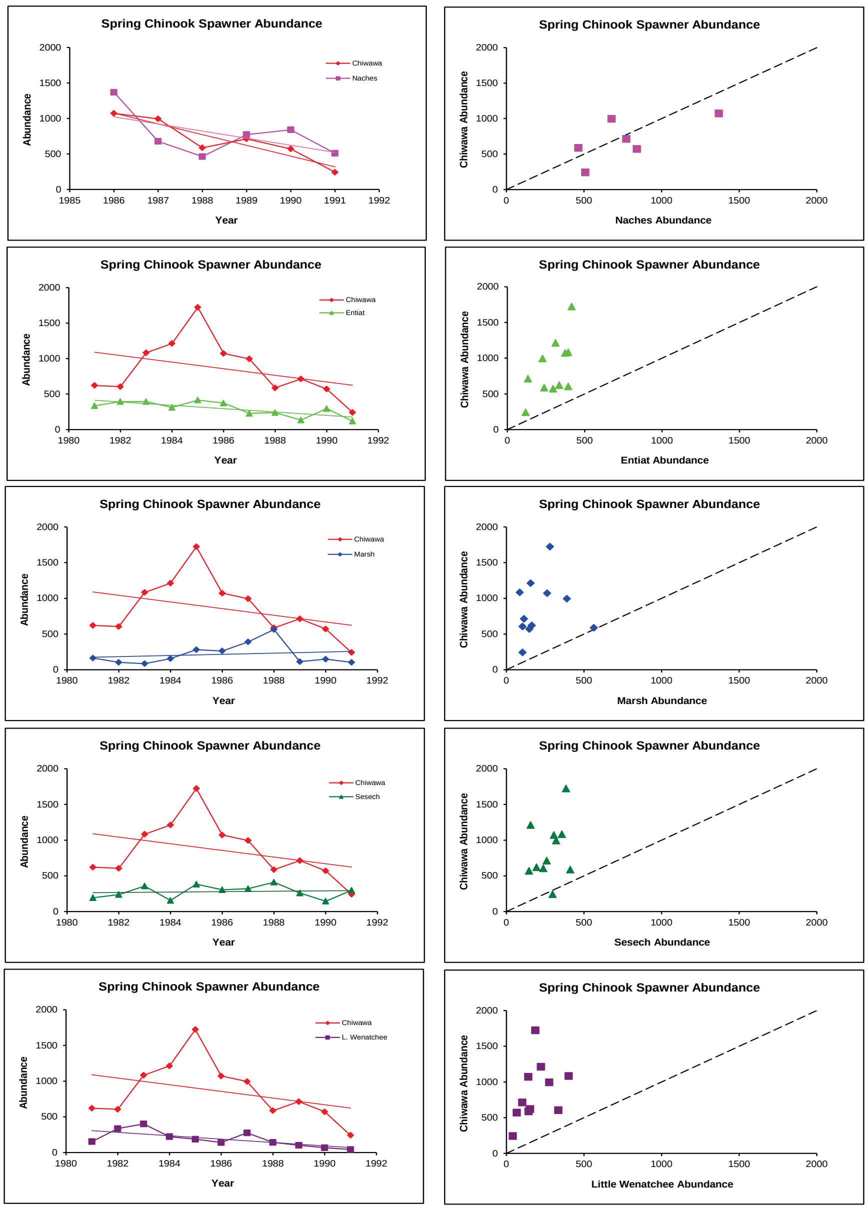


Figure 2. Time series of spawner abundance of potential reference populations and the Chiwawa spring Chinook population before the Chiwawa population was supplemented with hatchery fish.

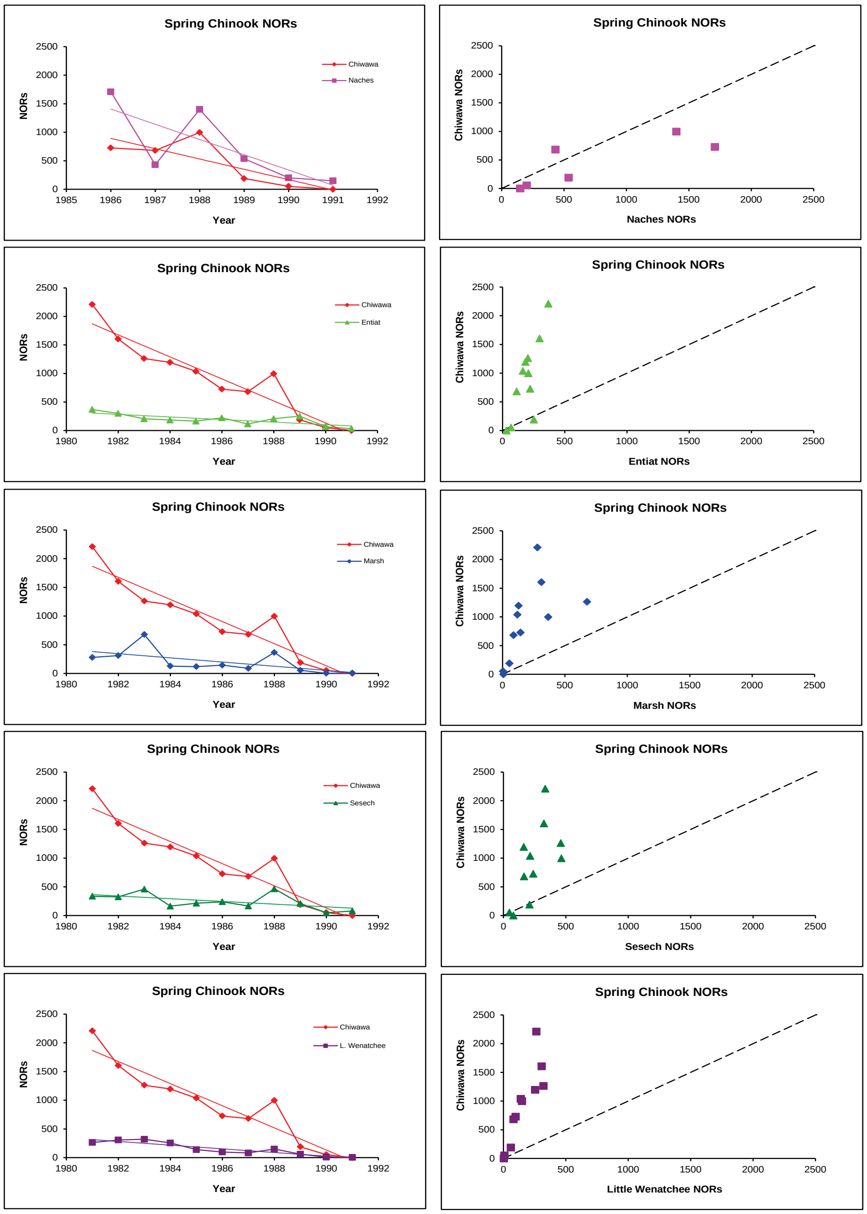


Figure 3. Time series of natural-origin recruits (NORs) of potential reference populations and the Chiwawa spring Chinook population before the Chiwawa population was supplemented with hatchery fish.

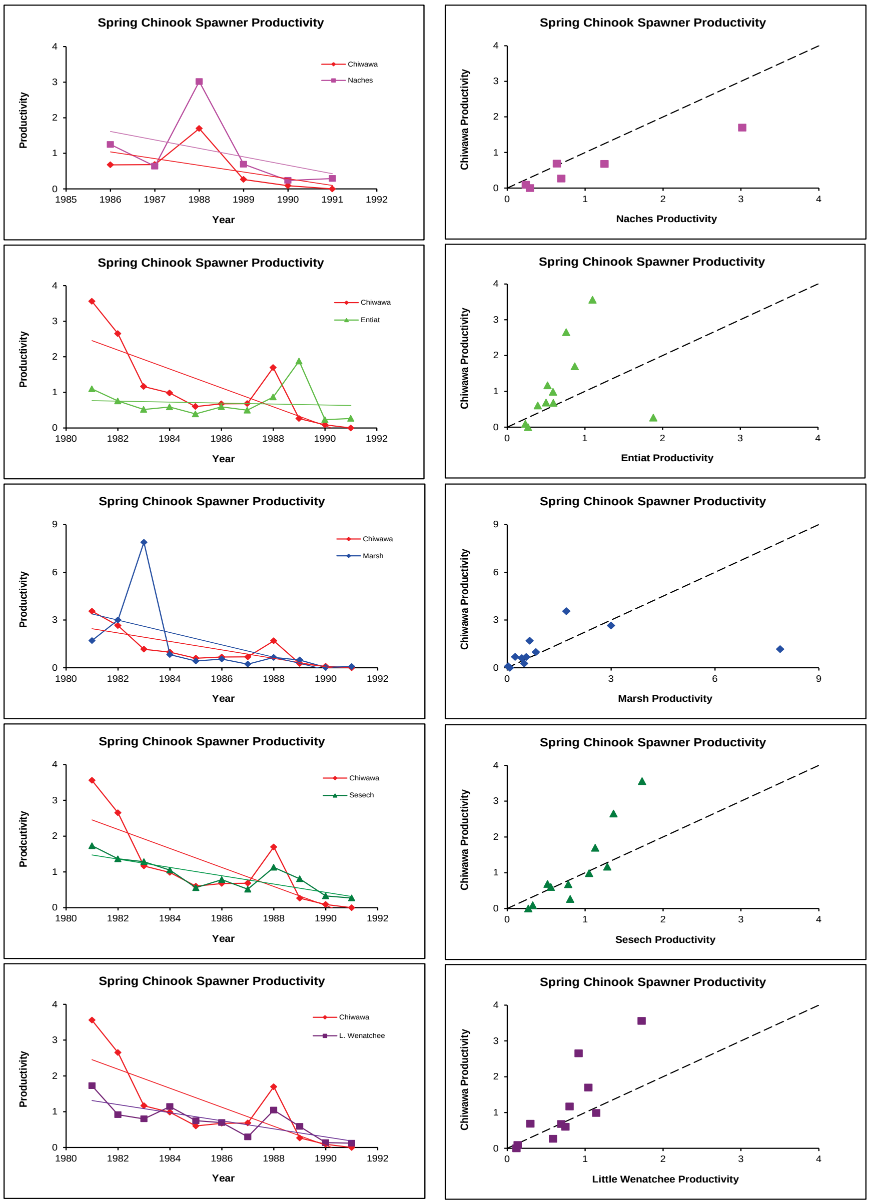


Figure 4. Time series of adult productivity of potential reference populations and the Chiwawa spring Chinook population before the Chiwawa population was supplemented with hatchery fish.

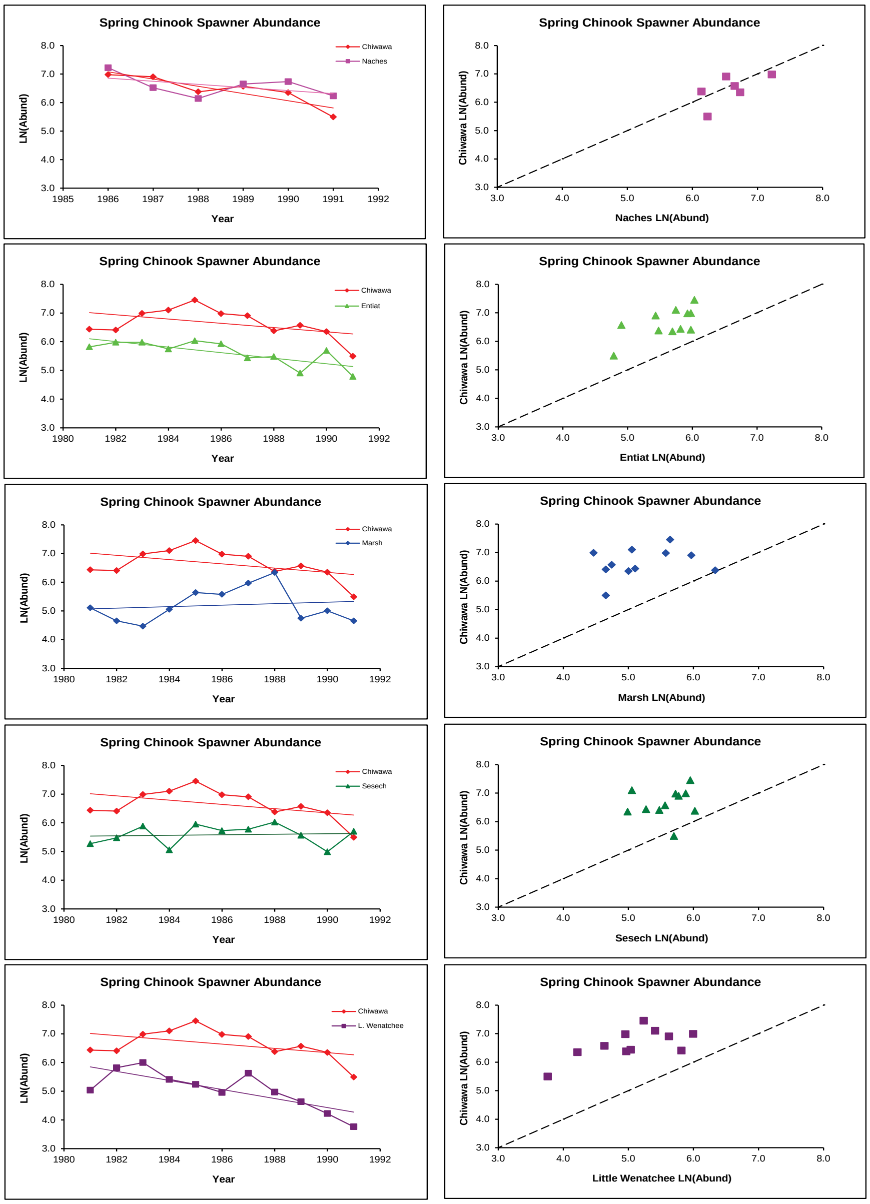


Figure 5. Time series of natural log spawner abundance of potential reference populations and the Chiwawa spring Chinook population before the Chiwawa population was supplemented with hatchery fish.

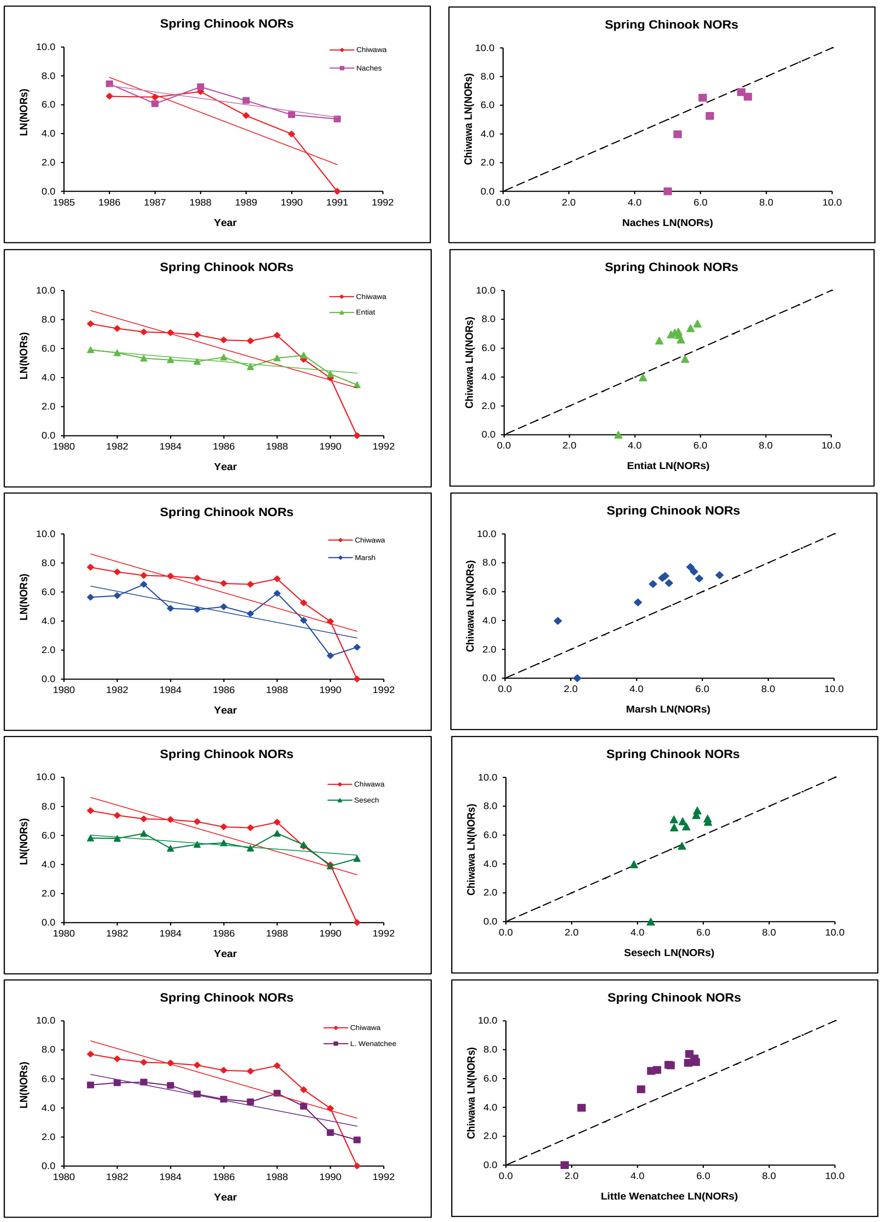


Figure 6. Time series of natural log natural-origin recruits (NORs) of potential reference populations and the Chiwawa spring Chinook population before the Chiwawa population was supplemented with hatchery fish.

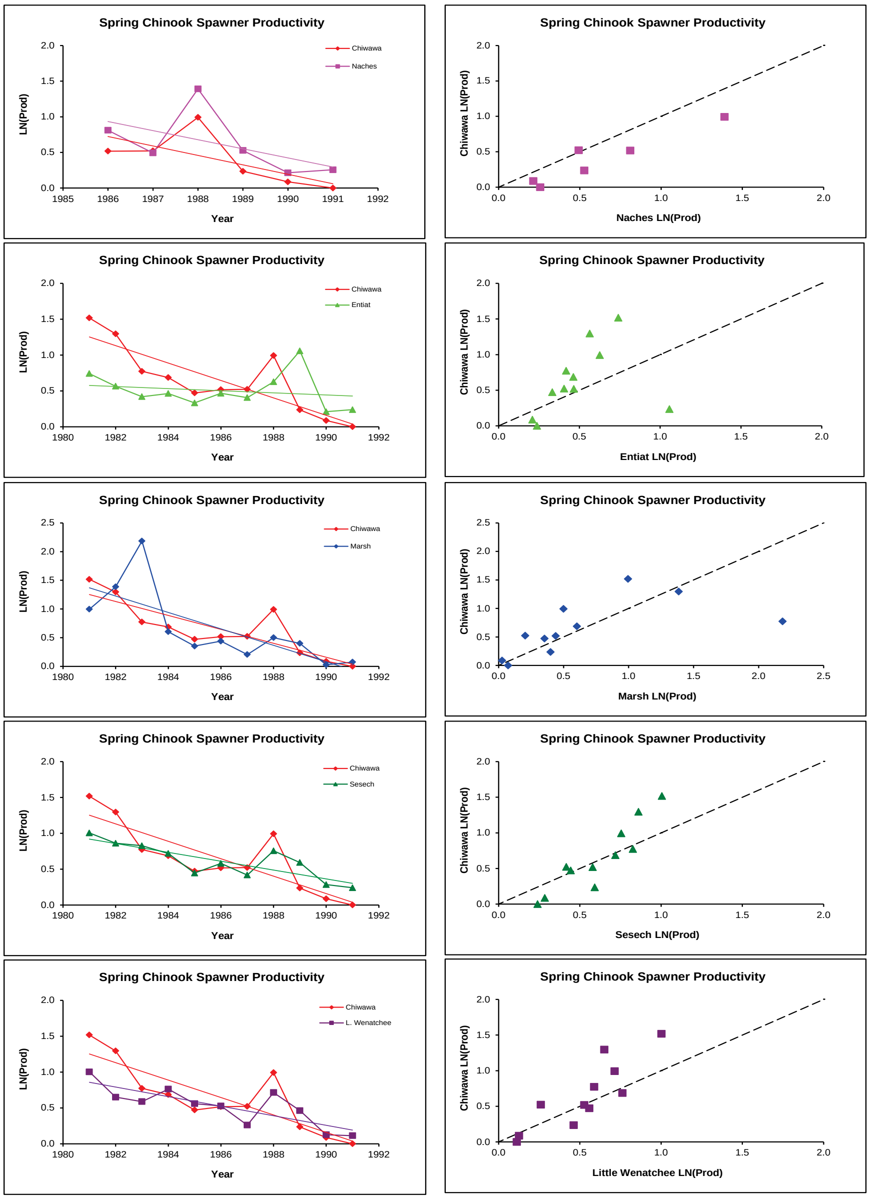


Figure 7. Time series of natural log adult productivity of potential reference populations and the Chiwawa spring Chinook population before the Chiwawa population was supplemented with hatchery fish.

Correlations and Trends

Other methods for evaluating the suitability of potential reference populations under Step 2 include correlation and trend analyses. For correlation analysis, we simply calculated the Pearson correlation coefficient, which is an index of the strength of the association between the potential reference populations and the Chiwawa population. The coefficient ranges from -1 to 1, where a value near 1 or -1 represents that strongest association between the populations. A value of 0 means no association. We used only spawner abundance, NORs, and productivity data during the pre-treatment period (1981-1992). We assumed that populations with coefficients greater than 0.6 represented reasonable reference conditions.

For trend analyses, we used least squares techniques to compute a straight-line trend through the spawner abundance and productivity data for the potential reference populations and the Chiwawa population. Trends were fit to the pre-treatment time series data (1981-1992). We then used t-tests to determine if the slopes of the trends between potential reference populations and the Chiwawa population differed significantly.

It is important to note that time-series trend analyses are susceptible to temporal correlations in the data. Autoregressive integrated moving average (ARIMA) models can be used to describe the correlation structure in temporal data (Gotelli and Ellison 2004). However, these models require a long time series (N > 40) and therefore we could not use them to model the spring Chinook data. As such, we were unable to correct for any temporal correlation that may exist within the time series.

Tests of correlation with spawner abundance data indicated that the Naches River closely correlated with the Chiwawa population (Table 2). There was no difference in abundance trends between the potential reference populations and the Chiwawa population (Table 2; Figure 2). For NORs, all potential reference populations correlated with the Chiwawa population (Table 2). However, trends in NORs of all reference populations, except Naches, differed significantly from the Chiwawa population (Table 2; Figure 3). For productivity, the Naches, Sesech, and Little Wenatchee correlated with the Chiwawa population (Table 2). Only the Entiat productivity trend differed significantly from the Chiwawa population trend (Table 2; Figure 4).

Table 2. Pearson correlation coefficients and t-test results comparing slopes of trends between potential reference populations and the Chiwawa spring Chinook population; d.f. = degrees of freedom and for correlation coefficients, an asterisk (*) indicates significance at P < 0.05.

Reference populations	Pearson correlation coefficient	t-test on slopes		
		t-value	d.f.	P-value
Spawner Abundance Data				
Naches	0.684*	-0.659	8	0.528
Entiat	0.598*	-0.596	18	0.559
Marsh	0.147	-1.341	18	0.197
Sesech	0.274	-1.265	18	0.222
Little Wenatchee	0.399	-0.591	18	0.562
Natural-Origin Recruits				
Naches	0.803*	0.666	8	0.524
Entiat	0.795*	-7.495	18	0.000

Reference populations	Pearson correlation coefficient	t-test on slopes		
		t-value	d.f.	P-value
Marsh	0.605*	-5.786	18	0.000
Sesech	0.648*	-6.874	18	0.000
Little Wenatchee	0.880*	-7.206	18	0.000
Productivity Data				
Naches	0.960*	0.169	8	0.870
Entiat	0.272	-3.057	18	0.007
Marsh	0.320	0.605	18	0.553
Sesech	0.903*	-2.059	18	0.054
Little Wenatchee	0.848*	-2.065	18	0.054

We also ran correlation and trend analyses on natural-log transformed spawner abundance, NORs, and productivity data. These analyses indicated that the Naches, Entiat, and Little Wenatchee abundance data correlated with the Chiwawa population data (Table 3). None of the abundance trends of the potential reference populations differed significantly from the Chiwawa population trend (Table 3; Figure 5). For NORs, all potential reference populations correlated with the Chiwawa population (Table 3). Only trends in NORs of the Entiat and Sesech differed significantly from the Chiwawa population (Table 2; Figure 6). For productivity, the Naches, Marsh, Sesech, and Little Wenatchee correlated with the Chiwawa population data (Table 3). Only the Entiat productivity trend differed significantly from the Chiwawa population trend (Table 3; Figure 7).

Table 3. Pearson correlation coefficients and t-test results comparing slopes of trends between potential reference populations and the Chiwawa spring Chinook population; d.f. = degrees of freedom and for correlation coefficients, an asterisk (*) indicates significance at P < 0.05. Analyses were conducted on natural-log transformed abundance and productivity data.

Reference populations	Pearson correlation coefficient	t-test on slopes		
		t-value	d.f.	P-value
LN Spawner Abundance Data				
Naches	0.642*	-1.323	8	0.222
Entiat	0.652*	0.412	18	0.685
Marsh	0.294	-1.324	18	0.202
Sesech	0.149	-1.431	18	0.170
Little Wenatchee	0.670*	1.325	18	0.202
LN Natural-Origin Recruits				
Naches	0.824*	-1.985	8	0.082
Entiat	0.886*	-2.563	18	0.019
Marsh	0.830*	-1.038	18	0.313
Sesech	0.730*	-2.664	18	0.016
Little Wenatchee	0.927*	-1.150	18	0.265
LN Productivity Data				

Reference populations	Pearson correlation coefficient	t-test on slopes		
		t-value	d.f.	P-value
Naches	0.944*	-0.042	8	0.968
Entiat	0.373	-3.043	18	0.007
Marsh	0.610*	0.428	18	0.674
Sesech	0.913*	-2.050	18	0.055
Little Wenatchee	0.862*	-1.811	18	0.087

In summary, based on correlation, trend, and graphic analyses, the Naches, Entiat, and Little Wenatchee populations appear to be reasonable reference populations for comparing spawner abundance data with Chiwawa data. For NORs, the Naches, Marsh, and Little Wenatchee appear to be reasonable reference populations. For productivity, the Naches, Marsh, Sesech, and Little Wenatchee populations appear to be reasonable reference populations for the Chiwawa population.

Minimal Detectable Differences (MDD)

Given a suite of potential reference populations, it is important to conduct power analyses to determine the minimum differences that can be detected when comparing the reference populations to the supplemented population. As a final exercise under Step 2, we examined potential reference populations for the smallest minimal detectable differences. Before conducting power analyses, several decisions needed to be made, including what statistical procedures will be used to analyze the data, the desired level of statistical power (probability of rejecting a false null hypothesis), the size of the type-I error (the probability of rejecting a true null hypothesis of no difference), and the number of samples (i.e., years) included in the analysis. In this case, the number of samples represents the number of treatment (supplementation) years. The number of pre-treatment years (1981-1992) was based on the number of years of quality data available for Chiwawa spring Chinook and potential reference populations.

We designed the study as a modified BACI (Before-After, Control-Impact) design, which includes replication before and after supplementation in both the treated (T) population and the reference (R) populations. A common approach used to analyze data from BACI designs includes analysis of difference scores (Stewart-Oaten et al. 1992; Smith et al. 1993). Differences are calculated between paired treatment and reference population scores (i.e., T-R). Another approach is to calculate ratios (treatment/reference; T/R) for paired treatment and reference population scores (Skalski and Robson 1992). Finally, differences in annual changes in paired treatment and reference population scores can be calculated (i.e., ΔT-ΔR) (Murdoch and Peven 2005; Hays et al. 2006).[17] These derived difference and ratio scores are then analyzed for a before-after treatment effect with a two-sample t-test, Aspin-Welch modification of the t-test, or a randomization test. For power analyses, we calculated minimal detectable differences assuming the use of an independent two-sample t-test with a type-I error rate of 0.05, power of 0.80 (beta or type-II error rate of 0.20), and sample sizes (treatment years) of 5, 10, 15, 20, 25, and 50 years.

[17] The difference of annual difference scores was estimated by first subtracting the population parameter (e.g., spawner abundance) in year 2 from year 1. This continues for all years in the data series for both treatment ($T_{t+1} – T_t$) and reference populations ($R_{t+1} – R_t$). We then calculated differences between paired treatment and reference annual difference scores [($T_{t+1} – T_t$) - ($R_{t+1} – R_t$) = ΔT-ΔR].

The power analysis calculated the minimal detectable difference between mean difference or ratio scores before and during supplementation. We used existing data to calculate variances for the pre-supplementation and supplementation periods. Thus, variances were known and unequal. For both spawner abundance and NORs, the null hypothesis tested was that the mean difference or ratio before supplementation equaled the mean difference or ratio during supplementation. The alternative hypothesis was that the mean difference or ratio before supplementation was less than the mean difference during supplementation (one-tail test; Difference < 0). For productivity, the null hypothesis tested was that the mean difference or ratio before supplementation equaled the mean difference or ratio during supplementation. The alternative hypothesis was that the mean difference or ratio before supplementation was greater than the mean difference during supplementation (one-tail test; Difference > 0).

Based on spawner abundance data, power analysis indicated that the Sesech-Chiwawa pairing consistently produced the smallest detectable differences (Table 4). However, when the abundance data were transformed using natural logs, the Entiat-Chiwawa pairing produced the smallest detectable difference (Table 5). Minimal detectable differences, based on mean difference scores on untransformed data and a treatment period of 20 years, ranged from 334 to 394 adult spawners; transformed data ranged from 0.479 to 1.010. These analyses indicate that the Naches, Entiat, Sesech, and Little Wenatchee populations appear to be reasonable reference populations for comparing spawner abundance data with Chiwawa data. The Marsh Creek population produced some of the largest detectable differences and based on these analyses may not be a reasonable reference population.

Table 4. Minimal detectable differences between mean difference and ratio scores before and during supplementation. Analyses were conducted on spawner abundance data.

Response variable	Treatment years	Minimal detectable differences by reference population				
		Naches	Entiat	Marsh	Sesech	Little Wenatchee
T-R	5	638	604	560	396	652
	10	464	448	444	354	481
	15	405	395	406	341	424
	20	376	368	387	334	394
	25	358	352	376	331	376
	50	322	319	354	323	340
T/R	5	0.600	2.084	39.251	1.569	5.498
	10	0.506	1.548	24.729	1.508	3.828
	15	0.478	1.367	19.646	1.490	3.256
	20	0.465	1.275	16.828	1.481	2.954
	25	0.458	1.219	14.974	1.475	2.765
	50	0.447	1.105	10.573	1.465	2.366
ΔT-ΔR	5	1,049	761	717	518	766
	10	750	542	539	411	547
	15	650	467	480	376	473
	20	598	429	450	359	434

Response variable	Treatment years	Minimal detectable differences by reference population				
		Naches	Entiat	Marsh	Sesech	Little Wenatchee
	25	567	405	431	348	410
	50	506	355	395	329	361

Table 5. Minimal detectable differences between mean difference and ratio scores before and during supplementation. Analyses were conducted on natural-log transformed spawner abundance data.

Response variable	Treatment years	Minimal detectable differences by reference population				
		Naches	Entiat	Marsh	Sesech	Little Wenatchee
T-R	5	0.975	0.871	2.061	0.828	1.013
	10	0.721	0.613	1.375	0.648	0.722
	15	0.637	0.525	1.138	0.588	0.623
	20	0.595	0.479	1.010	0.559	0.571
	25	0.569	0.450	0.928	0.541	0.539
	50	0.521	0.390	0.749	0.505	0.473
T/R	5	0.157	0.162	2.343	0.160	0.368
	10	0.116	0.115	1.474	0.125	0.247
	15	0.102	0.099	1.170	0.114	0.206
	20	0.095	0.090	1.001	0.108	0.183
	25	0.091	0.085	0.890	0.104	0.169
	50	0.082	0.075	0.625	0.098	0.138
ΔT-ΔR	5	1.261	1.288	3.076	1.160	1.467
	10	0.898	0.900	2.020	0.887	1.001
	15	0.776	0.768	1.653	0.797	0.840
	20	0.713	0.698	1.463	0.751	0.755
	25	0.675	0.655	1.325	0.724	0.701
	50	0.600	0.564	1.038	0.670	0.585

Based on NORs, power analysis indicated that the Entiat-Chiwawa, Marsh-Chiwawa, and Little Wenatchee-Chiwawa pairings produced the smallest detectable differences (Table 6). When NORs were transformed using natural logs, the Little Wenatchee-Chiwawa pairing produced the smallest detectable difference (Table 7). Minimal detectable differences, based on mean difference scores on untransformed data and a treatment period of 20 years, ranged from 483 to 640 NORs; transformed data ranged from 0.958 to 2.262. These analyses indicate that the Entiat, Marsh, and Little Wenatchee populations appear to be reasonable reference populations for comparing NORs with Chiwawa data.

Table 6. Minimal detectable differences between mean difference and ratio scores before and during supplementation. Analyses were conducted on natural-origin recruits.

Response variable	Treatment years	Minimal detectable differences by reference population				
		Naches	Entiat	Marsh	Sesech	Little Wenatchee
T-R	5	1,139	541	573	630	546
	10	809	511	515	550	503
	15	698	502	498	526	489
	20	640	497	489	514	483
	25	604	494	484	507	479
	50	534	489	474	493	472
T/R	5	0.469	2.538	5.196	1.976	6.973
	10	0.451	2.183	4.183	1.894	5.118
	15	0.446	2.072	3.854	1.869	4.492
	20	0.445	2.017	3.691	1.857	4.170
	25	0.444	1.986	3.594	1.850	3.973
	50	0.443	1.924	3.405	1.836	3.572
ΔT-ΔR	5	1,639	500	519	609	531
	10	1,239	386	409	433	396
	15	1,109	348	374	372	351
	20	1,046	329	356	341	328
	25	1,009	318	346	321	314
	50	943	295	325	281	285

Table 7. Minimal detectable differences between mean difference and ratio scores before and during supplementation. Analyses were conducted on natural-log transformed natural-origin recruits.

Response variable	Treatment years	Minimal detectable differences by reference population				
		Naches	Entiat	Marsh	Sesech	Little Wenatchee
T-R	5	2.380	1.646	1.967	2.247	1.174
	10	2.291	1.479	1.505	1.835	1.026
	15	2.270	1.428	1.351	1.702	0.980
	20	2.262	1.403	1.273	1.636	0.958
	25	2.258	1.389	1.227	1.597	0.945
	50	2.253	1.361	1.133	1.522	0.920
T/R	5	0.322	0.332	0.739	0.398	0.356
	10	0.301	0.289	0.581	0.334	0.322
	15	0.296	0.275	0.530	0.314	0.312
	20	0.294	0.269	0.504	0.305	0.307
	25	0.293	0.265	0.488	0.299	0.304

Response variable	Treatment years	Minimal detectable differences by reference population				
		Naches	Entiat	Marsh	Sesech	Little Wenatchee
	50	0.291	0.258	0.458	0.288	0.298
ΔT-ΔR	5	2.858	2.400	2.355	3.283	2.109
	10	2.560	1.714	1.881	2.311	1.552
	15	2.485	1.481	1.728	1.979	1.365
	20	2.456	1.360	1.652	1.805	1.269
	25	2.443	1.285	1.607	1.697	1.210
	50	2.430	1.130	1.519	1.471	1.092

Using untransformed productivity data, power analysis indicated that the Little Wenatchee-Chiwawa pairing consistently produced the smallest detectable differences (Table 8). The Marsh-Chiwawa pairings produced the largest detectable differences. When we analyzed natural-log transformed productivity data, the Naches-Chiwawa and Little Wenatchee-Chiwawa pairings produced the smallest detectable differences (Table 9). Minimal detectable differences, based on mean difference scores on untransformed data and a treatment period of 20 years, ranged from 0.754 to 1.839; transformed data ranged from 0.277 to 0.477. These analyses indicate that the Naches, Entiat, Sesech, and Little Wenatchee populations appear to be reasonable reference populations for comparing productivity data with Chiwawa data. The Marsh Creek population produced some of the largest detectable differences and based on these analyses may not be a reasonable reference population.

Table 8. Minimal detectable differences between mean difference and ratio scores before and during supplementation. Analyses were conducted on productivity data.

Response variable	Treatment years	Minimal detectable differences by reference population				
		Naches	Entiat	Marsh	Sesech	Little Wenatchee
T-R	5	2.181	1.382	2.033	3.517	1.192
	10	1.442	1.119	1.900	2.265	0.901
	15	1.186	1.033	1.859	1.828	0.804
	20	1.047	0.991	1.839	1.588	0.754
	25	0.959	0.966	1.828	1.432	0.724
	50	0.764	0.917	1.806	1.074	0.664
T/R	5	1.364	1.773	0.863	0.876	2.167
	10	1.095	1.359	0.831	0.687	1.587
	15	1.011	1.221	0.822	0.625	1.391
	20	0.971	1.152	0.817	0.594	1.290
	25	0.949	1.110	0.814	0.575	1.228
	50	0.910	1.027	0.908	0.538	1.102
ΔT-ΔR	5	3.298	1.864	3.211	4.420	1.942
	10	2.263	1.382	2.968	2.811	1.291

Response variable	Treatment years	Minimal detectable differences by reference population				
		Naches	Entiat	Marsh	Sesech	Little Wenatchee
	15	1.909	1.220	2.894	2.248	1.066
	20	1.723	1.137	2.859	1.938	0.944
	25	1.606	1.087	2.839	1.735	0.866
	50	1.365	0.986	2.800	1.259	0.695

Table 9. Minimal detectable differences between mean difference and ratio scores before and during supplementation. Analyses were conducted on natural-log transformed productivity data.

Response variable	Treatment years	Minimal detectable differences by reference population				
		Naches	Entiat	Marsh	Sesech	Little Wenatchee
T-R	5	0.540	0.551	0.674	0.890	0.585
	10	0.367	0.452	0.542	0.590	0.413
	15	0.308	0.421	0.499	0.486	0.355
	20	0.277	0.405	0.477	0.430	0.324
	25	0.257	0.396	0.465	0.393	0.305
	50	0.215	0.378	0.440	0.314	0.265
T/R	5	0.915	1.286	0.743	0.697	1.685
	10	0.744	0.973	0.704	0.541	1.227
	15	0.691	0.868	0.692	0.489	1.072
	20	0.666	0.815	0.687	0.463	0.993
	25	0.652	0.783	0.683	0.447	0.943
	50	0.628	0.719	0.677	0.416	0.843
ΔT-ΔR	5	0.885	0.810	1.028	1.252	0.971
	10	0.631	0.609	0.822	0.809	0.640
	15	0.546	0.542	0.755	0.655	0.525
	20	0.502	0.508	0.722	0.570	0.463
	25	0.475	0.487	0.702	0.516	0.423
	50	0.423	0.446	0.664	0.391	0.333

Step 3: Quantitative Method for Ranking Selection Criteria

Not surprisingly, different selection criteria produced different results (Table 10). Determining whether a given population is or is not a suitable reference population based on selection criteria such as graphic analysis can be subjective. In addition, treating each selection criterion as equally important may not be appropriate. For example, using the information in Table 10, is it appropriate to select a reference population that has two or three "Yes" entries, or should only populations with four "Yes" entries be selected as suitable reference populations? This approach does not allow certain selection criteria to carry more weight in the overall selection process. That is, correlation may be more important than graphic analysis in the overall selection process. In order to reduce

subjectivity, we developed a method of scoring and weighting each selection criterion. This method allows a more quantitative process for selecting suitable reference populations.

Table 10. Summary of results from graphic analysis, correlations, trend analysis, and power analysis (minimal detectable differences). "Yes" indicates that the population is a suitable reference population for the Chiwawa population; "No" indicates that it may not be a suitable reference population.

Potential reference populations	Graphic analysis	Correlation	Trends	Minimal detectable differences
Spawner Abundance				
Naches	Yes	Yes	Yes	Yes
Entiat	Yes	Yes	Yes	Yes
Marsh	No	No	Yes	No
Sesech	No	No	Yes	Yes
Little Wenatchee	Yes	Yes	Yes	Yes
Natural-Origin Recruits				
Naches	Yes	Yes	Yes	No
Entiat	No	Yes	No	Yes
Marsh	Yes	Yes	Yes	Yes
Sesech	No	Yes	No	No
Little Wenatchee	Yes	Yes	Yes	Yes
Productivity				
Naches	Yes	Yes	Yes	Yes
Entiat	No	No	No	Yes
Marsh	No	Yes	Yes	No
Sesech	Yes	Yes	Yes	Yes
Little Wenatchee	Yes	Yes	Yes	Yes

We developed scoring methods for each of the following five selection criteria:

(1) The proportion of natural-origin spawners (pNOS) in the reference population for the period before supplementation (pre-pNOS);

(2) pNOS in the reference population for the period following supplementation (post-pNOS);

(3) The correlation between the reference and supplemented populations before supplementation;

(4) The relative difference in slopes between the reference and supplemented populations before supplementation; and

(5) The coefficient of variation (CV) of the ratio of supplemented to reference populations before the period of supplementation.

Each selection criteria was scored from 0 to 1, with 0 being the worst possible score and 1 being the best.

The pre- and post-pNOS values were calculated as the average pNOS values before and after supplementation, respectively. Because pNOS values range from 0-1, we did not need to rescale

these values. When using reference populations to evaluate the effects of supplementation programs, it is important that the reference populations maintain high values of pNOS throughout the life of the monitoring program. Therefore, we heavily weighted the mean pNOS scores. We assigned weights of 30 and 40 to the mean pre- and post-pNOS scores, respectively. The relatively larger weight for the post-supplementation period is to reduce the likelihood of retaining a reference population that becomes influenced by hatchery fish during the supplementation period.

We assessed the association between the reference and supplemented populations during the pre-supplementation period by calculating the Pearson correlation coefficient, which ranges from -1 to 1. To scale the coefficient between 0 and 1, we took the absolute value of the coefficient. Thus, a coefficient of -0.92 would be reported as 0.92. For our analyses, we were not concerned with the direction of the relationship, only the strength of the relationship. The correlation coefficient was given a weight of 12.5.

As noted earlier, we used least squares to fit a linear trend to each of the reference populations and the supplemented population during the pre-supplementation period. Using the slope estimates for each trend line, we calculated the relative difference in slopes as the slope of the supplemented population minus the slope of the reference population, divided by the slope of the reference population. To scale this value between 0 and 1, we used absolute values, and depending on the direction of the slopes, we subtracted the relative difference from 1. The latter was needed to make sure a larger relative difference value indicated a small difference in slopes between the supplemented and reference populations. The relative difference score was given a weight of 7.5.

Finally, as a means to score effect size, we calculated the CV of the ratio of supplemented to reference population parameters (i.e., T/R). The CV was calculated as the standard deviation of the ratios divided by the absolute value of the mean ratios. The CV was subtracted from 1. This scaled the value from 0 to 1 with larger values representing the best condition. The CV was given a weight of 10, which is greater than the weight for trend, but less than the weight for correlation.

The total score for a reference population was calculated by multiplying the estimated value, which ranged from 0 to 1, by its weight. The sum of the five weighted values provided a total score, which ranged from 0 to 100. Based on several simulations, we set the cut-off score at 81. That is, if the total score for a given reference population equaled or exceeded 81, the population was included as a suitable reference population. If the total score fell below 81, the population was not considered a suitable reference. Based on the distribution of all scores possible, a score of 81 or greater represented only 3% of the total distribution. Thus, a cut-off of 81 is quite conservative.

Under Step 3, we used this method to select the final suite of suitable reference populations. Table 11 shows results from scoring each of the reference populations using the quantitative method. Using the cut-off criterion of 81, only the Naches, Marsh, and Sesech populations would be considered suitable reference populations for the Chiwawa supplementation program. Both the Entiat and Little Wenatchee populations failed to meet the minimum score, largely because of the influence of hatchery fish within those populations (i.e., relatively low pNOS values).

Table 11. Results from scoring potential reference populations using the selection criteria (pNOS, correlation, trend, and effect size). Populations with scores less than 81 were considered unsuitable as reference populations. Populations with scores equal to or greater than 81 were considered suitable references. These results were based on natural-log transformed data.

Potential reference populations	Population metric		
	Abundance	NORs	Productivity
Naches	85	88	91
Entiat	23	21	16
Marsh	79	91	87
Sesech	84	85	88
Little Wenatchee	51	53	49

An important benefit from scoring the different selection criteria is that the total scores can be used to weight the outcome of differing statistical results. For example, analyses may show that when three suitable reference populations are compared to the supplemented population, two of the reference populations may indicate a significant treatment effect, while the third indicates no effect. Under this scenario it is not clear if the supplementation program has or has not affected the abundance or productivity of the supplemented population. If, however, the two reference populations that produced a significant result had higher total scores than the reference population that did not indicate a significant result, one can place more weight on the results from populations with higher total scores.

Conclusions

The purpose of this exercise was to develop a method for selecting suitable reference populations that could be used to assess the effects of supplementation programs on spawner abundance, NORs, and productivity. The selection process included a three-step process (Figure 8). Step 1 identified populations with similar life-history characteristics, few or no hatchery spawners, a long time series of accurate abundance and productivity estimates, and similar freshwater habitat impairments and out-of-basin effects. Populations that met these criteria were then examined for their graphical and statistical relationship with the supplemented population (Step 2). The statistical analysis under Step 2 were converted to a quantitative model (Step 3) that was used to generate a weighted score for pNOS, correlation, trends, and effect sizes for each potential reference population. Reference populations with total scores of 81 or greater were selected as suitable reference populations.

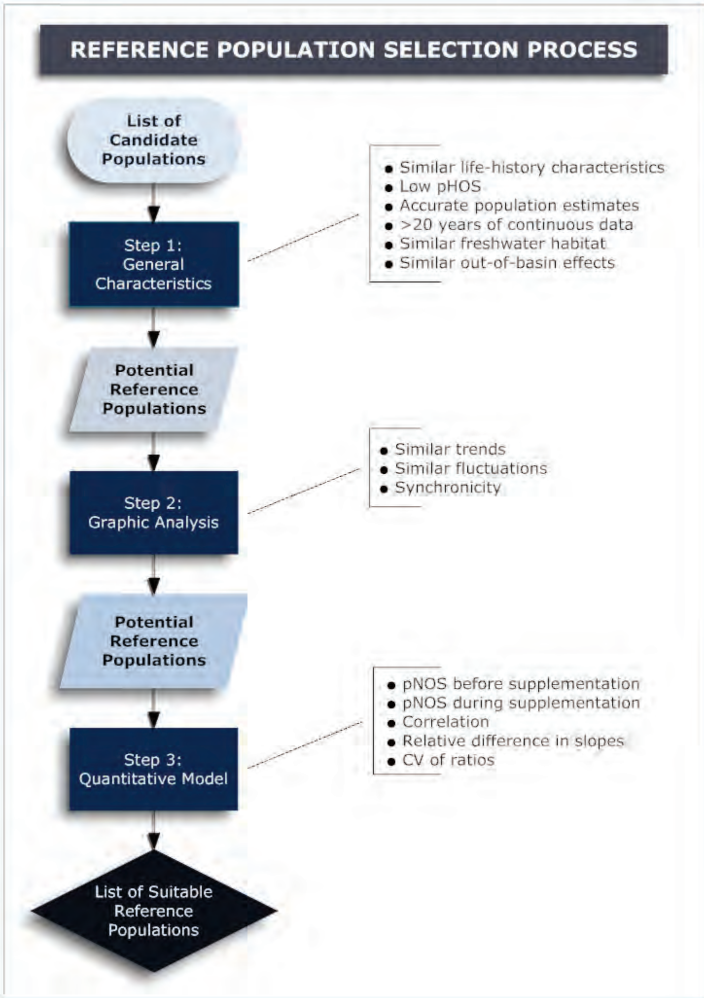


Figure 8. Three-step process for selecting suitable reference populations for supplemented populations.

We used this approach to select suitable reference populations for analyzing the effects of the Chiwawa spring Chinook supplementation program on fish abundance and productivity. The method indicated that the Naches, Marsh, and Sesech populations would serve as suitable reference populations for the Chiwawa spring Chinook supplementation program. Both the Entiat and Little Wenatchee populations failed to meet the minimum score, largely because of the influence of hatchery fish within those populations (i.e., relatively low pNOS values). However, because the presence of hatchery spring Chinook within those populations should decrease, they may serve as unique reference populations in which the comparisons change from all populations receiving

hatchery fish to only the Chiwawa population receiving hatchery fish. Therefore, we will continue to include both the Little Wenatchee and Entiat populations in future analyses.

An important assumption in the use of reference populations is that the supplemented and reference populations that tracked each other before supplementation would continue to track each other in the absence of supplementation. Given that the reference populations did not match the Chiwawa population on all criteria examined (Table 1) and some reference populations tracked the Chiwawa population more poorly than others (Figures 2-7; Tables 2-4), there may be some uncertainty as to whether differences observed between the Chiwawa and reference populations during the supplementation period are associated with the hatchery program, "nuisance" factors[18], or a combination of both. In addition, we have no ability to regulate or control activities in reference areas. Any large-scale change (man-made or natural) in reference areas could affect our ability to assess the effectiveness of the supplementation program.

Because we have no ability to maintain reference areas for long periods of time and may not be able to control all activities even within the supplemented populations, we propose the use of a "causal-comparative" approach to strengthen the certainty of our inferences (Pearsons and Temple 2010). The causal-comparative approach relies on correlative data to try and make a case for causal inference.[19] Correlation is used to rule out alternative hypotheses (note that we make our case as much if not more by disproving plausible alternatives as we do by showing that the data are consistent with a hypothesis). For example, large scale land-use activities or natural events can affect stream flows, fine sediment recruitment, and water temperatures. Changes in these factors can affect the freshwater survival and productivity of fish independently of supplementation programs. If changes in habitat, migratory, and ocean conditions do not affect reference and treatment populations similarly, inferences associated with supplementation programs may be confounded. By measuring and tracking these extraneous factors within reference and treatment areas, we can assess the effects of these state variables on population conditions independent of the supplementation programs. This allows us to more effectively assess the influence of supplementation programs on populations.

To that end, we recommend that the following state variables be measured and tracked within the Chiwawa Basin and each of the reference areas: mean annual precipitation, total and riparian forest cover, road density, impervious surface, and alluvium. These variables can be used to describe differences in water temperatures at different life stages (pre-spawning, egg incubation, and summer rearing) and substrate characteristics, including fine sediments and embeddedness (Jorgensen et al. 2009). They can be used to assess possible changes in spawner abundance, NORs, and productivity that are independent of supplementation.

18 A "nuisance" factor is any factor that is outside the control of the experimenter and can affect the response variable (spawner abundance or productivity). In this case, nuisance factors may include differences in freshwater habitat trends and conditions, out-of-basin effects (e.g., migration and ocean survival), and hatchery strays that affect the Chiwawa and reference populations differently.

19 It is important to point out that correlation does not demonstrate cause-and-effect. It only suggests a relationship between variables. Thus, inferences based on correlation lack the certainty that is associated with a design-based approach.

Analyses with Reference Populations

Once suitable reference populations are selected, methods for analyzing the supplemented and reference populations need to be identified. What follows is a description of different analyses that can be used to assess the effects of supplementation programs on spawner abundance, NORs, and productivity using reference populations. Later in this report we describe methods for assessing supplementation effects when reference populations are not available.

We used some of the reference populations selected for the Chiwawa program to illustrate the different methods for evaluating the effects of the supplementation program on spawner abundance, NORs, and productivity. For abundance, we selected the Naches, Entiat, Little Wenatchee, and Sesech populations as suitable references for the Chiwawa population. For NORs, we selected the Naches, Entiat, Marsh, and Little Wenatchee populations as suitable references. For productivity, we selected the Naches, Sesech, Little Wenatchee, and Marsh Creek as suitable references for the Chiwawa. As noted earlier, we included the Little Wenatchee and Entiat populations, even though they did not meet all the criteria for suitable reference populations.

Analysis of Trends

As a first step, we used trend analyses to assess the effects of the Chiwawa supplementation program on spring Chinook spawner abundance, NORs, and productivity. Here, we compared the slopes of the trends between each treatment/reference pair before and during supplementation using t-tests. If the hatchery program is successfully supplementing the natural spring Chinook population, trends in spawner abundance and NORs should deviate significantly (i.e., the slope of the supplemented population should be greater than the slopes of the reference populations during the supplementation period). For productivity, the slope of the supplemented population, relative to the reference population, should increase or remain the same.

Trend analysis indicated that the relationship of slopes of spawner abundance between the Chiwawa and reference populations did not change significantly after the initiation of supplementation (Figure 9; Table 12). This was true for both transformed and untransformed abundance data. Before supplementation, spawner abundances trended down in both the Chiwawa and reference populations (Figure 9). During the period of supplementation, abundances in both the Chiwawa and reference populations trended upward. Interestingly, in nearly all treatment/reference comparisons, the Pearson correlation coefficient was greater in the supplementation period than in the pre-supplementation period (Table 12). This was most evident in the transformed abundance data (Figure 9).

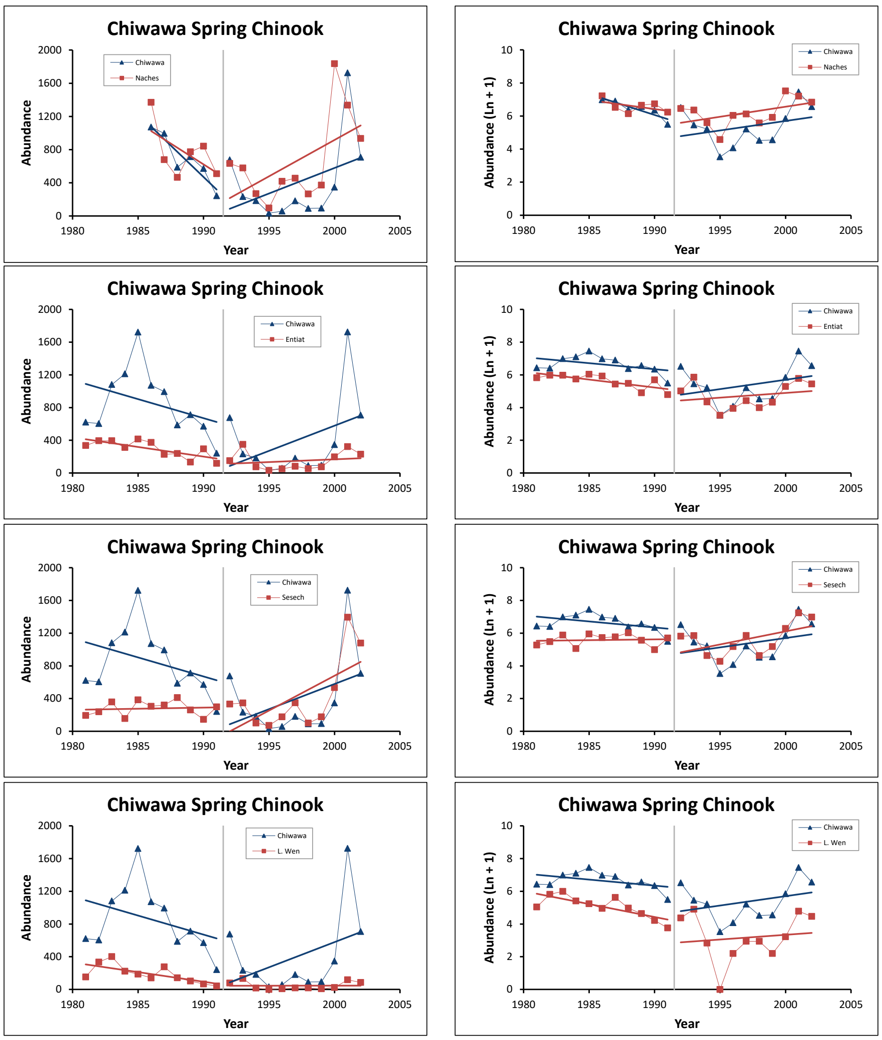


Figure 9. Trends in spring Chinook spawner abundance in the Chiwawa and reference populations. The vertical lines in the figures separate the pre- and post-supplementation periods. Figures on the left include untransformed spawner abundance data; those on the right include natural-log transformed data.

Table 12. Pearson correlation coefficients and t-test results comparing slopes of spawner abundance trends between reference populations and the Chiwawa spring Chinook population before and during the supplementation periods; for correlation coefficients, an asterisk (*) indicates significance at P < 0.05. Analyses include both untransformed and natural-log transformed spawner abundance data.

Reference population	Pearson correlation coefficient		Test on slopes			
			t-value		P-value	
	Before	During	Before	During	Before	During
Spawner Abundance						
Naches	0.684*	0.595	-0.659	-0.414	0.528	0.684
Entiat	0.598*	0.672*	-0.596	1.162	0.559	0.260
Sesech	0.274	0.904*	-1.265	-0.418	0.222	0.681
Little Wenatchee	0.399	0.685*	-0.591	1.330	0.562	0.200
LN Spawner Abundance						
Naches	0.642*	0.813*	-1.323	-0.047	0.222	0.963
Entiat	0.652*	0.860*	0.412	0.422	0.685	0.678
Sesech	0.149	0.878*	-1.431	-0.333	0.170	0.743
Little Wenatchee	0.670*	0.861*	1.325	0.316	0.202	0.756

Trend analysis indicated that the relationship of slopes of NORs between the Chiwawa and reference populations did not change significantly after the initiation of supplementation (Figure 10; Table 13). Before supplementation, Chiwawa NORs trended downward more strongly than the reference populations (Figure 10). However, during the supplementation period, both the Chiwawa and reference population NORs trended upward in parallel. In nearly all treatment/reference comparisons, the Pearson correlation coefficient was greater in the pre-supplementation period than in the supplementation period (Table 13).

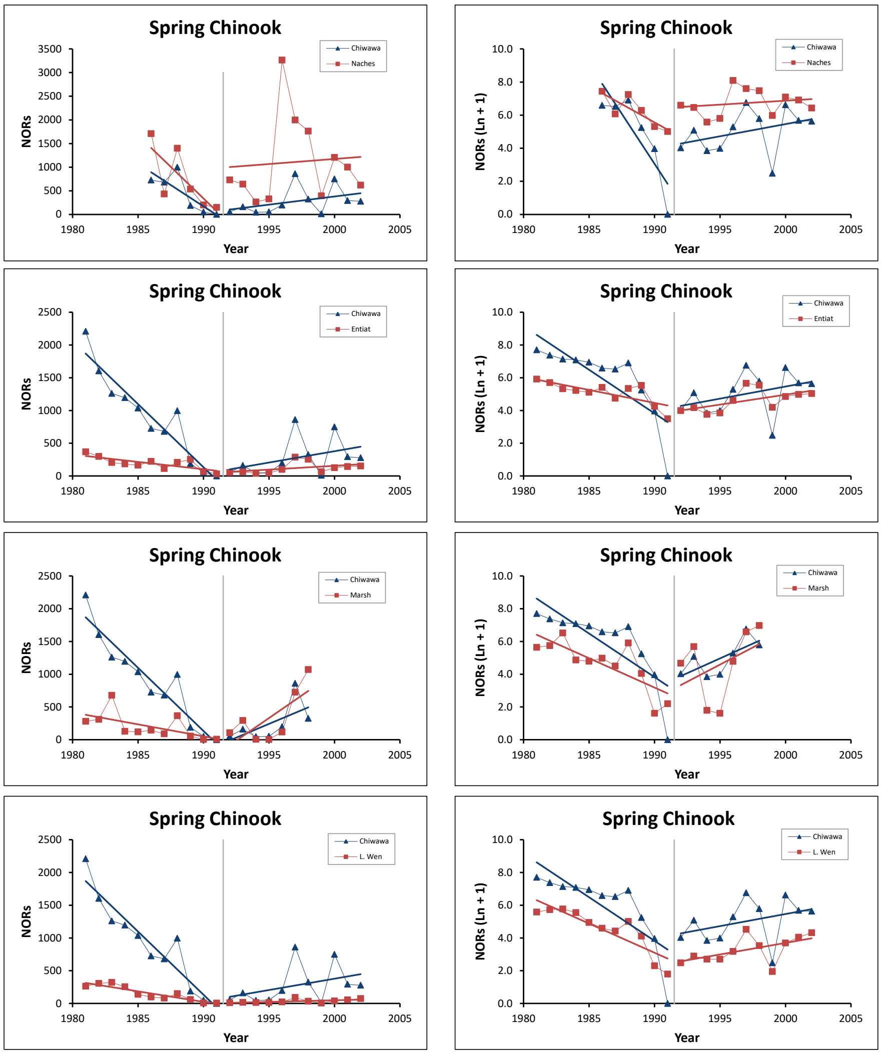


Figure 10. Trends in spring Chinook natural-origin recruits (NORs) in the Chiwawa and reference populations. The vertical lines in the figures separate the pre- and post-supplementation periods. Figures on the left include untransformed NORs; those on the right include natural-log transformed data.

Table 13. Pearson correlation coefficients and t-test results comparing slopes of natural-origin recruits trends between reference populations and the Chiwawa spring Chinook population before and during the supplementation periods; for correlation coefficients, an asterisk (*) indicates significance at P < 0.05. Analyses include both untransformed and natural-log transformed natural-origin recruits.

Reference population	Pearson correlation coefficient		Test on slopes			
			t-value		P-value	
	Before	During	Before	During	Before	During
Natural-Origin Recruits						
Naches	0.803*	0.432	0.666	0.140	0.524	0.890
Entiat	0.795*	0.754*	-7.495	0.847	0.000	0.408
Marsh	0.605*	0.677*	-5.786	-0.718	0.000	0.489
Little Wenatchee	0.880*	0.758*	-7.206	1.128	0.000	0.274
LN Natural-Origin Recruits						
Naches	0.824*	0.710*	-1.985	0.693	0.082	0.497
Entiat	0.886*	0.796*	-2.563	0.202	0.019	0.842
Marsh	0.830*	0.835*	-1.038	-0.134	0.313	0.896
Little Wenatchee	0.927*	0.898*	-1.150	0.046	0.265	0.964

As with NORs and spawner abundance data, trend analysis indicated that the relationship of slopes of productivity (recruits/spawner) between the Chiwawa and reference populations did not change significantly after the initiation of supplementation (Figure 11; Table 14). This was true for both transformed and untransformed productivity data. Before supplementation, productivities trended down in both the Chiwawa and reference populations (Figure 11). During the period of supplementation, productivities fluctuated widely in both the Chiwawa and reference populations. Nevertheless, during the supplementation period, productivities generally increased in both the reference and Chiwawa populations. Unlike with spawner abundance, the Pearson correlation coefficients resulting from analysis of productivity data were generally higher in the pre-supplementation period than during the supplementation period (Table 14).

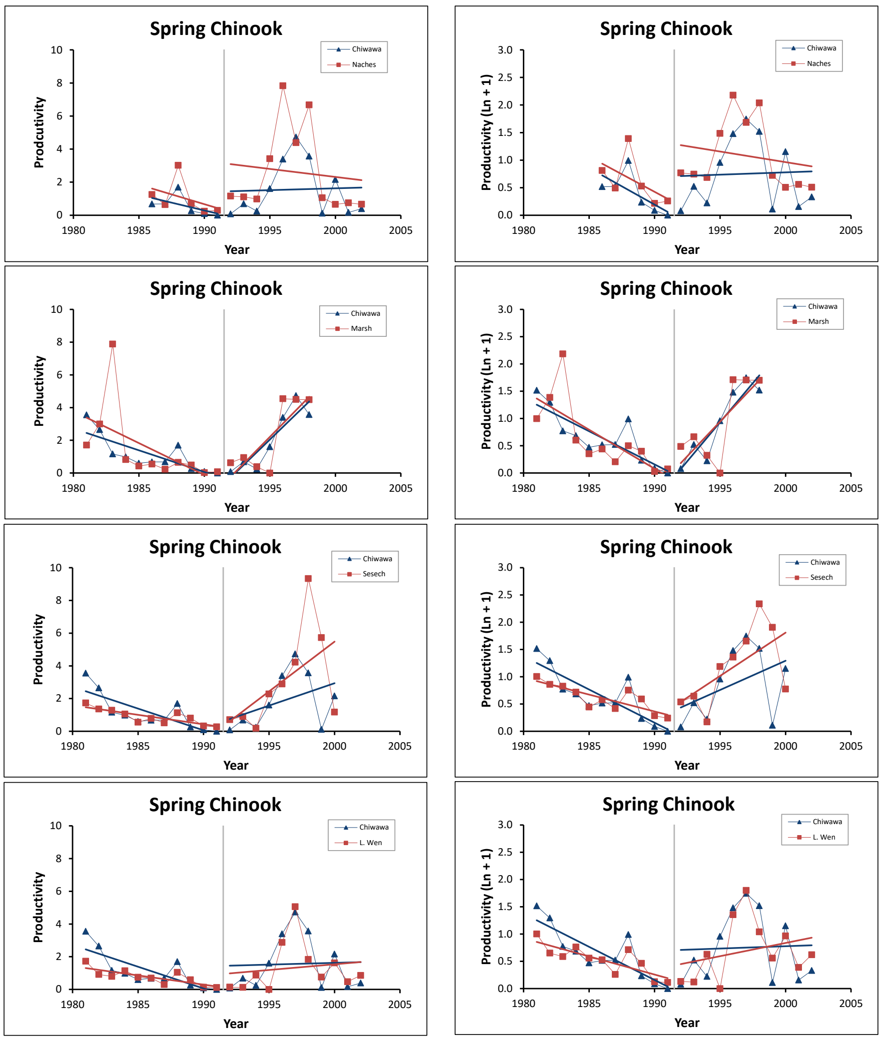


Figure 11. Trends in spring Chinook productivity (recruits/spawner) in the Chiwawa (supplemented) and reference populations. The vertical lines in the figures separate the pre- and post-supplementation periods. Figures on the left include untransformed productivity data; those on the right include natural-log transformed data.

Table 14. Pearson correlation coefficients and t-test results comparing slopes of productivity (recruits/spawner) trends between reference populations and the Chiwawa spring Chinook population before and during the supplementation periods; for correlation coefficients, an asterisk (*) indicates significance at $P < 0.05$. Analyses include both untransformed and natural-log transformed productivity data.

Reference population	Pearson correlation coefficient		Test on slopes			
			t-value		P-value	
	Before	During	Before	During	Before	During
Productivity						
Naches	0.960*	0.802*	0.169	0.387	0.870	0.703
Marsh	0.320	0.910*	0.605	-0.132	0.553	0.898
Sesech	0.903*	0.491	-2.059	-0.837	0.054	0.417
Little Wenatchee	0.848*	0.864*	-2.065	-0.213	0.054	0.834
LN Productivity						
Naches	0.944*	0.805*	-0.042	0.526	0.968	0.605
Marsh	0.610*	0.804*	0.428	0.281	0.674	0.784
Sesech	0.913*	0.531	-2.050	-0.463	0.055	0.651
Little Wenatchee	0.862*	0.751*	-1.811	-0.480	0.087	0.637

Using trend analysis, we found no evidence that the supplementation program has significantly increased the spawner abundance and NORs of spring Chinook in the Chiwawa Basin. Even though we documented an increasing trend in spawner abundance and NORs during the supplementation period, a similar increase in spawner abundance and NORs was observed in the reference populations. In addition, we found no evidence that the supplementation program has increased the productivity of spring Chinook in the Chiwawa Basin. Importantly, the productivity of spring Chinook in the Chiwawa Basin did not trend downward during the supplementation period. Thus, based on trend analysis, it appears that the supplementation program has not increased or decreased the abundance and productivity of spring Chinook in the Chiwawa Basin.

We note that this exercise only tests the slopes of the trend lines. It does not test for differences in elevations of the trend lines. A supplementation program could increase spawner abundance, NORs, and productivity of the target population without changing the slopes of the trend lines. That is, supplementation could cause the elevation of the trend line to be greater during the supplementation period than during the pre-supplementation period. In the next section we evaluate elevation differences by testing mean differences before and after supplementation.

Analysis of Mean Differences, Ratios, and Rates

For assessing mean differences between supplemented and reference populations, we derived three different response variables using transformed and untransformed spawner abundance, NORs, and productivity data. The first included difference scores, which were calculated as the difference between paired treatment and reference data (T-R). The second included ratios, which were calculated as the ratio of paired treatment and reference data (T/R). Finally, we calculated the differences in annual changes in paired treatment and reference population data (ΔT-ΔR; see footnote #2).

If the hatchery program is successfully supplementing the natural spring Chinook population, the mean difference or ratio score of paired spawner abundance data and NORs during the supplementation period should be greater than the pre-supplementation period. For productivity, the mean difference or ratio score during the supplementation period should be equal to or higher than the pre-supplementation period. We tested the following statistical hypotheses.

Spawner Abundance and NORs:

> Ho: Mean Difference (or Ratio) before supplementation ≥ Mean Difference (or Ratio) during supplementation.
>
> Ha: Mean Difference (or Ratio) before supplementation < Mean Difference (or Ratio) during supplementation (i.e., μ_{pre} - $\mu_{post} < 0$).

Productivity (Recruits/Spawner):

> Ho: Mean Difference (or Ratio) before supplementation ≤ Mean Difference (or Ratio) during supplementation.
>
> Ha: Mean Difference (or Ratio) before supplementation > Mean Difference (or Ratio) during supplementation (i.e., μ_{pre} - $\mu_{post} > 0$).[20]

For each set of response variables, we tested before/after supplementation effects using a one-tailed Aspin-Welch unequal-variance test. We used the Aspin-Welch unequal-variance test instead of Student's t-test, because in nearly every case, the variances of response variables in the pre-treatment and supplementation periods were unequal.[21] This was true even for natural-log transformed variables. We used the modified Levene equal-variance test to assess the equality of variance. In some cases, the distributions of response variables were not normal (based on the Omnibus Normality test and examination of histograms, normal probability plots, and box plots). Therefore, we also used a randomization test, based on 10,000 Monte Carlo simulations, to assess differences in response variables before and during supplementation. The randomization procedure only allowed the testing of two-tailed hypotheses. Therefore, we generated 95% confidence intervals on the mean difference (μ_{pre} - μ_{post}) using bootstrapping methods to determine the direction of the difference. We generated 5,000 bootstrap samples to calculate confidence intervals.

All these statistical methods assume that the samples of derived difference or ratio scores from the pre-supplementation and supplementation periods were independent. However, BACI designs, like time-series trend analysis, are repeated-measures designs and therefore are susceptible to temporal correlations in the data. This means that the two samples of difference or ratio scores may not be independent. Under this scenario, ARIMA models can be used to describe the correlation structure in temporal data (Gotelli and Ellison 2004). ARIMA models can be fit individually to the reference and supplemented time series data, or to a derived data series created by taking the ratio or difference of the supplemented/reference data at each time step. ARIMA models, however, require a long time series (N > 40) and therefore we could not use them to model

20 Because of the logic of null hypothesis testing, the rejection of the null hypothesis of no difference in productivity would mean that the supplementation program has reduced the productivity of the target population (here rejection of the null indicates "harm"). Notice that the rejection of the null hypothesis of no difference in spawner abundance means that the supplementation program has improved the spawner abundance in the target population (here rejection of the null indicates "benefit").

21 In cases in which the variances were equal, both the Aspin-Welch test and Student's t-test gave the same result.

the spring Chinook data. Thus, we acknowledge that our analyses may be confounded if the samples are not independent.

Difference Scores (T-R)

Analysis of supplementation effects on spawner abundance using difference scores indicated that supplementation did not significantly increase spawning abundance in the Chiwawa Basin (Table 15; Figure 12). Only the Little Wenatchee-Chiwawa pairing using transformed abundance data indicated a significant increase in spawning abundance following supplementation. The randomization test indicated significant differences in several of the treatment-reference pairs; however, the bootstrap CIs indicated that those differences were in the wrong direction (i.e., CIs > 0). That is, compared to the reference populations, spawner abundance decreased in the Chiwawa Basin during the supplementation period (Figure 12).

Table 15. Results of the Aspin-Welch unequal-variance test, randomization test (based on 10,000 Monte Carlo samples), and 95% CI (based on 5,000 bootstrap samples) on transformed and untransformed spawner abundance data. Tests determined if the mean difference scores during the supplementation period were greater than mean difference scores during the pre-supplementation period.

Reference population	Aspin-Welch unequal-variance test			Randomization test P-value	Bootstrap 95% CI
	t-value	P-value	Effect size		
Spawner Abundance					
Naches	1.066	0.848	184	0.322	-162 – 472
Entiat	1.872	0.962	316	0.078	17 – 633
Sesech	4.502	0.999	607	0.000	349 – 851
Little Wenatchee	1.773	0.954	321	0.093	0 – 690
LN Spawner Abundance					
Naches	2.603	0.990	0.701	0.026	0.210 – 1.214
Entiat	1.701	0.946	0.388	0.108	-0.033 – 0.811
Sesech	5.394	0.999	1.327	0.000	0.891 – 1.805
Little Wenatchee	-2.259	0.018	0.609	0.034	-1.125 – -0.097

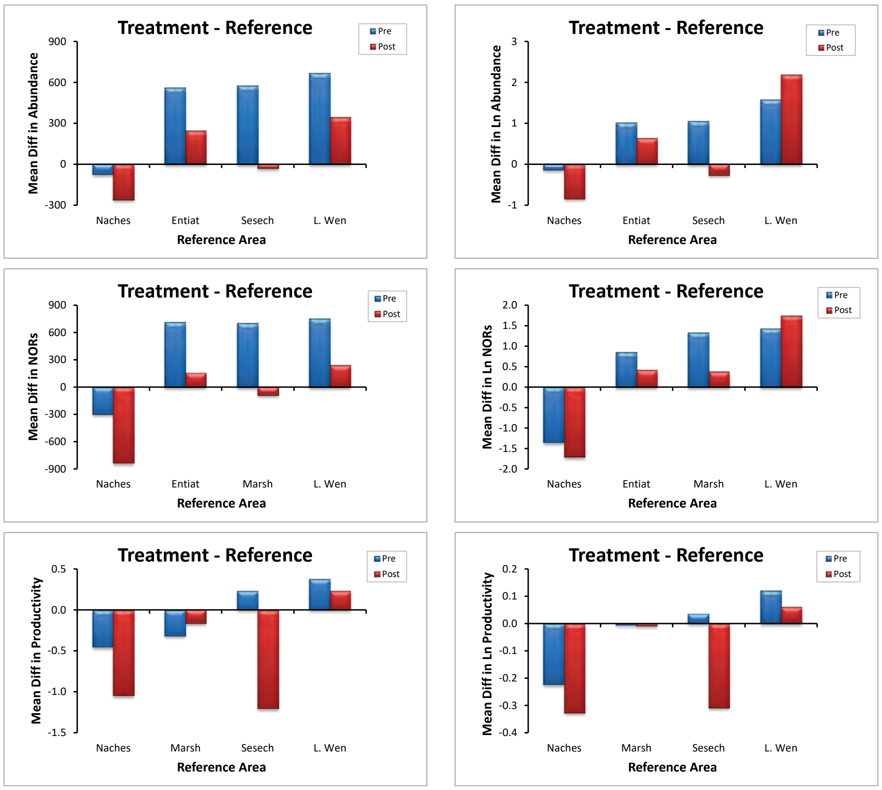


Figure 12. Mean difference (Treatment – Reference) scores of untransformed (figures on the left) and transformed (figures on the right) spawner abundance, natural-origin recruits (NORs), and productivity data before (pre) and after (post) spring Chinook supplementation in the Chiwawa Basin. Positive effects of supplementation on spawner abundance and NORs are indicated when the post-supplementation (red) bars are greater than their corresponding pre-supplementation (blue) bars. Negative effects of supplementation on productivity are indicated when the pre-supplementation (blue) bars are greater than their corresponding post-supplementation (red) bars.

Analysis of supplementation effects on NORs using difference scores indicated that supplementation did not significantly increase NORs in the Chiwawa Basin (Table 16; Figure 12). The randomization test indicated significant differences in several of the treatment-reference pairs; however, the bootstrap CIs indicated that those differences were in the wrong direction. That is, compared to the reference populations, NORs decreased in the Chiwawa Basin during the supplementation period (Figure 12).

Table 16. Results of the Aspin-Welch unequal-variance test, randomization test (based on 10,000 Monte Carlo samples), and 95% CI (based on 5,000 bootstrap samples) on transformed and untransformed natural-origin recruits. Tests determined if the mean difference scores during the supplementation period were greater than mean difference scores during the pre-supplementation period.

Reference population	Aspin-Welch unequal-variance test			Randomization test P-value	Bootstrap 95% CI
	t-value	P-value	Effect size		
Natural-Origin Recruits					
Naches	1.787	0.953	537	0.081	-60 – 1039
Entiat	2.879	0.993	558	0.007	201 – 916
Marsh	3.817	0.999	795	0.001	381 – 1153
Little Wenatchee	2.668	0.991	510	0.013	145 – 863
LN Natural-Origin Recruits					
Naches	0.430	0.659	0.354	0.686	-0.948 – 1.975
Entiat	0.788	0.779	0.445	0.465	-0.504 – 1.583
Marsh	1.45	0.916	0.953	0.168	-0.169 – 2.243
Little Wenatchee	-0.813	0.214	-0.319	0.506	-0.948 – 0.484

Analysis of supplementation effects on productivity (adult recruits/spawner) using difference scores indicated that supplementation did not significantly decrease productivity in the Chiwawa Basin (Table 17; Figure 12). All tests, regardless of treatment-reference pairs, indicated that productivity did not change significantly during the supplementation period. These tests indicate that supplementation has not negatively affected the productivity of spring Chinook salmon in the Chiwawa Basin.

Table 17. Results of the Aspin-Welch unequal-variance test, randomization test (based on 10,000 Monte Carlo samples), and 95% CI (based on 5,000 bootstrap samples) on transformed and untransformed productivity data. Tests determined if the mean difference scores during the supplementation period were less than mean difference scores during the pre-supplementation period.

Reference population	Aspin-Welch unequal-variance test			Randomization test P-value	Bootstrap 95% CI
	t-value	P-value	Effect size		
Productivity					
Naches	1.134	0.139	0.594	0.296	-0.427 – 1.540
Marsh	-0.203	0.579	0.152	0.932	-0.304 – 1.381
Sesech	1.607	0.071	1.435	0.151	-0.403 – 2.917
Little Wenatchee	0.431	0.335	0.147	0.665	-0.498 – 0.762
LN Productivity					
Naches	0.770	0.227	0.104	0.480	-0.125 – 0.378
Marsh	0.012	0.495	0.003	0.992	-0.375 – 0.493
Sesech	1.463	0.087	0.343	0.161	-0.135 – 0.732
Little Wenatchee	0.390	0.351	0.060	0.701	-0.229 – 0.347

Ratio Scores (T/R)

As with difference scores, analysis of supplementation effects on spawner abundance using ratios indicated that supplementation did not significantly increase spawning abundance in the Chiwawa Basin (Table 18; Figure 13). Only the Little Wenatchee-Chiwawa pairing indicated a significant increase in spawning abundance following supplementation. Analysis with both transformed and untransformed Little Wenatchee-Chiwawa data indicated a significant effect. In contrast, only difference scores derived from transformed data indicated a significant effect. The randomization test indicated significant differences in several of the treatment-reference pairs; however, the bootstrap CIs indicated that those differences were in the wrong direction. That is, compared to the reference populations, spawner abundance decreased in the Chiwawa Basin during the supplementation period (Figure 13).

Table 18. Results of the Aspin-Welch unequal-variance test, randomization test (based on 10,000 Monte Carlo samples), and 95% CI (based on 5,000 bootstrap samples) on transformed and untransformed spawner abundance data. Tests determined if the mean ratios during the supplementation period were greater than mean ratios during the pre-supplementation period.

Reference population	Aspin-Welch unequal-variance test			Randomization test P-value	Bootstrap 95% CI
	t-value	P-value	Effect size		
Spawner Abundance					
Naches	2.110	0.970	0.398	0.065	0.056 – 0.737
Entiat	1.254	0.888	0.731	0.223	-0.365 – 1.834
Sesech	4.251	0.999	2.428	0.000	1.278 – 3.435
Little Wenatchee	-2.649	0.009	3.897	0.018	-6.579 – -1.202
LN Spawner Abundance					
Naches	2.783	0.993	0.120	0.021	0.045 – 0.199
Entiat	1.273	0.890	0.055	0.220	-0.026 – 0.135
Sesech	5.143	0.999	0.244	0.000	0.160 – 0.335
Little Wenatchee	-3.462	0.002	0.327	0.003	-0.516 – -0.154

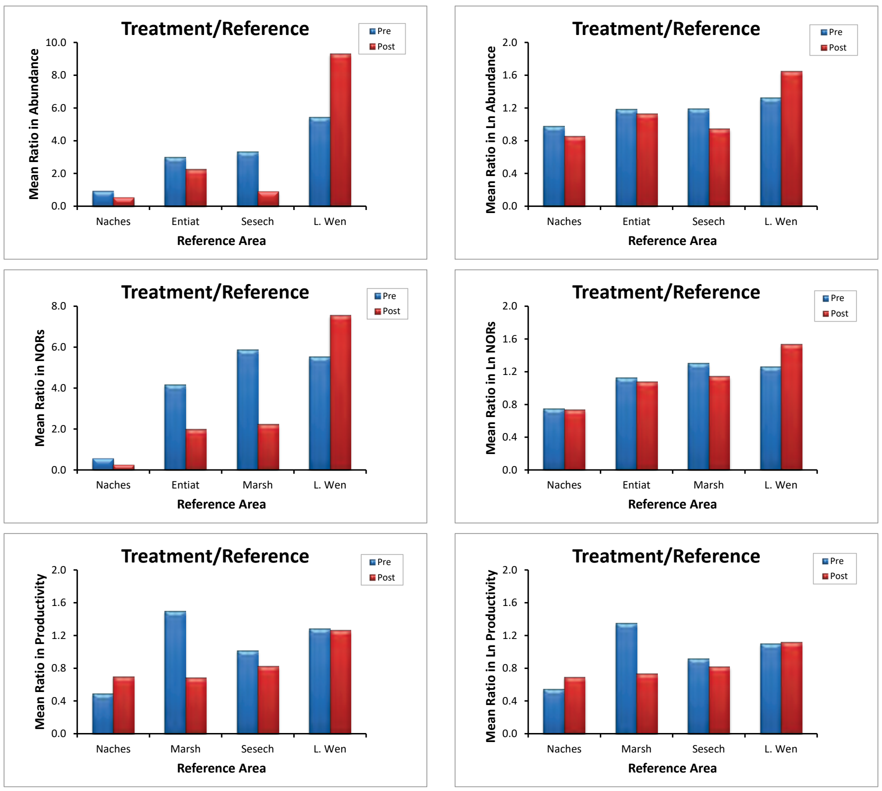


Figure 13. Mean ratios (Treatment/Reference) scores of untransformed (figures on the left) and transformed (figures on the right) spawner abundance, natural-origin recruits (NORs), and productivity data before (pre) and after (post) spring Chinook supplementation in the Chiwawa Basin. Positive effects of supplementation on spawner abundance and NORs are indicated when the post-supplementation (red) bars are greater than their corresponding pre-supplementation (blue) bars. Negative effects of supplementation on productivity are indicated when the pre-supplementation (blue) bars are greater than their corresponding post-supplementation (red) bars.

Analysis of supplementation effects on NORs using ratios indicated that supplementation did not significantly increase NORs in the Chiwawa Basin (Table 19; Figure 13). Only the Little Wenatchee-Chiwawa pairing indicated a significant increase in transformed NORs following supplementation. The randomization test indicated significant differences in several of the treatment-reference pairs; however, the bootstrap CIs indicated that those differences were in the wrong direction. That is, compared to the reference populations, NORs decreased in the Chiwawa Basin during the supplementation period (Figure 13).

Table 19. Results of the Aspin-Welch unequal-variance test, randomization test (based on 10,000 Monte Carlo samples), and 95% CI (based on 5,000 bootstrap samples) on transformed and untransformed natural-origin recruits. Tests determined if the mean ratios during the supplementation period were greater than mean ratios during the pre-supplementation period.

Reference population	Aspin-Welch unequal-variance test			Randomization test P-value	Bootstrap 95% CI
	t-value	P-value	Effect size		
Natural-Origin Recruits					
Naches	1.318	0.881	0.306	0.219	-0.157 – 0.670
Entiat	2.447	0.987	2.172	0.028	0.593 – 3.871
Marsh	2.001	0.965	3.638	0.075	0.532 – 7.201
Little Wenatchee	-1.148	0.136	2.020	0.284	-5.055 – 1.516
LN Natural-Origin Recruits					
Naches	0.057	0.522	0.009	0.967	-0.230 – 0.351
Entiat	0.359	0.638	0.049	0.759	-0.173 – 0.336
Marsh	0.603	0.721	0.161	0.579	-0.272 – 0.681
Little Wenatchee	-1.914	0.038	0.277	0.027	-0.504 – 0.031

Analysis of supplementation effects on productivity (adult recruits/spawner) using ratios indicated that supplementation did not significantly decrease productivity in the Chiwawa Basin (Table 20; Figure 13). Although the Aspin-Welch test indicated a significant effect when comparing the Chiwawa to the Marsh Creek population, both the randomization test and the bootstrap CI did not indicate a significant effect. These tests indicate that supplementation has probably not negatively affected the productivity of spring Chinook salmon in the Chiwawa Basin.

Table 20. Results of the Aspin-Welch unequal-variance test, randomization test (based on 10,000 Monte Carlo samples), and 95% CI (based on 5,000 bootstrap samples) on transformed and untransformed productivity data. Tests determined if the mean ratios during the supplementation period were less than mean ratios during the pre-supplementation period.

Reference population	Aspin-Welch unequal-variance test			Randomization test P-value	Bootstrap 95% CI
	t-value	P-value	Effect size		
Productivity					
Naches	-0.677	0.745	0.209	0.688	-0.700 – 0.425
Marsh	2.236	0.022	0.814	0.054	0.112 – 1.459
Sesech	0.677	0.253	0.191	0.515	-0.356 – 0.718
Little Wenatchee	0.033	0.487	0.018	0.979	-0.879 – 1.162
LN Productivity					
Naches	-0.639	0.734	0.148	0.616	-0.548 – 0.316
Marsh	1.952	0.036	0.613	0.081	-0.003 – 1.170
Sesech	0.447	0.330	0.098	0.663	-0.301 – 0.515
Little Wenatchee	-0.034	0.513	0.015	0.982	-0.692 – 0.861

Difference of Annual Difference Scores (ΔT-ΔR)

Analysis of supplementation effects on spawner abundance using difference scores of annual changes indicated that supplementation did not significantly increase spawning abundance in the Chiwawa Basin (Table 21; Figure 14). None of the statistical analyses detected a significant increase in annual change in the Chiwawa Basin relative to the reference populations.

Table 21. Results of the Aspin-Welch unequal-variance test, randomization test (based on 10,000 Monte Carlo samples), and 95% CI (based on 5,000 bootstrap samples) on transformed and untransformed spawner abundance data. Tests determined if mean difference scores of annual change during the supplementation period were greater than mean difference scores of annual change during the pre-supplementation period.

Reference population	Aspin-Welch unequal-variance test			Randomization test P-value	Bootstrap 95% CI
	t-value	P-value	Effect size		
Spawner Abundance					
Naches	0.009	0.503	2	0.995	-502 – 539
Entiat	-0.239	0.407	48	0.826	-414 – 327
Sesech	-0.126	0.451	20	0.902	-311 – 266
Little Wenatchee	-0.318	0.377	65	0.761	-452 – 311
LN Spawner Abundance					
Naches	-0.425	0.339	0.142	0.698	-0.744 – 0.466
Entiat	-0.084	0.467	0.028	0.933	-0.681 – 0.593
Sesech	-0.349	0.366	0.117	0.740	-0.741 – 0.515
Little Wenatchee	0.001	0.500	0.000	0.999	-0.663 – 0.687

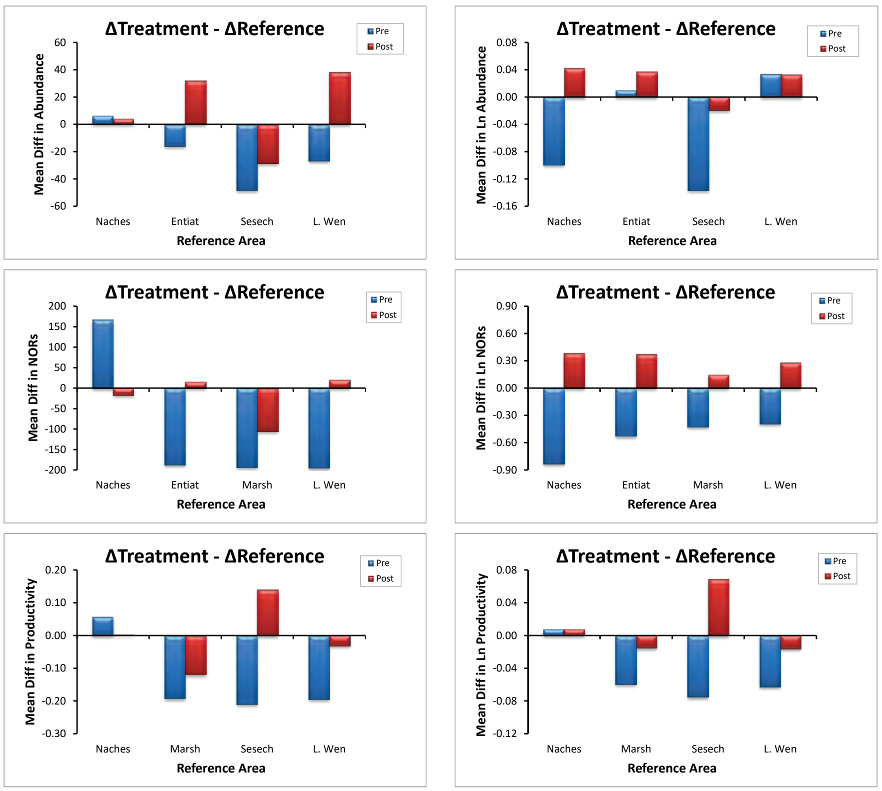


Figure 14. Mean difference scores of annual changes (ΔTreatment – ΔReference) of untransformed (figures on the left) and transformed (figures on the right) spawner abundance and productivity data before (pre) and after (post) spring Chinook supplementation in the Chiwawa Basin.

Analysis of supplementation effects on NORs using difference scores of annual changes indicated that supplementation did not significantly increase NORs in the Chiwawa Basin (Table 22; Figure 14). None of the statistical analyses detected a significant increase in annual change in the Chiwawa Basin relative to the reference populations.

Table 22. Results of the Aspin-Welch unequal-variance test, randomization test (based on 10,000 Monte Carlo samples), and 95% CI (based on 5,000 bootstrap samples) on transformed and untransformed natural-origin recruits. Tests determined if mean difference scores of annual change during the supplementation period were greater than mean difference scores of annual change during the pre-supplementation period.

Reference population	Aspin-Welch unequal-variance test			Randomization test P-value	Bootstrap 95% CI
	t-value	P-value	Effect size		
Natural-Origin Recruits					
Naches	0.399	0.652	184	0.741	-699 – 989
Entiat	-1.381	0.092	202	0.194	-471 – 86
Marsh	-0.505	0.311	88	0.624	-425 – 206
Little Wenatchee	-1.437	0.084	214	0.179	-481 – 64
LN Natural-Origin Recruits					
Naches	-1.301	0.118	1.214	0.224	-2.783 – 0.531
Entiat	-1.408	0.088	0.901	0.188	-1.977 – 0.387
Marsh	-0.712	0.244	0.570	0.517	-1.952 – 0.975
Little Wenatchee	-1.154	0.132	0.674	0.274	-1.706 – 0.497

Analysis of supplementation effects on productivity (adult recruits/spawner) using difference scores of annual changes indicated that supplementation did not significantly decrease productivity in the Chiwawa Basin (Table 23; Figure 14). All tests, regardless of treatment-reference pairs, indicated that productivity did not change significantly during the supplementation period.

Table 23. Results of the Aspin-Welch unequal-variance test, randomization test (based on 10,000 Monte Carlo samples), and 95% CI (based on 5,000 bootstrap samples) on transformed and untransformed productivity data. Tests determined if the mean difference scores of annual change during the supplementation period were less than mean difference scores of annual change during the pre-supplementation period.

Reference population	Aspin-Welch unequal-variance test			Randomization test P-value	Bootstrap 95% CI
	t-value	P-value	Effect size		
Productivity					
Naches	0.002	0.475	0.054	0.952	-1.464 – 1.583
Marsh	-0.063	0.525	0.074	0.948	-2.395 – 2.031
Sesech	-0.317	0.621	0.350	0.628	-2.387 – 1.695
Little Wenatchee	-0.347	0.633	0.163	0.728	-1.023 – 0.725
LN Productivity					
Naches	0.000	0.500	0.000	0.999	-0.408 – 0.445
Marsh	-0.126	0.549	0.044	0.904	-0.715 – 0.595
Sesech	-0.449	0.668	0.144	0.727	-0.685 – 0.509
Little Wenatchee	-0.200	0.578	0.047	0.842	-0.466 – 0.391

We believe results from analysis of mean differences of annual change (ΔT-ΔR) in spawning abundance, NORs, and productivity are difficult to interpret and may be insensitive to treatment effects. A simpler analysis, which is also easier to interpret, is the use of trend analysis. Therefore, we recommend that analyses using differences of annual change be replaced with trend analysis.

Corrections for Density Dependence and Carrying Capacity

The analyses described above assume that the density of spawners or recruits does not affect the survival and productivity of fish. However, it is well known that the density of fish can affect the number of recruits as well as the productivity of the population. This occurs through the relationship between density and mortality. Mortality of fish can be generally classified as density independent and density dependent. In general, when densities are low, the mortality is density independent, but as densities increase, the amount of density-dependent mortality increases. Monitoring programs can make use of this information to derive density-corrected estimates of productivity. In this section, we describe two different methods for deriving density-corrected estimates of productivity.

The first method controlled the effects of density on productivity (adult recruits/spawner; R/S) by partitioning observed productivities into density-independent and density-dependent productivity. When abundance is below the minimum number of spawners (S) needed to produce the maximum number of recruits (K_{sp}), the observed productivity is used in statistical tests. However, when the abundance is equal to or above K_{sp}, the modeled value of productivity (R/K_{sp}) is used in statistical tests.

$$\boldsymbol{Adj\ R/S} = \begin{cases} \boldsymbol{R/S,} & \boldsymbol{if\ S < K_{sp}} \\ \boldsymbol{R/K_{sp},} & \boldsymbol{if\ S \geq K_{sp}} \end{cases}$$

The density-independent and density-dependent productivities were then combined in a single test.

The second method was based on one of the goals of supplementation, which is to fill the capacity of the environment with fish. This method corrects for differences in carrying capacities between the supplemented and reference populations. We did this by calculating the percent saturation of NORs. That is, we calculated the fraction of the habitat (τ) that was filled with NORs by dividing the observed NOR by the modeled maximum number of NORs (K_R) that the habitat could support.

$$\boldsymbol{\tau = \frac{NOR_{obs}}{K_R}}$$

Note that 1-τ represents the unused portion of the carrying capacity and is the term that is multiplied by the exponential growth equation to derive the logistic growth equation. We included τ in the statistical analyses.

These two methods require the estimation of carrying capacity (K_R) and the spawning abundance that produces the maximum number of recruits (K_{sp}). We estimated these parameters for both reference populations and the supplemented population using Ricker, Beverton-Holt, and smooth hockey stick stock-recruitment models. We used only spawner abundance as a predictor of subsequent brood recruitment. We made the following assumptions in proceeding with the analysis:

- *Density-dependent mortality*—For some time period before recruitment, the brood instantaneous mortality rate is proportional to the number of parent spawners (Ricker 1954).
- *Lognormal variation*—At any particular spawning stock size, the variation in recruitment is log-normally distributed about its average, and acts multiplicatively (Quinn and Deriso 1999).
- *Measurement error*—Error in spawning stock size estimates (measurement error) is small relative to the range of spawning stock sizes observed (Hilborn and Walters 1992). Variation in realized recruitment at any particular spawning stock size (process error) dominates recruitment measurement error.
- *Stationarity*—The average stock-recruitment relationship is constant over time (Hilborn and Walters 1992). That is, environmental conditions randomly affect survival independent of stock size or time.

In general, the methods we used to fit the models to the data followed those outlined in Hilborn and Walters (1992) and Froese (2008). The Ricker model, which assumes that the number of recruits increases to a maximum and then declines as the number of spawners increases, takes the form:

$$\boldsymbol{E(R) = \alpha S e^{-\beta S}}$$

where E(R) is the expected recruitment, S is spawner abundance, α is the number of recruits per spawner at low spawning levels, and β describes how quickly the recruits per spawner drop as the number of spawners increases. We estimated K_R as:

$$\boldsymbol{K_R = \left(\frac{\alpha}{\beta}\right) e^{-1}}$$

and K_{sp} as:

$$\boldsymbol{K_{sp} = \frac{1}{\beta}}$$

The Beverton-Holt model assumes that the number of recruits increases constantly toward an asymptote as the number of spawners increases. After the asymptote is reached, the number of recruits neither increases nor decreases. The asymptote represents the maximum number of recruits the system can support (i.e., carrying capacity for the system; K_R). The Beverton-Holt curve takes the form:

$$\boldsymbol{E(R) = \frac{(\alpha S)}{(\beta + S)}}$$

where E(R) and S are as above, α is the maximum number of recruits produced (K_R), and β is the number of spawners needed to produce (on average) recruits equal to one-half the maximum number of recruits. Because $K_{sp} = \infty$ in the Beverton-Holt model, we estimated K_{sp} as the number of spawners needed to produce $0.99(K_R)$.

Like the Beverton-Holt model, the smooth hockey stick model assumes that the number of recruits increases toward an asymptote (carrying capacity; K_R) as the number of spawners increases. After the carrying capacity is reached, the number of recruits neither increases nor decreases. The carrying capacity represents the maximum number of recruits the system can support. This curve

takes the form (Froese 2008):

$$E(R) = R_{\infty}\left(1 - e^{-\left(\frac{\alpha}{R\infty}\right)S}\right)$$

where E(R) and S are as above, α is the slope at the origin of the spawner-recruitment curve, and R_{∞} is the carrying capacity of recruits (note that $R_{\infty} = K_R$). As with the Beverton-Holt model, we estimated K_{sp} as the number of spawners needed to produce $0.99(K_R)$.

We used non-linear regression to fit the three models to spawner-recruitment data. Before fitting the models, we transformed recruitment data using natural logs. We estimated bias and uncertainty measures (95% CI) for the model parameters using bootstrap procedures, which assumed that the {R, S} sample represented or approximated the population. The number of bootstrap samples was 3,000. We computed and stored the non-linear regression results for each bootstrap sample. We then calculated the bootstrap 95% CI by arranging the 3,000 bootstrap parameter values in sorted order and selected the 2.5 and 97.5 percentiles from the list.

We used Akaike's Information Criterion for small sample size (AIC_c) to determine which model(s) best explained the relationship between spawners and recruitment in the supplemented and reference populations. AIC_c was estimated as:

$$AIC_c = -2log\left(£(\theta|data)\right) + 2K + \left(\frac{2K(K+1)}{n-K-1}\right)$$

where $log(£(\theta|data))$ is the maximum likelihood estimate, K is the number of estimable parameters (structural parameters plus the residual variance parameter), and n is the sample size (Burnham and Anderson 2002). We used least-squares methods to estimate $log(£(\theta|data))$, which was calculated as $log(\sigma^2)$, where σ^2 = residual sum of squares divided by the sample size ($\sigma^2 = RSS/n$). AIC_c assessed model fit in relation to model complexity (number of parameters). The model with the smallest AIC_c value represented the "best approximating" model within the model set. Remaining models were ranked relative to the best model using AIC_c difference scores (ΔAIC_c), Akaike weights (w_i), and evidence ratios. Models with ΔAIC_c values less than 2 indicated that there is substantial support for these models as being the best-fitting models within the set (Burnham and Anderson 2002). Models with values greater than 2 had less support. Akaike weights are probabilities estimating the strength of the evidence supporting a particular model as being the best model within the model set. Models with small w_i values are less plausible as competing models (Burnham and Anderson 2002). If no single model could be specified as the best model, a "best subset" of competing models was identified using (1) AIC_c differences to indicate the level of empirical support each model had as being the best model, (2) evidence ratios based on Akaike weights to indicate the relative probability that any model is the best model, and (3) coefficients of determination (R^2) assessing the explanatory power of each model.

Stock-Recruitment Analysis

We successfully fit stock-recruitment models to the Chiwawa and reference population data. The span of spawner data for the Chiwawa and reference populations was greater than 14 times the minimum observed spawners, which should provide sufficient contrast for estimation of model parameters. In addition, the span of recruitment data was greater than 12 times the minimum observed recruitment, again providing sufficient contrast for estimation of parameters. The relationship between natural log R/S and spawners indicated that some of the highest productivities occurred at the lower spawner levels and the lowest productivities generally occurred at the highest spawner levels (Figure 15). This is consistent with the assumption of density-dependent mortality.

Although model fits were generally poor, explaining less than 40% of the residual variation in natural-log recruitment data, we were able to estimate average maximum recruitment levels (K_R) and the spawning levels needed to produce maximum recruitment (K_{sp}) (Table 24; Figure 15). For all populations examined, Akaike information criterion was unable to identify a best approximating model (i.e., ΔAIC_c values were less than 2, indicating support for all three models). However, evaluation of 95% CIs and the asymptotic correlation coefficients indicated that the smooth hockey stick model may be the best approximating model for each population. Therefore, we used estimates of K_R and K_{sp} derived from the smooth hockey stick model to correct for density dependence and different carrying capacities in treatment-reference comparisons.

As part of the regression diagnostics, we examined the dependence of the model residuals on time and found a significant ($P < 0.05$), positive, one-year-lag autocorrelation for the Entiat (0.562), Marsh (0.551), Sesech (0.564), and Little Wenatchee (0.629) populations. For the purposes of our work here, we did not attempt to correct for this one-year-lag correlation in the residuals. Future analyses will explore the use of autoregressive models (e.g., AR1; Noakes et al. 1987) to correct for autocorrelation.

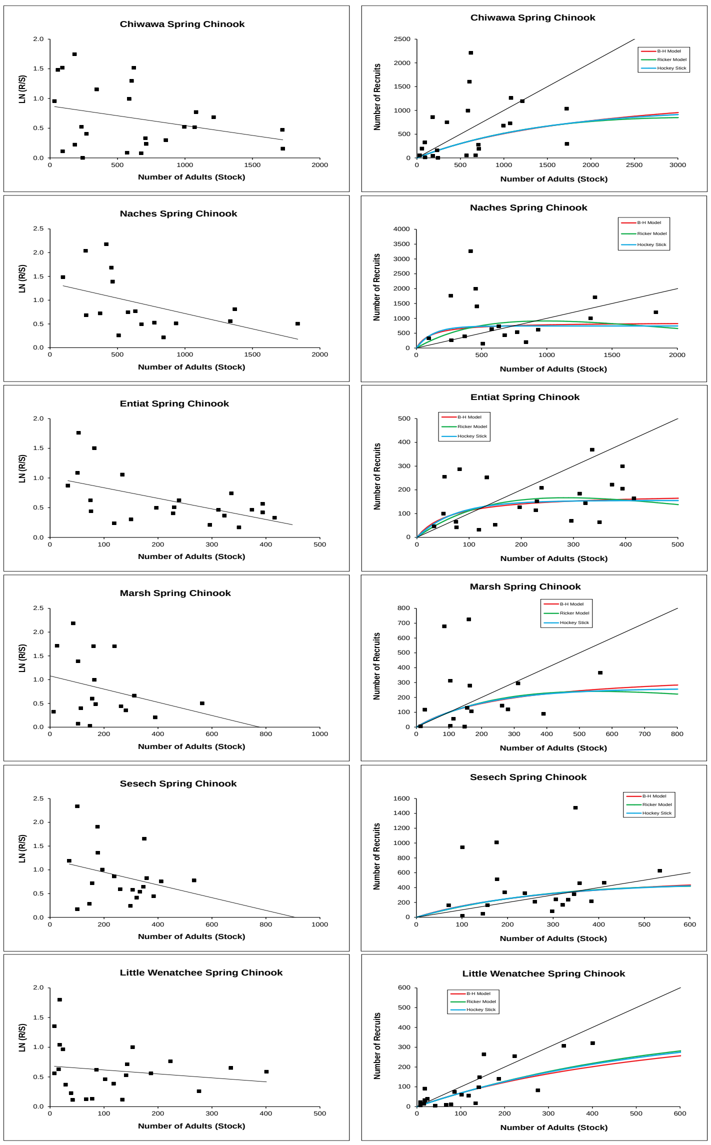


Figure 15. Relationships between natural log recruits/spawner (LN R/S) and spawners (Stock) in the Chiwawa and reference populations (figures on the left) and relationships between numbers of untransformed recruits and spawners in the Chiwawa and reference populations (figures on the right). Figures on the right also show the fit of the Ricker, Beverton-Holt, and the smooth hockey stick models to the data (black straight line represents R=S).

Table 24. Results from fitting Ricker, Beverton-Holt, and smooth hockey stick models to stock-recruitment data from the Chiwawa and reference populations. 95% CI on parameter estimates are based on 3,000 bootstrap trials; Corr coef = asymptotic correlation of the parameter estimates; K_R = maximum natural origin recruits (recruits at carrying capacity); K_{sp} = number of spawners needed to produce K_R; AICc = Akaike's Information Criterion for small sample size; Adj R^2 = coefficient of determination that is adjusted for the number of parameters in the model.

Model	Parameter	Parameter value	Bootstrap 95% CI	Corr coef	K_R	K_{sp}	AICc	Adj R^2
Chiwawa Population								
Ricker	α	0.7048	-0.6197 1.1055	0.791	852	3,285	-47.949	0.125
	β	0.000304	-0.000668 0.000609					
Beverton-Holt	α	1687.4	-65654539 3062.1	0.989	1,687	43,760	-47.962	0.125
	β	2308.5	-99999538 4526.1					
Smooth hockey stick	α	6.956	-41.313 8.2270	-0.708	1,049	6,847	-47.949	0.125
	β	0.7118	-2.397 1.122					
Naches Population								
Ricker	α	2.5223	-2.0003 3.9672	0.844	912	983	-45.063	-0.143
	β	0.001018	-0.000752 0.001717					
Beverton-Holt	α	869.4	97.4 1641.4	0.858	869	11,455	-46.801	-0.097
	β	111.8	-346.2 569.8					
Smooth hockey stick	α	6.612	5.9223 7.006	-0.399	744	565	-46.831	-0.095
	β	6.013	-89.071 12.026					
Entiat Population								
Ricker	α	1.5843	0.1609 2.4178	0.867	167	286	-68.365	-0.049
	β	0.003496	0.001141 0.005906					
Beverton-Holt	α	186.1	67.9 304.3	0.880	186	1,277	-69.895	0.029
	β	65.0	-59.1 189.2					
Smooth hockey stick	α	5.045	4.381 5.378	-0.450	155	344	-69.379	0.003
	β	2.180	-89.369 3.704					
Marsh Creek Population								
Ricker	α	1.1852	-1.8268 1.9269	0.823	241	552	-32.237	0.218

Model	Parameter	Parameter value	Bootstrap 95% CI	Corr coef	K_R	K_{sp}	AICc	Adj R^2
	β	0.001810	-0.003063 0.003625					
Beverton-Holt	α	383.3	-85109314 665.4	0.970	383	5,310	-32.291	0.234
	β	282.4	-99999944 564.9					
Smooth hockey stick	α	5.565	-22.631 6.584	-0.694	261	984	-32.264	0.227
	β	1.265	-108.574 2.531					
Sesech Population								
Ricker	α	1.6835	-2.9253 2.5951	0.912	421	680	-54.589	-0.005
	β	0.001470	-0.002951 0.002941					
Beverton-Holt	α	689.9	-986.8 2366.7	0.981	690	6,591	-54.678	0.000
	β	351.7	-1059.0 1762.5					
Smooth hockey stick	α	6.1528	-22.851 6.815	-0.821	470	1,185	-54.633	-0.002
	β	0.8000	-119.370 2.909					
Little Wenatchee Population								
Ricker	α	0.7447	0.0828 1.0280	0.735	356	1,298	-66.978	0.357
	β	0.000770	-0.003052 0.001541					
Beverton-Holt	α	564.7	-74423355 1067.6	0.994	565	13,400	-67.055	0.358
	β	719.7	-99999856 1413.4					
Smooth hockey stick	α	6.0181	-49.5620 8.1122	-0.683	411	2,544	-67.000	0.357
	β	0.7550	-0.9539 1.0452					

Method 1: Productivity Data Adjusted for Density Dependence

Analysis of supplementation effects on productivity (adult recruits/spawner adjusted for density-dependent effects based on the smooth hockey stick model) using difference scores indicated that supplementation did not significantly decrease productivity in the Chiwawa Basin (Table 25; Figure 16). All tests, regardless of treatment-reference pairs, indicated that productivity did not change significantly during the supplementation period, even though productivity did decrease during the supplementation period (Figure 16). These results are consistent with those based on unadjusted productivity data (Table 17). This is because most abundance estimates were below the level of assumed density dependence.

Table 25. Results of the Aspin-Welch unequal-variance test, randomization test (based on 10,000 Monte Carlo samples), and 95% CI (based on 5,000 bootstrap samples) on transformed and untransformed productivity data corrected for density dependence. Tests determined if the mean difference scores during the supplementation period were greater than mean difference scores during the pre-supplementation period.

Reference population	Aspin-Welch unequal-variance test			Randomization test P-value	Bootstrap 95% CI
	t-value	P-value	Effect size		
Productivity					
Naches	0.904	0.190	0.496	0.412	-0.511 – 1.497
Marsh	-0.203	0.579	0.152	0.927	-1.298 – 1.372
Sesech	1.607	0.071	1.435	0.146	-0.359 – 2.911
Little Wenatchee	0.431	0.335	0.147	0.668	-0.487 – 0.781
LN Productivity					
Naches	0.570	0.290	0.083	0.568	-0.168 – 0.362
Marsh	0.012	0.495	0.003	0.991	-0.373 – 0.480
Sesech	1.463	0.087	0.343	0.171	-0.125 – 0.732
Little Wenatchee	0.390	0.351	0.060	0.709	-0.218 – 0.365

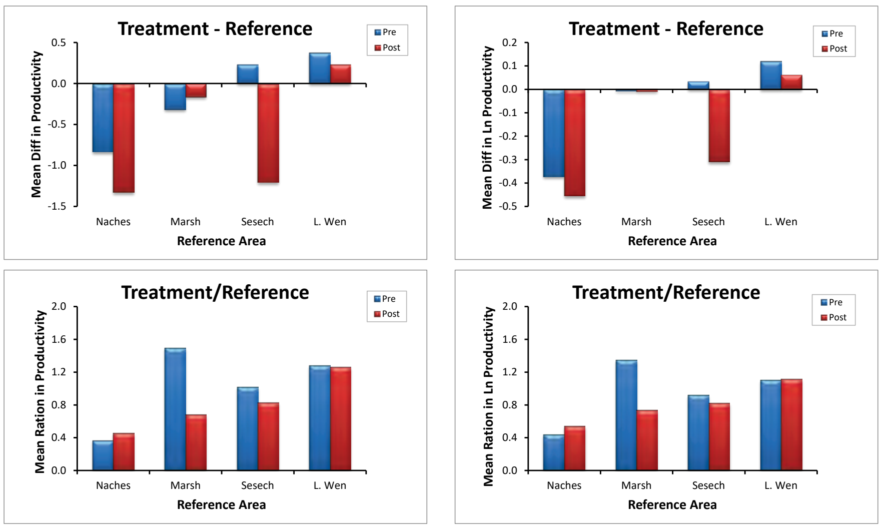


Figure 16. Mean differences (Treatment – Reference; figures on the top) and mean ratios (Treatment/Reference; figures on the bottom) of transformed and untransformed productivity data (adjusted for density dependence) before (pre) and after (post) spring Chinook supplementation in the Chiwawa Basin. Negative effects of supplementation on productivity are indicated when the pre-supplementation (blue) bars are greater than their corresponding post-supplementation (red) bars.

Analysis of supplementation effects on productivity (adult recruits/spawner adjusted for density-dependent effects) using ratios indicated that supplementation did not significantly decrease productivity in the Chiwawa Basin (Table 26; Figure 16). The Aspin-Welch test and the 95% CIs did indicate a significant effect when comparing the Chiwawa to the Marsh Creek population. These results are consistent with those using unadjusted productivity data (Table 20). Again, this is because most abundance estimates were below the level of assumed density dependence.

Table 26. Results of the Aspin-Welch unequal-variance test, randomization test (based on 10,000 Monte Carlo samples), and 95% CI (based on 5,000 bootstrap samples) on transformed and untransformed productivity data corrected for density dependence. Tests determined if the mean ratios during the supplementation period were less than mean ratios during the pre-supplementation period.

Reference population	Aspin-Welch unequal-variance test			Randomization test	Bootstrap 95% CI
	t-value	P-value	Effect size	P-value	
Productivity					
Naches	-0.529	0.696	0.087	0.597	-0.394 – 0.214
Marsh	2.236	0.022	0.814	0.056	0.140 – 1.470
Sesech	0.677	0.253	0.191	0.496	-0.343 – 0.727
Little Wenatchee	0.033	0.487	0.018	0.978	-0.902 – 1.181
LN Productivity					
Naches	-0.621	0.726	0.104	0.536	-0.406 – 0.191

Reference population	Aspin-Welch unequal-variance test			Randomization test P-value	Bootstrap 95% CI
	t-value	P-value	Effect size		
Marsh	1.952	0.036	0.613	0.076	0.005 – 1.163
Sesech	0.447	0.330	0.098	0.649	-0.312 – 0.498
Little Wenatchee	-0.034	0.513	0.015	0.980	-0.697 – 0.852

Our analyses assume that there is a spawner abundance (K_{sp}) at which density-independent effects end and density-dependent effects begin. In reality, density-dependent effects occur at low spawning abundance and intensify as spawning abundance increases (evident in the changing slope of the three stock-recruitment curves used in our analyses). We did not account for these increasing density-dependent effects at spawner abundances less than K_{sp}. If we accounted for the increasing effects of density dependence at spawning abundances less than K_{sp}, the analysis with and without productivity adjustments may give different results.

Method 2: Fraction of Carrying Capacity Filled with NORs

We analyzed the effects of supplementation on filling the capacity of the habitat with natural-origin recruits. The smooth hockey stick model derived the carrying capacity (K_R) estimates for the Chiwawa and reference populations. The fraction of the carrying capacity filled with Chinook recruits before and during supplementation for the Chiwawa and reference populations is provided in Table 27. These data indicate that for the Chiwawa population, the mean fraction of the K_R filled with fish decreased significantly from the pre-supplementation period through the supplementation period (Table 27). Likewise, the Entiat and Little Wenatchee populations showed a significant decline in the mean fraction of K_R filled with adult recruits. In contrast, the mean fraction of K_R in the Naches and Marsh Creek populations increased during the same period (Table 27).[22] Interestingly, the fraction of K_R filled with adult recruits for all populations trended downward during the pre-supplementation period (Figure 17). During the supplementation period, however, the fraction of K_R filled with adult recruits trended upward for all populations. These results suggest that agents of mortality outside the Chiwawa and reference populations were reducing recruitment to the populations.

22 Although we do not show the results here, statistical analysis of the mean fraction of carrying capacity filled by adult recruits using natural-log transformed data produced the same result as using untransformed data. This was true for all populations.

Table 27. Fraction of the carrying capacity that was filled with Chinook salmon adult recruits in the Chiwawa and reference populations before (pre) and during (post) supplementation in Chiwawa Basin. The smooth hockey stick model estimated carrying capacity for each population. Statistical results from comparing the pre and post mean scores using the Aspin-Welch unequal-variance test are provided at the bottom of the table.

Supplementation period	Chiwawa	Reference populations			
		Naches	Entiat	Marsh	L. Wenatchee
Pre-supplementation period (1981-1992)	2.11		2.38	1.07	0.64
	1.53		1.93	1.20	0.75
	1.20		1.32	2.60	0.78
	1.14		1.19	0.49	0.62
	0.99		1.06	0.46	0.34
	0.70	2.30	1.43	0.56	0.24
	0.65	0.58	0.74	0.34	0.20
	0.95	1.88	1.34	1.40	0.36
	0.18	0.72	1.63	0.22	0.15
	0.05	0.27	0.45	0.02	0.02
	0.00	0.20	0.21	0.03	0.01
Pre-Mean:	0.86	0.99	1.24	0.76	0.37
Pre-Range:	0.00 – 2.11	0.20 – 2.30	0.21 – 2.38	0.02 – 2.60	0.01 – 0.78
Post-supplementation period (1992-2002)	0.05	0.98	0.34	0.41	0.03
	0.15	0.86	0.41	1.13	0.04
	0.04	0.35	0.27	0.02	0.03
	0.05	0.44	0.30	0.02	0.03
	0.19	4.39	0.65	0.45	0.06
	0.82	2.68	1.85	2.78	0.22
	0.31	2.37	1.65	4.10	0.08
	0.01	0.53	0.42		0.02
	0.71	1.62	0.82		0.10
	0.28	1.35	0.93		0.14
	0.27	0.83	0.98		0.18
Post-Mean:	0.26	1.49	0.78	1.27	0.08
Post-Range:	0.04 – 0.82	0.35 – 4.39	0.30 – 1.85	0.02 – 4.10	0.02 – 0.22
One-sided Aspin-Welch t-test of pre and post means	t = 2.846; P = 0.007	t = -0.967; P = 0.825	t = 1.833; P = 0.041	t = -0.799; P = 0.776	t = 3.321; P = 0.003

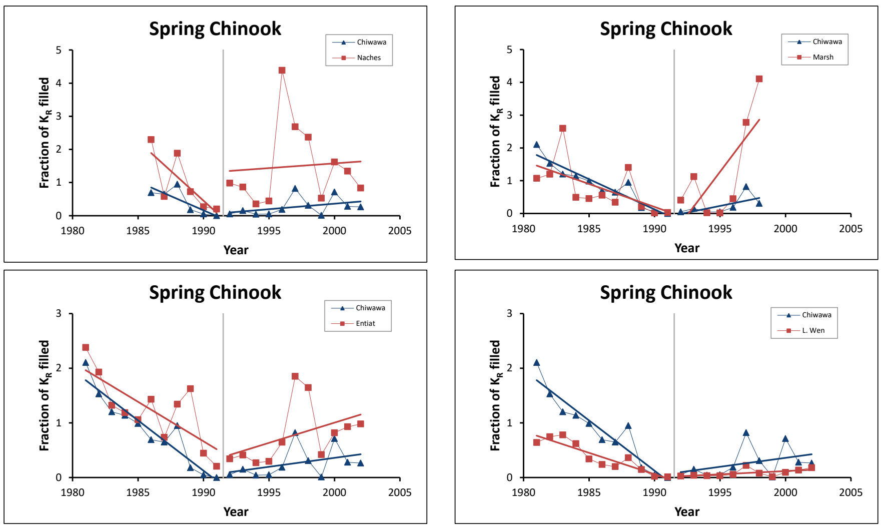


Figure 17. Trends in the fraction of the carrying capacity that was filled with Chinook salmon adult recruits in the Chiwawa and reference populations before (pre) and during (post) supplementation in Chiwawa Basin. The vertical lines in the figures separate the pre- and post-supplementation periods. The smooth hockey stick model estimated carrying capacity for each population.

We then compared the mean difference scores and ratios between the Chiwawa and reference populations before and during supplementation using data representing the fraction of K_R filled with adult recruits. In most of the Chiwawa-reference population comparisons, the absolute value of the mean difference between the fraction of K_R filled with recruits was greater in the supplementation period than during the pre-supplementation period; two of the four pairings were significant (Table 28; Figure 18). Analysis of difference scores using natural-log transformed data indicated that three of the four pairings were significant (Table 28).

Results from analyses using ratios were similar to results using difference scores. Mean ratio scores were generally smaller during the supplementation period than during the pre-supplementation period (Figure 18). This indicated that the mean fraction of K_R filled by adult recruits in most reference populations was greater during the supplementation period than during the pre-supplementation period (i.e., the denominator in the ratio increased between the pre- and post-supplementation periods). In contrast, the fraction of K_R filled by adult recruits in the Chiwawa decreased from the pre- to post-supplementation period (i.e., the numerator in the ratio decreased between the pre- and post-supplementation periods). Thus, unlike the Chiwawa population, the capacity of most reference populations was becoming more saturated during the period when the Chiwawa was being supplemented. Statistical analysis with mean ratios indicated that two of the four pairings were significant (Table 29).

Analyses comparing the Little Wenatchee with the Chiwawa indicate that adult recruits to the Little Wenatchee have been well below its carrying capacity. During the pre-supplementation period, the capacity of the Little Wenatchee was on average 37% saturated with adult recruits. During the supplementation period, the capacity of the Little Wenatchee declined to 8% saturation

with adult recruits (a 22% decline). The Chiwawa, during the pre-supplementation period, was on average 86% saturated. During the supplementation period, percent saturation in the Chiwawa decreased to 26% (a 30% decrease). During the same time periods, the capacity of the Entiat population, which until recently has been supplemented, declined from 124% to 78% saturation (a 63% decline).

Table 28. Results of the Aspin-Welch unequal-variance test, randomization test (based on 10,000 Monte Carlo samples), and 95% CI (based on 5,000 bootstrap samples) on the fraction of the habitat capacity (K_R) that is filled with natural origin recruits. Analyses include both transformed and untransformed data. Tests determined if the mean difference scores during the supplementation period were greater than mean difference scores during the pre-supplementation period.

Reference population	Aspin-Welch unequal-variance test			Randomization test P-value	Bootstrap 95% CI
	t-value	P-value	Effect size		
Fraction of Capacity Filled					
Naches	1.550	0.071	0.657	0.145	-0.173 – 1.378
Entiat	0.835	0.207	0.141	0.422	-0.167 – 0.475
Marsh	2.026	0.040	1.141	0.055	0.064 – 2.054
Little Wenatchee	2.166	0.023	0.310	0.031	0.035 – 0.569
LN Fraction of Capacity Filled					
Naches	2.123	0.026	0.311	0.039	0.031 – 0.575
Entiat	1.405	0.087	0.122	0.176	-0.034 – 0.289
Marsh	2.547	0.017	0.519	0.017	0.125 – 0.864
Little Wenatchee	1.744	0.049	0.130	0.100	-0.004 – 0.273

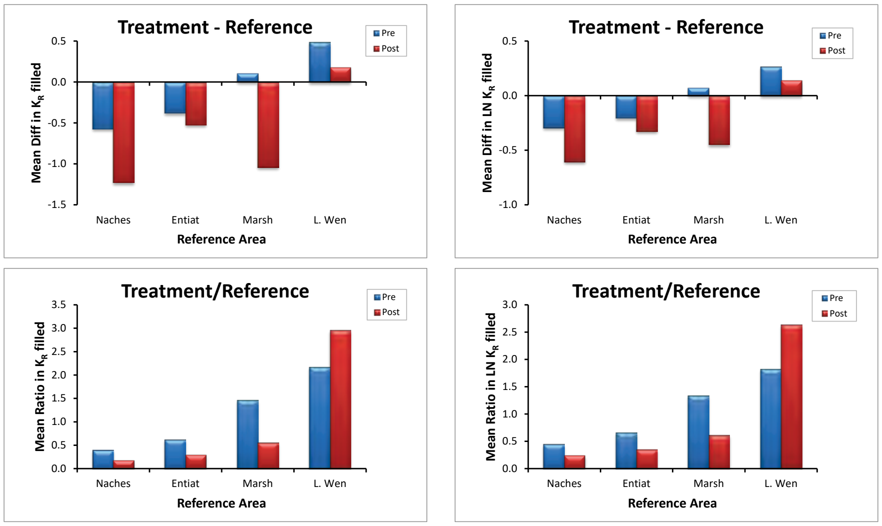


Figure 18. Mean differences (Treatment – Reference; figures on the top) and mean ratios (Treatment/Reference; figures on the bottom) of transformed and untransformed fractions of carrying capacity filled with adult recruits before (pre) and after (post) spring Chinook supplementation in the Chiwawa Basin.

Table 29. Results of the Aspin-Welch unequal-variance test, randomization test (based on 10,000 Monte Carlo samples), and 95% CI (based on 5,000 bootstrap samples) on the fraction of the habitat capacity (K_R) that is filled with natural origin recruits. Analyses include both transformed and untransformed data. Tests determined if the mean ratios during the supplementation period were less than mean ratios during the pre-supplementation period.

Reference population	Aspin-Welch unequal-variance test			Randomization test P-value	Bootstrap 95% CI
	t-value	P-value	Effect size		
Fraction of Capacity Filled					
Naches	1.317	0.119	0.217	0.219	-0.103 – 0.482
Entiat	2.449	0.013	0.321	0.028	0.085 – 0.577
Marsh	2.001	0.035	0.905	0.070	0.138 – 1.788
Little Wenatchee	-1.148	0.864	0.791	0.278	-1.979 – 0.578
LN Fraction of Capacity Filled					
Naches	1.257	0.127	0.207	0.249	-0.099 – 0.484
Entiat	2.346	0.016	0.313	0.031	0.072 – 0.583
Marsh	1.737	0.056	0.729	0.111	0.028 – 1.531
Little Wenatchee	-1.525	0.924	0.815	0.142	-1.751 – 0.195

Comparing Stock-Recruitment Curves

As a final set of treatment and reference population comparisons, we compared the stock-recruitment curves of the Chiwawa population (using {R, S} data only from the supplementation period) to the reference populations (using all available {R, S} data). Specifically, we tested whether the regression parameters were equal between the Chiwawa population and the reference populations, and whether the fitted curves coincided between populations. Earlier in this report we described the data, methods, and results of fitting the Ricker, Beverton-Holt, and smooth hockey stick curves to the data. Because AIC_c was unable to identify a best approximating model, here we included all three models in our analyses. We tested the following hypotheses.

Parameter equivalence:

Ho: Stock-recruitment parameters (α and β) of the Chiwawa population = Stock-recruitment parameters of the reference populations.

Ha: Stock-recruitment parameters (α and β) of the Chiwawa population ≠ Stock-recruitment parameters of the reference populations.

Curve equivalence:

Ho: Modeled stock-recruitment curves of the Chiwawa population = Modeled stock-recruitment curves of the reference populations.

Ha: Modeled stock-recruitment curves of the Chiwawa population ≠ Modeled stock-recruitment curves of the reference populations.

We used two-sided randomization tests to test the null hypotheses of equal model parameters and that fitted curves coincided. Because the total number of permutations was in the millions, we used a Monte Carlo approach to randomly select 10,000 permutations. The test statistic for comparing the model parameters was formed by summing the difference between the population parameter estimates for each pair of populations. The test statistic for comparing the whole curve was formed by summing the difference between the estimated predicted values for each pair of populations at 500 equally spaced points along the curve.

Ricker Relationships

Ricker curves differed significantly between the Chiwawa and reference populations (Figure 19; Table 30). Interestingly, however, the parameters in the Ricker model did not differ significantly among most populations (Table 30). Only the β parameter differed significantly between the Chiwawa and Entiat populations.

In the Ricker model, the α parameter represents intrinsic productivity (i.e., recruits per spawner at low spawner densities). In this analysis, there was not enough evidence in the stock-recruitment data to reject the hypothesis of inequality in intrinsic productivity. Thus, this test was unable to demonstrate that supplementation, based on the Ricker curve, affected productivity in the Chiwawa population.

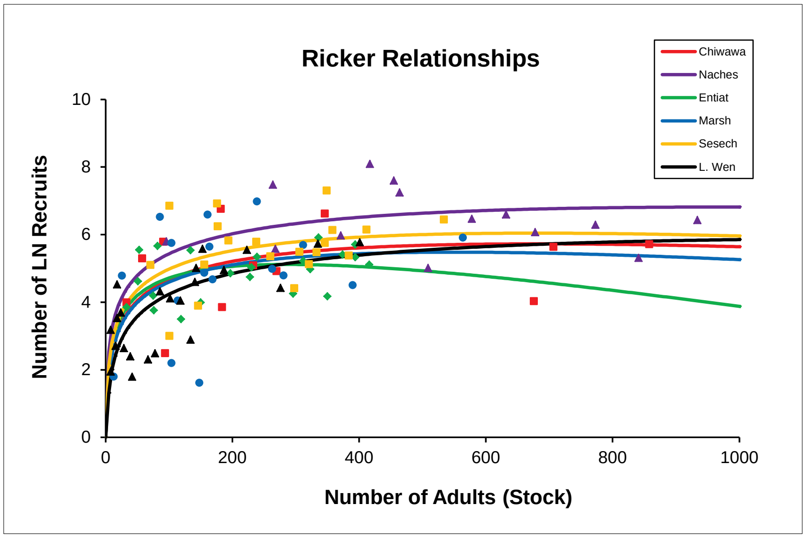


Figure 19. Scatter plot of the number of spawners and natural log adult recruits and fitted Ricker curves to the Chiwawa (supplemented population) and reference (un-supplemented) populations.

Table 30. Randomization test results comparing the equality of Ricker curves and equality of parameter values (α and β). Randomization tests were based on 10,000 Monte Carlo samples. Equality or curves was based on 500 points along the x-axis (spawner abundance axis).

Curves tested	Curve inequality randomization P-value	Parameter inequality		
		Model Parameter		Randomization P-value
		Chiwawa	Reference	
Chiwawa v. Naches	0.008	α = 1.2247	α = 2.5267	0.236
		β = 0.0015	β = 0.0010	0.600
Chiwawa v. Entiat	0.004	α = 1.2247	α = 1.5836	0.978
		β = 0.0015	β = 0.0035	0.025
Chiwawa v. Marsh	0.034	α = 1.2247	α = 1.1855	0.997
		β = 0.0015	β = 0.0018	0.688
Chiwawa v. Sesech	0.036	α = 1.2247	α = 1.6818	0.972
		β = 0.0015	β = 0.0015	0.997
Chiwawa v. L. Wenatchee	0.034	α = 1.2247	α = 0.7439	0.969
		β = 0.0015	β = 0.0008	0.203

Beverton-Holt Relationships

Beverton-Holt curves differed significantly only between the Chiwawa and Naches populations (Figure 20; Table 31). There was no significant difference in curves between the Chiwawa and the other reference populations. The parameters in the Beverton-Holt model did not differ significantly among any of the populations (Table 31). This was true even for the Chiwawa and Naches populations.

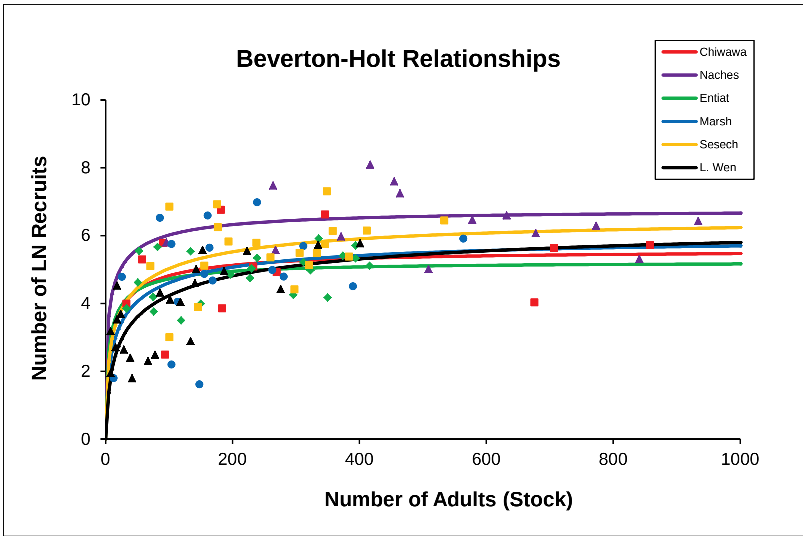


Figure 20. Scatter plot of the number of spawners and natural log adult recruits and fitted Beverton-Holt curves to the Chiwawa (supplemented population) and reference (un-supplemented) populations.

Table 31. Randomization test results comparing the equality of Beverton-Holt curves and equality of parameter values (α and β). Randomization tests were based on 10,000 Monte Carlo samples. Equality or curves was based on 500 points along the x-axis (spawner abundance axis).

Curves tested	Curve inequality randomization P-value	Parameter inequality		
		Model Parameter		Randomization P-value
		Chiwawa	Reference	
Chiwawa v. Naches	0.036	α = 264.25	α = 870.62	0.777
		β = 113.79	β = 112.24	0.963
Chiwawa v. Entiat	0.746	α = 264.25	α = 186.34	0.960
		β = 113.79	β = 65.33	0.954
Chiwawa v. Marsh	0.850	α = 264.25	α = 381.79	0.944
		β = 113.79	β = 281.04	0.891

Curves tested	Curve inequality randomization P-value	Parameter inequality		
		Model Parameter		Randomization P-value
		Chiwawa	Reference	
Chiwawa v. Sesech	0.272	α = 264.25	α = 689.31	0.821
		β = 113.79	β = 351.59	0.869
Chiwawa v. L. Wenatchee	0.654	α = 264.25	α = 568.69	0.864
		β = 113.79	β = 725.87	0.751

Smooth Hockey Stick Relationships

Smooth hockey stick curves differed significantly between the Chiwawa and Naches populations and the Chiwawa and Sesech populations (Figure 21; Table 32). There was no significant difference in curves between the Chiwawa and the other reference populations. Most of the parameters in the smooth hockey stick model did not differ significantly among the populations (Table 32). However, the productivity parameter β did differ significantly between the Chiwawa and the Naches and the Chiwawa and Little Wenatchee populations. The β parameter for the Naches was significantly greater than the Chiwawa, while the β parameter for the Little Wenatchee was significantly less than the Chiwawa.

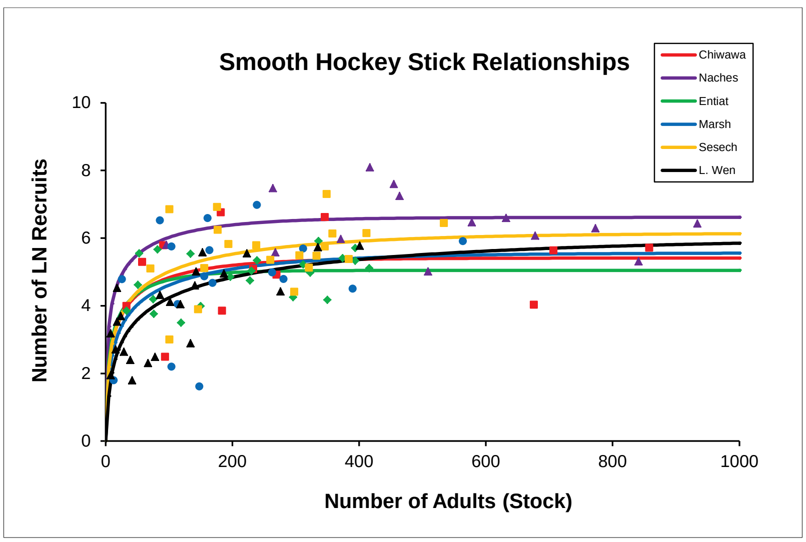


Figure 21. Scatter plot of the number of spawners and natural log adult recruits and fitted smooth hockey stick curves to the Chiwawa (supplemented population) and reference (un-supplemented) populations.

Table 32. Randomization test results comparing the equality of smooth hockey stick curves and equality of parameter values (α and β). Randomization tests were based on 10,000 Monte Carlo samples. Equality or curves was based on 500 points along the x-axis (spawner abundance axis).

Curves tested	Curve inequality randomization P-value	Parameter inequality		
		Model Parameter		Randomization P-value
		Chiwawa	Reference	
Chiwawa v. Naches	0.000	α = 5.41	α = 6.61	0.000
		β = 1.84	β = 5.99	0.000
Chiwawa v. Entiat	0.999	α = 5.41	α = 5.05	0.999
		β = 1.84	β = 2.17	0.999
Chiwawa v. Marsh	0.999	α = 5.41	α = 5.56	0.999
		β = 1.84	β = 1.27	0.999
Chiwawa v. Sesech	0.000	α = 5.41	α = 6.15	0.000
		β = 1.84	β = 1.80	0.999
Chiwawa v. L. Wenatchee	0.990	α = 5.41	α = 6.02	0.999
		β = 1.84	β = 0.75	0.000

Comparing different stock-recruitment curves and their parameters did not provide strong evidence that the supplementation program has negatively affected the productivity of the Chiwawa population.

Analysis without Reference Populations

In some cases, suitable reference populations may not exist to compare with supplemented populations. It is therefore important to have alternative analyses to assess supplementation effects. In this section, we describe methods that can be used to assess supplementation effects when suitable reference populations are not available. We discuss before-after comparisons, correlation analysis, and comparisons to standards as alternatives when reference populations are unavailable.

Before-After Comparisons

Before-after analyses compare population metrics (spawner abundance, NORs, and productivity) before supplementation to those during supplementation. In this case, data collected before supplementation represent the reference condition. The assumption is that population trajectories measured during the pre-supplementation period would continue in the absence of supplementation. We compared trends in abundance and productivity, mean abundance and productivity, and stock-recruitment relationships before and after supplementation.

Trend Analysis

Comparing trends before and after supplementation can be used to assess the effects of supplementation. Here, we compared the slopes of trends of spawner abundance, NORs, and productivity before and during supplementation using t-tests. If the hatchery program is successfully supplementing the natural spring Chinook population, the trend for spawner abundance and NORs during supplementation should be greater than the slope during the pre-supplementation period. For productivity, the slope during the supplementation period should increase or remain the same as that during the pre-supplementation period.

Visual examination of trends of Chiwawa data indicates that spawner abundance, NORs, and productivity decreased during the pre-supplementation period, but increased during the supplementation period (Figure 22). Only the changes in NOR trends were significant (Figure 22). This was true for both transformed and untransformed data.

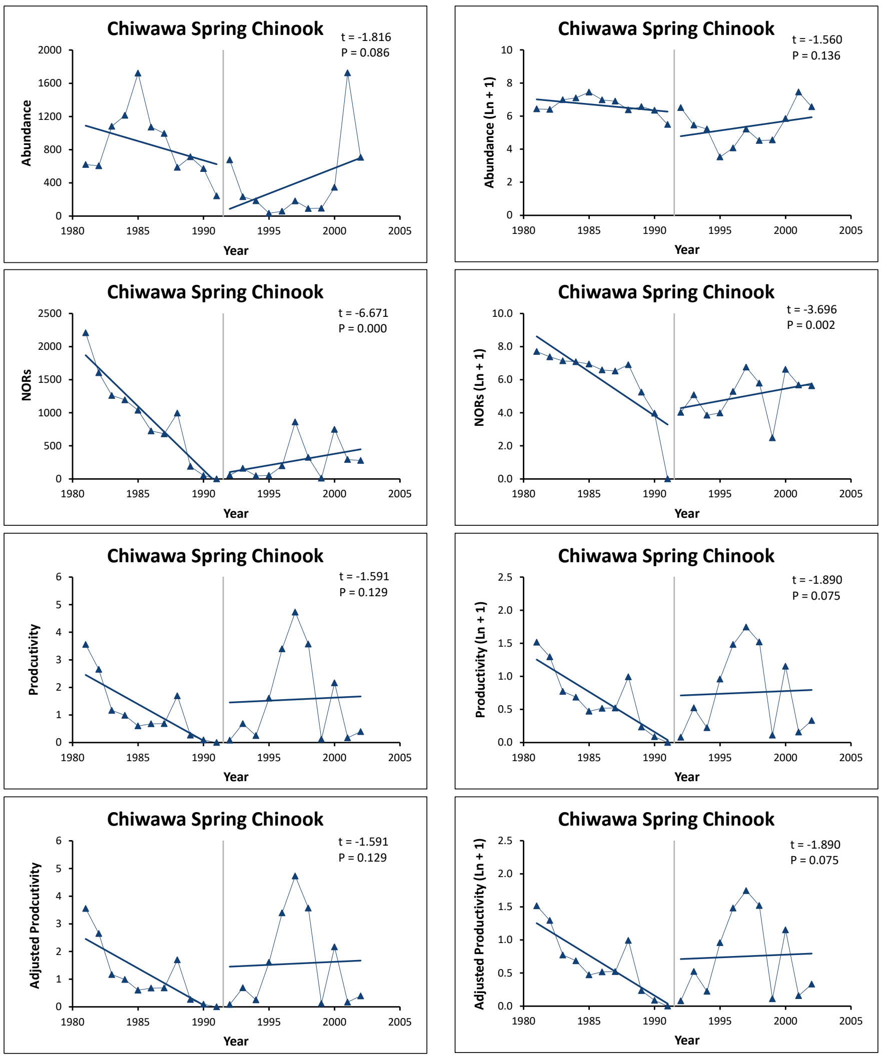


Figure 22. Trends in Chiwawa spring Chinook spawner abundance, natural-origin recruits (NORs), productivity (adults recruits per spawner), and adjusted productivity (adjusted for density dependence) before and during supplementation. The vertical lines in the figures separate the pre- and post-supplementation periods. Figures on the left show untransformed data; figures on the right include natural-log transformed data. Figures include results of t-tests comparing slope of trends before and during supplementation.

Analysis of Mean Scores

We also compared mean spawner abundance, NORs, and productivity data before and after supplementation. If the hatchery program is successfully supplementing the natural spring Chinook population, mean spawner abundance and NORs during the supplementation period should be greater than the pre-supplementation period. For productivity, the mean productivity during the supplementation period should be equal to or higher than the pre-supplementation period. We tested the following statistical hypotheses.

Spawner Abundance and NORs:

Ho: Mean spawner abundance and NORs before supplementation ≥ Mean spawner abundance and NORs during supplementation.

Ha: Mean spawner abundance and NORs before supplementation < Mean spawner abundance and NORs during supplementation.

Productivity (Recruits/Spawner):

Ho: Mean productivity before supplementation ≤ Mean productivity during supplementation.

Ha: Mean productivity before supplementation > Mean productivity during supplementation.

We tested before-after supplementation effects using a one-tailed Aspin-Welch unequal-variance test. We also used a randomization test, based on 10,000 Monte Carlo simulations, to assess differences in spawner abundance and productivity before and during supplementation. The randomization procedure only allowed the testing of two-tailed hypotheses. Therefore, we generated 95% confidence intervals on the mean difference (μ_{pre} - μ_{post}) using bootstrapping methods to determine if the significant result from the randomization test was in the right direction. We generated 5,000 bootstrap samples to calculate confidence intervals.

Mean spawner abundance during the supplementation period was significantly less than the pre-supplementation spawner abundance (Table 33). Mean spawner abundance decreased 46% between the pre- and post-supplementation periods. Likewise, mean NORs decreased significantly between the two periods (Table 33). On the other hand, productivity increased slightly, but not significantly, between the pre- and post-supplementation periods (Table 33). This was true for both adjusted and transformed productivity data.

Table 33. Statistical results comparing mean scores of spawner abundance, natural-origin recruits (NORs), and productivity (using both untransformed and natural-log transformed) before and during supplementation of Chiwawa spring Chinook. Randomization tests were based on 10,000 Monte Carlo samples and 95% CI were based on 5,000 bootstrap samples.

Population metric	Mean scores		Test on means			
			Aspin-Welch test		Random test P-value	Bootstrap 95% CI
	Before	During	t-value	P-value		
Abundance	856	393	2.383	0.986	0.028	112 - 843
LN Abundance	6.6	5.4	3.304	0.997	0.004	0.56 – 1.99
NORs	905	275	2.846	0.993	0.009	214 – 1034
LN NORs	6.0	5.0	1.197	0.876	0.250	-0.40 – 2.54
Productivity	1.13	1.56	-0.721	0.759	0.479	-1.55 – 0.73
LN Productivity	0.64	0.75	-0.450	0.671	0.649	-0.55 – 0.35
Adj Productivity	1.12	1.56	-0.721	0.759	0.477	-1.54 – 0.71
LN Adj Productivity	0.64	0.75	-0.450	0.671	0.652	-0.57 – 0.34

Analysis of Stock-Recruitment Curves

The third method compared stock-recruitment curves of the Chiwawa population during supplementation with those generated before supplementation. Specifically, we tested whether the regression parameters were equal between the pre- and post-supplementation periods, and whether the fitted curves coincided between the two time periods. We used the methods described earlier to fit the Ricker, Beverton-Holt, and smooth hockey stick curves to the two data sets. We tested the following hypotheses.

Parameter equivalence:

Ho: Stock-recruitment parameters (α and β) of the pre-supplementation period = Stock-recruitment parameters of the supplementation period.

Ha: Stock-recruitment parameters (α and β) of the pre-supplementation period $\neq$ Stock-recruitment parameters of the supplementation period.

Curve equivalence:

Ho: Modeled stock-recruitment curves from the pre-supplementation period = Modeled stock-recruitment curves from the pre-supplementation period.

Ha: Modeled stock-recruitment curves from the pre-supplementation period $\neq$ Modeled stock-recruitment curves from the pre-supplementation period.

We were only able to fit stock-recruitment curves to the post-supplementation data. Non-linear regression was unable to converge on a solution using only pre-supplementation data. Therefore, we were unable to use this method to test supplementation effects on the Chiwawa spring Chinook population. If we could have fit curves to both the pre- and post-supplementation periods, we would have used two-sided randomization tests to evaluate the null hypotheses of equal model parameters and that fitted curves coincided.

Before describing correlation approaches, it is important to note that comparing before-after data can sometimes be misleading. For example, the spawner abundance, NORs, and productivity data presented in Figure 22 suggest that supplementation is increasing the abundance and productivity of spring Chinook in the Chiwawa Basin. However, when we compared these trends to those from reference populations during the same time periods (Figures 9-11), it becomes clear that supplementation was not responsible for increasing the trends in spawner abundance, NORs, and productivity of the Chiwawa population. Thus, whenever possible, it is wise to compare before-after data with a reference population.

Correlation Analyses

A simple way to see if the supplementation program is increasing or decreasing productivity is to assess the association between the proportion of adult spawners that are made up of hatchery adults (pHOS) and productivity (recruits/spawner). If the supplementation program is working as planned, the increase in hatchery fish spawning naturally should increase the productivity of the population. It should not decrease the productivity of the population.

We tested the association between pHOS and adult productivity[23] using Pearson correlation. During the pre-supplementation period, productivity averaged 1.13 recruits/spawner; during the supplementation period, productivity averaged 1.39 recruits/spawner. This increase in productivity did not appear to be strongly correlated to pHOS (Figure 23). Correlation analysis showed that there was no significant association between pHOS and productivity, even though productivity increased with increasing pHOS.

[23] Note that the analysis could also include juvenile productivity (e.g., smolts/spawner).

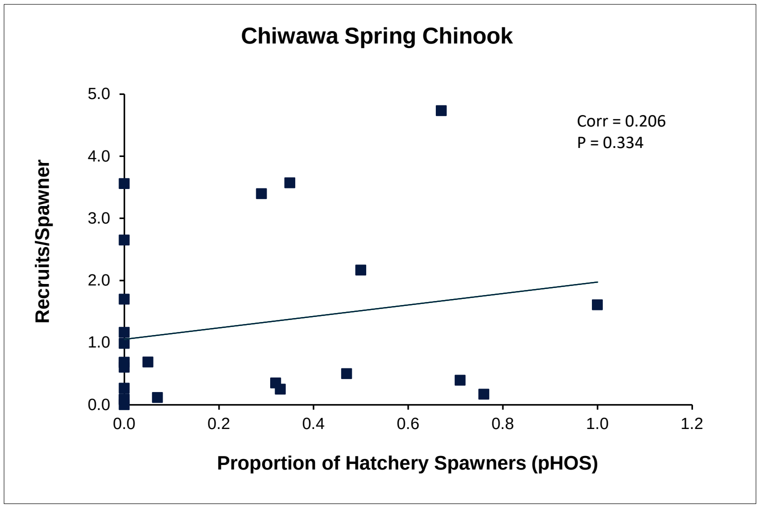
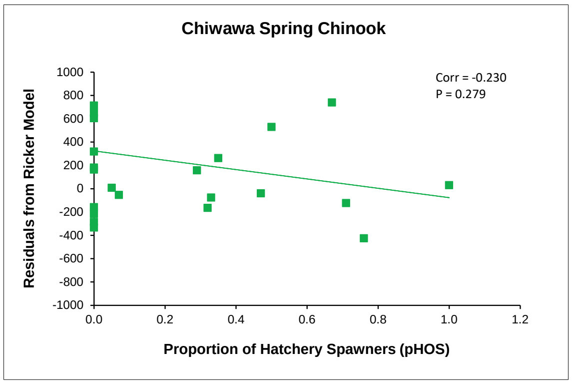


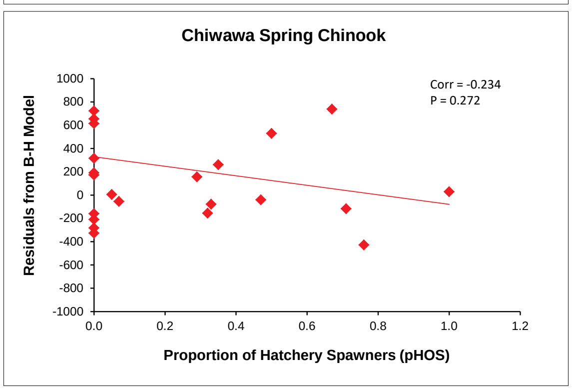
Figure 23. Association between the proportion of spawners that are made up of hatchery adults (pHOS) and the number of natural-origin recruits. The Pearson correlation coefficient (Corr) and its P-value (P) are shown in the figure.

The association between pHOS and productivity can also be assessed by testing the correlation between pHOS and the residuals from stock-recruitment curves fitted to the Chiwawa spawner and natural-origin recruitment data. This approach removes the effects of density dependence on the relationship between pHOS and productivity. A significant negative association provides evidence that hatchery-origin spawners may not be as productive as natural-origin spawners.

The Ricker, Beverton-Holt, and smooth hockey stick models were fit to the Chiwawa stock and recruitment data (including {S, R} data from both the pre- and post-supplementation period, 1981-2004) using methods described earlier. Residuals were calculated by subtracting the predicted recruitment values from the observed (modeled) values. Pearson correlation then tested the association between pHOS and the residuals from each model.

Although there was a negative trend in residuals with increasing pHOS, suggesting that hatchery-origin spawners may not be as productive as natural-origin spawners, the association was not significant (Figure 24). Thus, based on these analyses, there is no strong evidence that the supplementation program has significantly benefited or harmed the natural spring Chinook population.





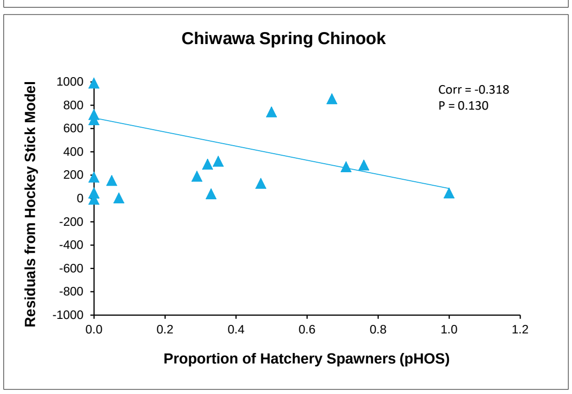


Figure 24. Association between the proportion of spawners that are made up of hatchery adults (pHOS) and the residuals from Ricker, Beverton-Holt (B-H), and smooth hockey stick stock-recruitment models. The Pearson correlation coefficient (Corr) and its P-value (P) are shown in the figures.

Comparison to Standards

In those cases in which suitable reference populations are not available and there are no pre-supplementation data, the investigator is left with comparing population parameters to relevant standards. Standards can include performance of natural-origin fish in similar environments (a type of reference condition), mitigation requirements, quantitative objectives of the program, Biological Assessment and Management Plan (BAMP) values, or other appropriate standards. An example of a statistical hypothesis would be:

Ho: Productivity (Recruits/Spawner) of the supplemented population ≥ standard productivity.

Ha: Productivity (Recruits/Spawner) of the supplemented population < standard productivity.

For these analyses to be useful, the standards must be based on biological reality.

Conclusions and Recommendations

Hatcheries are an important component of fish production within the Upper Columbia Basin. The goal of some of these programs is to supplement natural production in declining populations. The supplementation programs generally use both hatchery and natural (spawned and reared in nature from either wild or hatchery parents) adults for hatchery broodstock. These programs are designed to supplement natural populations by increasing natural reproduction while preventing the establishment of a domesticated hatchery stock. Thus, the programs should increase total spawning escapement and NORs, and not reduce the productivity of the natural population. Measuring the success of these programs is challenging and expensive.

In this paper, we described methods that can be used to determine if supplementation programs are achieving some of their goals. This paper focused on the use of reference populations to determine if the supplementation programs increase total spawning escapement, NORs, and maintain or increase productivities. In some cases, suitable reference populations may not be available (e.g., we found no suitable reference populations for Upper Columbia steelhead and sockeye). In these cases, alternative methods are needed to assess supplementation effects. We also described these alternative methods in this paper.

Identification of Reference Populations

Finding suitable reference populations that match well with supplemented populations is a difficult and time-consuming process. Our three-step selection process included identification of populations with similar life-history characteristics, few or no hatchery spawners, a long time series of accurate abundance and productivity estimates, and similar freshwater habitat impairments and out-of-basin effects. Those populations that met these criteria were then examined for their relationship with the supplemented population (in this case, the Chiwawa spring Chinook population). Several criteria were scored, including pNOS, correlation, trend, and effect size. Reference populations with total weighed scores of 81 or greater were selected as suitable reference populations.

This selection process provided a valuable framework for selecting suitable reference populations for supplemented populations. Interestingly, we found that a given reference population may match well with one parameter of the supplemented population (e.g., spawning escapement), but not for all parameters (e.g., not NORs or productivity). The reason for this may be related to errors

in the estimation of population parameters and/or differential factors limiting population parameters of supplemented and reference populations. Therefore, depending on the parameter analyzed, a different suite of reference populations may be needed.

An important assumption in the use of reference populations is that the supplemented and reference populations that tracked each other before supplementation would continue to track each other in the absence of supplementation. Given that the reference populations did not match the Chiwawa population on all criteria examined, and some reference populations tracked the Chiwawa population more poorly than others, there may be some uncertainty as to whether differences observed between the supplemented and reference populations during the supplementation period are associated with the hatchery program, or other unaccounted factors. For example, any large-scale change (man-made or natural) within the reference or supplemented population could affect our ability to assess the effectiveness of the supplementation program.

To account for some of these uncontrollable factors, we recommend the use of a "causal-comparative" approach to strengthen the certainty of our inferences. This approach relies on correlative data to try and make a case for causal inference. We recommend that the following state variables be measured and tracked within the supplemented and reference populations: mean annual precipitation, total and riparian forest cover, road density, impervious surface, and alluvium. These variables can be used to describe differences in water temperatures at different life stages (pre-spawning, egg incubation, and summer rearing) and substrate characteristics, including fine sediments and embeddedness. These state variables can be used to help explain possible changes in spawner abundance, NORs, and productivity that are independent of supplementation. In addition, the use of multiple reference streams reduces the possibility that man-made changes to a single reference stream will influence the interpretation of the results.

Analyses with Reference Populations

Using reference populations, we evaluated the effects of supplementation on natural-log transformed and untransformed total spawning escapement, NORs, and productivity by comparing trends, analyzing mean differences, ratios, and rates, and comparing stock-recruitment curves and their parameters. For trend analysis, we compared the slopes of the trends between each supplemented/reference pair before and during supplementation. If the hatchery program is successfully supplementing the natural population, trends in spawner abundance and NORs should deviate significantly during the supplementation period (i.e., the slope of the supplemented population should be greater than the slopes of the reference populations during the supplementation period), but not during the pre-supplementation period. For productivity, the slope of the supplemented population, relative to the reference population, should increase or remain the same.

Because trend analysis only tests the slopes of the trend lines, it does not test for differences in elevations of the trend lines, additional analyses were needed to determine if supplementation increased spawner abundance, NORs, and productivity of the target population without changing the slopes of the trend lines. To do this, we derived three different response variables using natural-log transformed and untransformed spawner abundance, NORs, and productivity data. The first derived variable included difference scores, which were calculated as the difference between paired treatment and reference data (T-R). The second included ratios, which were calculated as the ratio of paired treatment and reference data (T/R). Finally, we calculated the differences in annual changes in paired treatment and reference population data (ΔT-ΔR). If the hatchery

program is successfully supplementing the natural population, the mean difference or ratio score of paired spawner abundance data and NORs during the supplementation period should be greater than the pre-supplementation period. For productivity, the mean difference or ratio score during the supplementation period should be equal to or higher than the pre-supplementation period.

As a final set of analyses, we compared the stock-recruitment curves of the supplemented population (using stock and recruitment data only from the supplementation period) to the reference populations (using all available stock and recruitment data). Specifically, we tested whether the regression parameters were equal between the supplemented population and the reference populations, and whether the fitted curves coincided between populations. Here, we were most interested in comparing the productivity parameters in the models.

Surprisingly, these different analyses yielded similar results when they were applied to the Chiwawa spring Chinook and reference population data. Trend analysis was unable to detect a significant difference in trends between the supplemented and reference populations during the supplementation period. Even though we measured an increasing trend in spawner abundance, NORs, and productivity in the supplemented population during the supplementation period, these same parameters trended upward in the reference populations. Likewise, we were unable to detect a significant supplementation effect using difference scores, ratios, and differences in annual changes. However, we found the results from analysis of mean differences of annual change difficult to interpret and they may be insensitive to treatment effects. A simpler analysis, which is also easier to interpret, is to use trend analysis. Finally, comparing stock-recruitment curves and their parameters did not provide strong evidence that supplementation has affected the productivity of the natural population.

Based on these results, we do not recommend using difference scores of annual change (ΔT-ΔR), nor do we recommend comparing stock-recruitment curves and their parameters. As noted above, difference scores of annual change are difficult to interpret and may be redundant with trend analysis. Testing stock-recruitment curves and their parameters appears redundant with testing differences in productivity using difference scores or ratios. In addition, the analyses are computer intensive and do not appear to be very sensitive to changes.

There was little difference in results using difference scores and ratios. It appears that ratios may be more sensitive to change than difference scores (e.g., we found significant differences in some comparisons using ratios but not with difference scores), but ratios can be more difficult to interpret than difference scores. Nevertheless, we recommend the use of ratios in future analyses.

Correcting for Density Dependence and Carrying Capacity

The analyses described so far assumed that the density of spawners or recruits did not affect the survival and productivity of fish. However, without controlling for density effects, productivity of the population would continue to decline with increasing abundance. This scenario could occur in supplementation programs that increase the number of spawners, and could result in lower productivities relative to reference populations. In addition, lower productivities may be caused by differential environmental carrying capacities rather than the capacity of the supplemented fish to produce offspring. Therefore, we described two different methods for deriving density-corrected estimates of productivity. The first controlled the effects of density on productivity by partitioning observed productivities into density-independent and density-dependent productivity. These productivities were then combined in a single test. The second method corrected for differences in carrying capacities between the supplemented and reference populations. This was accomplished

by calculating the percent saturation of NORs, which was estimated as the ratio of observed NORs to the maximum number of NORs that the habitat could support.

We fit Ricker, Beverton-Holt, and smooth hockey stick models to stock and recruitment data to estimate the maximum number of NORs (NORs at carrying capacity) and the maximum number of spawners needed to produce maximum NORs. We fit models to the supplemented and reference populations. Using information-theoretic criterion and evaluating the precision of estimated parameters, we found that the smooth hockey stick model provided the best estimates of maximum NORs and spawners. We used these modeled values to estimate density-independent and density-dependent productivities, and saturation of NORs.

Statistical analyses, using difference scores and ratios of adjusted Chiwawa spring Chinook productivity data, found no significant effects of supplementation on the productivity of the supplemented population. Indeed, the results from correcting for density dependence were similar to those without correcting for density dependence. This is in part because the abundance of the supplemented and reference populations has been below their respective carrying capacities in most years. This was clearly demonstrated in the analyses of NORs corrected for carrying capacity. In the supplemented population, the mean fraction of the carrying capacity filled with NORs decreased significantly during the supplementation period. In other words, the carrying capacity was filled with more NORs during the pre-supplementation period than during the supplementation period, which is contrary to the goal of supplementation. By comparison, two of the reference populations showed a similar decrease in saturation, while the other two reference populations actually increased in saturation. Analyzing the saturation scores using BACI-design analyses indicated that two of the four pairings differed significantly. That is, the percent saturation of the supplemented population decreased significantly relative to two reference populations.

Because productivity can be affected by the abundance of spawners and recruits, we recommend that future analyses comparing supplemented and reference populations adjust for density-dependent effects and differential carrying capacities. Although we detected only slight differences between adjusted and unadjusted results, as supplemented stocks recover, it will become more important to adjust productivities to account for density dependence. Importantly, the analyses using percent saturation placed NORs in the context of the carrying capacity of the environment. This will help managers determine if supplementation programs are filling or over-filling the capacity of the habitat with NORs.

As we noted earlier, analyses using productivities adjusted for density dependence assume that there is a spawner abundance at which density-independent effects end and density-dependent effects begin. In reality, density-dependent effects occur at low spawning abundance and intensify as spawning abundance increases. We did not account for these increasing density-dependent effects at lower spawner abundances. This is an area that needs additional attention.

Analyses without Reference Populations

Because of the rigorous criteria we used to select reference populations, it is likely that reference populations may not exist for making comparisons with supplemented populations. For example, we used the criteria described in this paper to identify reference populations for supplemented steelhead and sockeye populations in the Upper Columbia Basin. We were unsuccessful in identifying any suitable reference populations. Therefore, in the absence of suitable reference populations, it is important to have alternative methods for assessing supplementation effects. We described three different types of analyses one can use to assess supplementation effects in the

absence of reference populations. They include before-after comparisons, correlation analysis, and comparisons to standards.

Before-after analyses compare population metrics before supplementation with those during supplementation. In this case, data collected before supplementation represent the reference condition. The assumption is that population trajectories measured during the pre-supplementation period would continue in the absence of supplementation. We compared trends in spawner abundance, NORs, and productivity before and after supplementation. In addition, we compared mean scores in these three parameters before and after supplementation. Finally, we attempted to compare stock-recruitment parameters before and after supplementation. The hypotheses examined were that the spawner abundance and NORs would be greater during the supplementation period, and that productivities would not decline during the supplementation period.

Trend analysis indicated that the all three Chiwawa spring Chinook population parameters trended downward during the pre-supplementation period, but trended upward during supplementation. On the other hand, mean spawner abundance and NORs were lower during the supplementation period than during the pre-supplementation period. Mean productivities increased, but not significantly, during the supplementation period. We were unable to compare pre- and post-supplementation stock-recruitment curves because we were unable to fit stock-recruitment models to the pre-supplementation data.

We used correlation analyses to determine if the proportion of hatchery-origin fish that spawn naturally on the spawning grounds (pHOS) increased productivity. In addition, we used correlation to assess the association between pHOS and the residuals from stock-recruitment relationships. A significant negative association provides evidence that hatchery-origin spawners may not be as productive as natural-origin spawners. The analysis indicated that the productivity of Chiwawa spring Chinook increased with increasing pHOS, but the association was not significant. In contrast, there was a negative association between pHOS and the stock-recruitment residuals, but again the association was not significant. The latter analysis accounts for density-dependent effects.

In concert, the before-after comparisons and correlation analyses do not provide conclusive evidence that the supplementation program has increased spawner abundance and NORs, or that it has significantly reduced the productivity of the supplemented population. Although increasing the number of hatchery fish on the spawning grounds appears to reduce NORs and productivity, mean productivity actually increased during the supplementation period compared to the pre-supplementation period.

It is important to note that relying on only one set of analysis could result in drawing a wrong conclusion. For example, if we had only conducted trend analysis, we may have concluded wrongly that the Chiwawa spring Chinook supplementation program significantly increased spawner abundance, NORs, and productivity in the supplemented population. The analysis of mean scores and correlations indicates that the supplementation program has not increased spawner abundance or NORs in the supplemented population. Therefore, in the absence of suitable reference populations, we recommend that analyses include the evaluation of trends, means scores, and correlations. By conducting more than one set of analyses, one can use weight-of-evidence to assess the effects of supplementation programs.

Under the scenario that there are no reference populations or pre-supplementation data, one is left with comparing population parameters to relevant standards. These standards could come from mitigation requirements, quantitative objectives, or published or unpublished standards. One could also use correlation to evaluate the association between productivity and pHOS, but this requires a wide range in pHOS values to be most effective. A more extreme approach, which probably would not gain much traction with managers, is to shutoff the supplementation program for some time and then evaluate the effects of the program in a before-after design. The Entiat spring Chinook hatchery program provides a unique opportunity to evaluate this type of management decision.

Some Concerns and Limitations

No matter how hard we try to explain different sources of variation in population data, we are limited by the quality of the data. Teasing out the effects of supplementation requires long time series of population data. Because funding levels and methods change over time, the quality (i.e., accuracy and precision) of the data also changes over time. Importantly, the population parameters examined in this paper (spawner abundance, NORs, and productivity) are rarely measured directly in the field. That is, other population metrics, such as numbers of redds, number of fish counted at weirs or dams, scales, tags, etc., are sampled in the field. These metrics are then used to calculate spawner abundance[24], NORs, and productivity, often based on assumptions about fish/redd, pre-spawning loss, marking rates, and sampling rates. This has a tendency to increase the variability in the data independent of supplementation programs. In our studies, we can only control sampling within the supplemented populations, and even that is limited by available funding. We have no control over the sampling within reference populations. Thus, we have to assume that sampling within the reference populations will continue and that sampling effort will remain comparable to that in the supplemented populations.

In our analyses, we included both the Entiat and Little Wenatchee populations as references for the Chiwawa population. In the analyses, we treated them as equivalent to the other reference populations. That is, the statistical procedures used to compare the supplemented population to each reference population were identical. This is appropriate. However, the interpretation of the results must be different when comparing the Entiat and Little Wenatchee to the supplemented population, because they are populations that were influenced by hatchery fish. As noted earlier, the Entiat spring Chinook hatchery program has been discontinued. Therefore, it provides a unique type of reference where the comparison changes from both populations being supplemented to only one population being supplemented. For the Little Wenatchee, nearly all the strays came from the Chiwawa program. Straying should stop or be greatly reduced with the change in water supply to the Chiwawa Rearing Ponds. In sum, one must be careful in how they interpret these test-reference results.

Finally, it is important to point out that for this paper, we conducted 463 statistical tests. Because we set our Type I error rate at 0.05, by random chance alone, we may have incorrectly rejected about 23 null hypotheses. Inasmuch as this work was designed to evaluate different ways to analyze test-reference data, the number of future analyses will be greatly reduced based on the results from this work. However, if the Type I error rate is a concern to managers, researchers can

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24 The smooth hockey stick model, which we used to estimate density-dependent correction factors for productivity and NORs, is sensitive to errors in spawner escapement estimates. Therefore, it is important to use accurate and precise estimates of spawner escapement.

use a lower error rate, such as α = 0.01. Another option is to analyze test-reference data graphically. Although this is subjective, there are no statistical analyses and therefore no concerns with violating assumptions of statistical tests, including temporal correlation. We believe researchers should use the statistical procedures recommended in this report to support graphic analysis.

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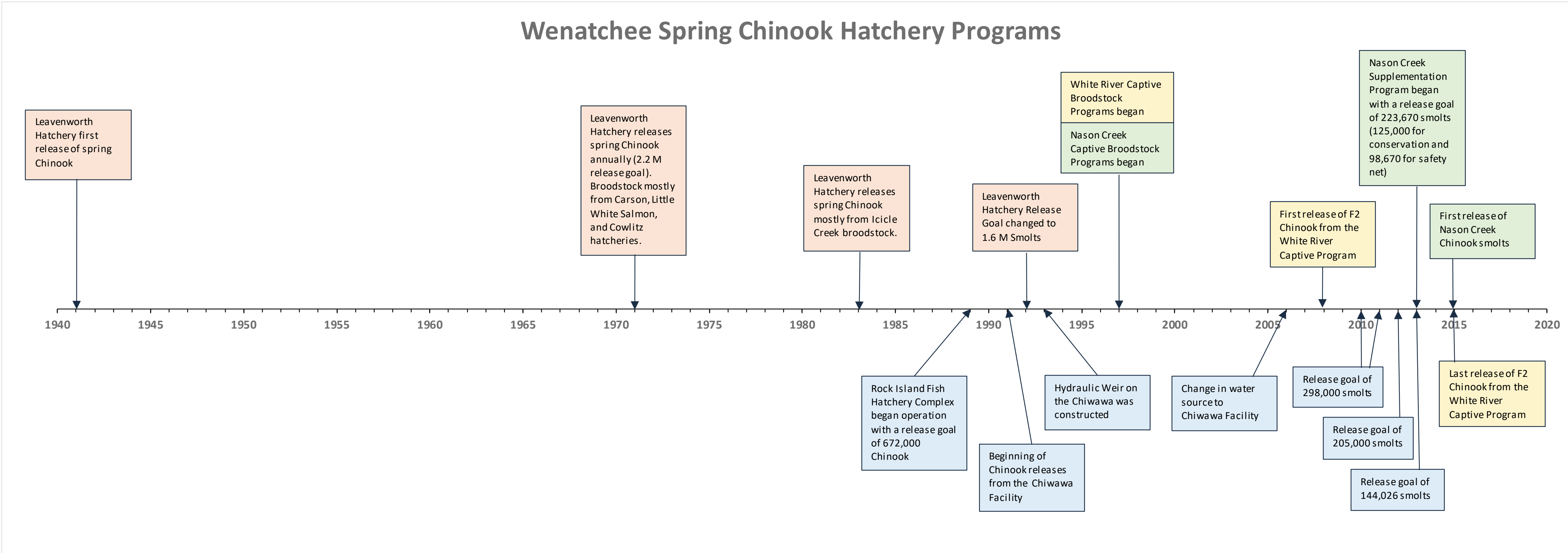
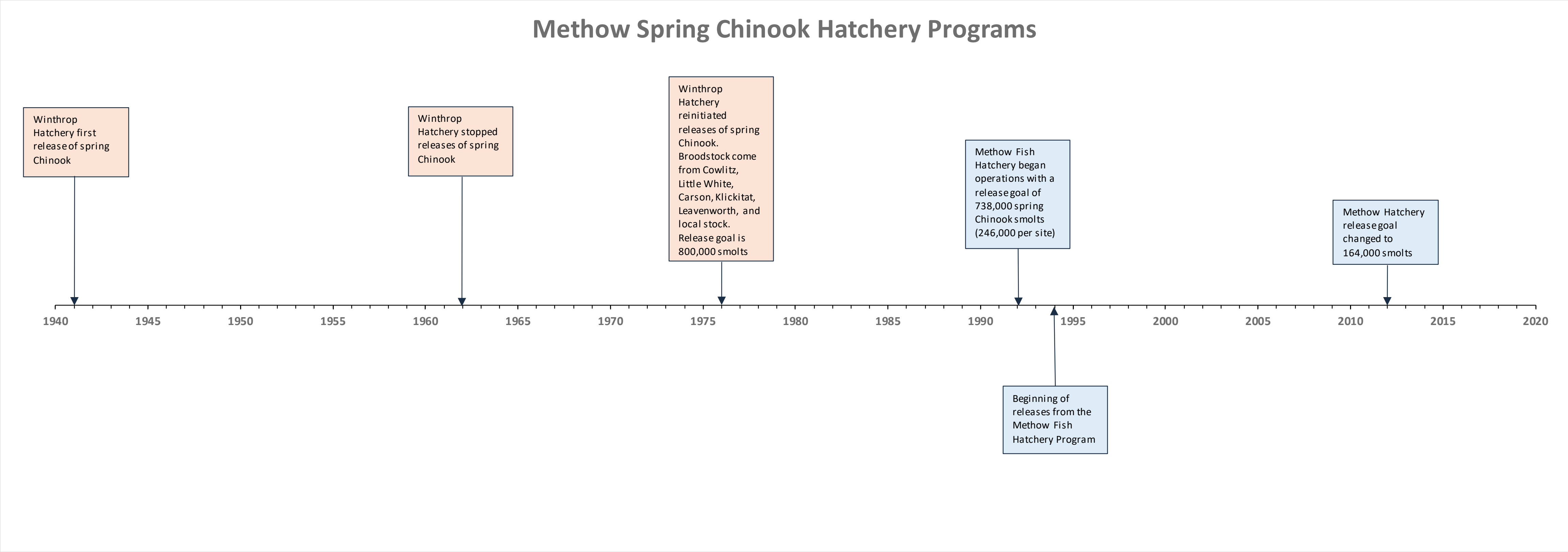

Wenatchee Spring Chinook Hatchery Programs
Leavenworth Hatchery first release of spring Chinook
Leavenworth Hatchery releases spring Chinook annually (2.2 M release goal). Broodstock mostly from Carson, Little White Salmon, and Cowlitz hatcheries.
Leavenworth Hatchery releases spring Chinook mostly from Icicle Creek broodstock.
Leavenworth Hatchery Release Goal changed to 1.6 M Smolts
White River Captive Broodstock Programs began
Nason Creek Captive Broodstock Programs began
First release of F2 Chinook from the White River Captive Program
Nason Creek Supplementation Program began with a release goal of 223,670 smolts (125,000 for conservation and 98,670 for safety net)
First release of Nason Creek Chinook smolts
1940
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020
Rock Island Fish Hatchery Complex began operation with a release goal of 672,000 Chinook
Beginning of Chinook releases from the Chiwawa Facility
Hydraulic Weir on the Chiwawa was constructed
Change in water source to Chiwawa Facility
Release goal of 298,000 smolts
Release goal of 205,000 smolts
Release goal of 144,026 smolts
Last release of F2 Chinook from the White River Captive Program


Methow Spring Chinook Hatchery Programs
Winthrop Hatchery first release of spring Chinook
Winthrop Hatchery stopped releases of spring Chinook
Winthrop Hatchery reinitiated releases of spring Chinook. Broodstock come from Cowlitz, Little White, Carson, Klickitat, Leavenworth, and local stock. Release goal is 800,000 smolts
Methow Fish Hatchery began operations with a release goal of 738,000 spring Chinook smolts (246,000 per site)
Methow Hatchery release goal changed to 164,000 smolts
1940
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020
Beginning of releases from the Methow Fish Hatchery Program

FINAL

720 Olive Way, Suite 1900
Seattle, Washington 98101
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ANCHOR QEA

Memorandum

To: Wells, Rocky Reach, and Rock Island HCP Hatchery Committees

Date: January 21, 2018

From: Tracy Hillman, HCP Hatchery Committees Chairman

cc: Sarah Montgomery, Anchor QEA, LLC

Re: Final Minutes of the November 15, 2017 HCP Hatchery Committees Meeting

The Wells, Rocky Reach, and Rock Island Hydroelectric Projects Habitat Conservation Plan (HCP) Hatchery Committees meeting was held at the Grant PUD office in Wenatchee, Washington, on Wednesday, November 15, 2017, from 9:00 to 11:45 a.m. Attendees are listed in Attachment A to these meeting minutes.

Action Item Summary

- Andrew Murdoch (Washington Department of Fish and Wildlife [WDFW]) will write an overview of proposed expanded sampling at the off-ladder fish trap (OLAFT) at Priest Rapids Dam (Item I-A). *(Note: this item is ongoing.)*
- Mike Tonseth will coordinate with Todd Seamons (WDFW) to produce an outline or recommended approach for genetic monitoring (Item I-A). *(Note: this item is ongoing.)*
- Bill Gale, Matt Cooper, Charlie Snow (WDFW), Tom Kahler, and Greg Mackey will develop management alternatives for the Twisp River and Winthrop National Fish Hatchery steelhead programs (Item I-A). *(Note: this item is ongoing.)*
- Greg Mackey will revise the Douglas PUD steelhead surplus document and send it to the Hatchery Committees (Item III-A). *(Note: Mackey sent the revision to Sarah Montgomery, which she forwarded to the Hatchery Committees following the meeting on November 15, 2017.)*
- Greg Mackey will provide an update on the Wells and Methow fish hatcheries transition process, particularly regarding fish health and marking strategies, near the end of the transition period (Item III-C). *(Note: Mackey provided this update via email on December 7, 2017.)*
- Greg Mackey will provide an update on summer Chinook salmon spawning numbers for the Douglas PUD programs to the Hatchery Committees (Item IV-A).
- Tracy Hillman will revise non-target taxa of concern language in the draft Monitoring and Evaluation (M&E) Plan for PUD Hatchery Programs (2017 Update) and provide the final approved version to the Hatchery Committees, the Independent Scientific Advisory Board (ISAB), and Greer Maier (Upper Columbia Salmon Recovery Board [UCSRB]; Item V-C). (*Note: Hillman revised and sent the final Plan to Sarah Montgomery, which she distributed to the*

Hatchery Committees and Maier on November 17, 2017. Hillman also sent the plan to the ISAB on November 17, 2017.)

- Tracy Hillman will distribute the draft timelines for Wenatchee and Methow spring Chinook salmon programs for Hatchery Committees review (Item V-D). *(Note: Hillman sent the timelines to Sarah Montgomery, which she forwarded to the Hatchery Committees on November 15, 2017.)*
- Tracy Hillman will draft timelines for summer Chinook salmon, steelhead, and sockeye salmon, and for hatchery programs in the Entiat River basin (Item V-D).
- Sarah Montgomery will distribute Greer Maier's presentation, "Integrated Recovery," from the November 15, 2017 Hatchery Committees meeting (Item IV-E). *(Note: Montgomery sent the presentation to the Hatchery Committees following the meeting on November 15, 2017.)*

Decision Summary

- The Rocky Reach and Rock Island Hatchery Committees approved Chelan PUD's Statement of Agreement (SOA), "Regarding District's Coho Obligation" as follows: Colville Confederated Tribes (CCT) approved via email on November 14, 2017, and Chelan PUD, WDFW, U.S. Fish and Wildlife Service (USFWS), Yakama Nation (YN), and National Marine Fisheries Service (NMFS) approved on November 15, 2017 (Item II-A). *(Note: Sarah Montgomery distributed the Final SOA to the Hatchery Committees on November 16, 2017.)*
- The Hatchery Committees approved the draft M&E Plan for PUD Hatchery Programs (2017 Update), contingent on one edit to the non-target taxa of concern section, as follows: CCT approved via email on November 15, 2017, and Chelan PUD, Douglas PUD, WDFW, USFWS, NMFS, and YN approved on November 15, 2017. Grant PUD (PRCC HSC) also indicated approval of the Plan during the joint HCP-HC/PRCC HSC section of the meeting (Item V-C). (*Note: Sarah Montgomery distributed the final Plan to the Hatchery Committees on November 17, 2017.*)

Agreements

- Wells Hatchery Committee representatives agreed to the following items regarding the surplus of brood year 2017 steelhead for Douglas PUD's program:
  - Release all Twisp no-net-impact and inundation program fish on-station at time of release (55,620 or fewer).
  - Release all Methow inundation program fish on-station at time of release (72,768 or fewer).
  - Retain 210,412 Columbia Safety-Net program fish on-station for release.

 - Release the target of 160,000 Columbia Safety-Net program fish plus a surplus (50,412 or fewer) to make up the shortfall (27,232 or more fish) in the Methow inundation program release, for a total release of 338,800 fish or less.
 - Remove additional surplus fish (37,034 or fewer) from the Columbia Safety-Net program and release in non-anadromous waters under direction of WDFW (Item III-A).

Review Items

- Sarah Montgomery sent an email to the Hatchery Committees on November 27, 2017, notifying them that the *Draft Upper Columbia River Summer/Fall and Fall Chinook Biological Opinion* (BiOp) is available for review with edits and comments due to Emi Kondo by December 11, 2017.

Finalized Documents

- Sarah Montgomery sent an email to the Hatchery Committees on November 7, 2017, notifying them that the *Douglas PUD Final Transition Plan for Wells and Methow Fish Hatcheries* is now available for download from the Hatchery Committees Extranet site.
- Sarah Montgomery sent an email to the Hatchery Committees on November 15, 2017, notifying them that the *Douglas PUD Final 2016 M&E Annual Report* is now available for download from the Hatchery Committees Extranet site.
- Sarah Montgomery sent an email to the Rocky Reach and Rock Island Hatchery Committees on November 16, 2017, notifying them that the Final SOA, *Regarding District's Coho Obligation*, is now available for download from the Hatchery Committees Extranet site.
- Sarah Montgomery sent an email to the Hatchery Committees and PRCC HSC on November 17, 2017, notifying them that the *Final M&E Plan for PUD Hatchery Programs (2017 Update)* is now available for download from the Hatchery Committees Extranet site.
- Sarah Montgomery sent an email to the Hatchery Committees on December 7, 2017 , notifying them that Douglas PUD's *Final 2018 M&E Implementation Plan* is now available for download from the Hatchery Committees Extranet site.

I. Welcome

A. Review Agenda, Review Last Meeting Action Items, and Approve the October 18, 2017 Meeting Minutes (Tracy Hillman)

Tracy Hillman welcomed the Hatchery Committees and asked for any additions or changes to the agenda. Greg Mackey added Douglas PUD items for a steelhead surplus discussion, the Douglas PUD Draft 2018 M&E Implementation Plan, and a discussion about the Wells and Methow fish hatcheries transition. Mike Tonseth added an item for summer Chinook salmon spawning at Wells Fish Hatchery.

The Hatchery Committees representatives reviewed the revised draft October 18, 2017 meeting minutes. Sarah Montgomery said there are a few outstanding comments, and representatives revised the meeting minutes. Hatchery Committees representatives present approved the draft October 18, 2017 meeting minutes as revised.

Action items from the Hatchery Committees meeting on October 18, 2017, and follow-up discussions were addressed *(note: italicized text below corresponds to agenda items from the meeting on October 18, 2017)*:

- *Andrew Murdoch (Washington Department of Fish and Wildlife [WDFW]) will write an overview of proposed expanded sampling at the off-ladder fish trap (OLAFT) at Priest Rapids Dam (Item I-A).*
  This item is ongoing. Mike Tonseth indicated expanded sampling is likely not implementable in 2018.
- *Mike Tonseth will coordinate with Todd Seamons (WDFW) to produce an outline or recommended approach for genetic monitoring (Item I-A).*
  This item is ongoing. Tonseth indicated it will be addressed at the beginning of 2018.
- *Kirk Truscott will discuss internally and coordinate with Keely Murdoch on potential edits to Chelan PUD's Draft Statement of Agreement (SOA) Regarding District's Coho Obligation (Item I-A).*
  This item is complete.
- *Sarah Montgomery and Mike Tonseth will coordinate to revise and finalize the September 20, 2017 Hatchery Committees meeting minutes (Item I-A).*
  This item is complete.
- *Sarah Montgomery will distribute Barry Berejikian's (Northwest Fisheries Science Center [NWFSC]) presentation, "Potential to improve the conservation benefits of steelhead hatcheries," to the Hatchery Committees (Item II-C).*
  This item is complete.
- *Bill Gale, Matt Cooper, Charlie Snow (WDFW), Tom Kahler, and Greg Mackey will develop management alternatives for the Twisp River and Winthrop National Fish Hatchery (NFH) steelhead programs (Item II-C).*
  This item is ongoing.
- *Sarah Montgomery will notify the Hatchery Committees that the Draft Monitoring and Evaluation Plan for PUD Hatchery Programs (2017 Update) will be a decision item at the Hatchery Committees November 15, 2017 meeting (Item III-C).*

This item will be discussed today.

- *Tracy Hillman will distribute the draft timelines for Wenatchee and Methow spring Chinook salmon programs for Hatchery Committees review (Item III-D).*
  This item is complete.

II. Chelan PUD

A. Decision: Coho Salmon SOA (Catherine Willard)

Catherine Willard shared the document, "Draft SOA Regarding District's Coho Obligation," which Sarah Montgomery distributed to the Hatchery Committees on November 3, 2017. Willard said this version of the draft SOA includes the methodology for meeting Chelan PUD's coho salmon obligation, but not the funding arrangement with YN, which will be determined later in a separate SOA after further coordination with YN and CCT.

Bill Gale asked when the second SOA will be brought to the committees. Willard said in order to meet the obligation in 2018, the second agreement should be decided in early 2018, and said contracting can be completed quickly in order to arrange funding shortly after the agreement is made. Gale asked why the original SOA, including the funding arrangement, has been separated into two SOAs. Willard said Chelan PUD wants to record that the methods for calculating the District's obligation are agreed to now, then later agree to the funding arrangement. The Rocky Reach and Rock Island Hatchery Committees approved the SOA as follows: Chelan PUD, YN, WDFW, USFWS, and NMFS approved during the meeting on November 15, 2017, and CCT approved via email on November 14, 2017. (Note: the final version was distributed on November 16, 2017 [Attachment B]).

III. Douglas PUD

A. Steelhead Program Surplus Brood Year 2017 (Greg Mackey)

Greg Mackey shared the document, "Douglas PUD Steelhead Program Surplus BY 2017," which Sarah Montgomery distributed to the Hatchery Committees on November 14, 2017. (Note: a revised version was distributed following the meeting on November 15, 2017 [Attachment C]).

Mackey said the Douglas PUD steelhead program has an excess of 7,620 fish in the Twisp program, an excess of 87,446 in the Columbia program, and a shortage of 27,232 fish in the Methow program. Mike Tonseth said the numbers he received regarding the surplus are different, and Mackey said he would check accuracy and distribute a final document with the numbers; regardless, there is a surplus and the committees need to discuss how to meet obligations and release excess fish. Tonseth said long-term commitments are to manage programs to 100%, not 110% of targets, based on input from Craig Busack (NMFS). Keely Murdoch agreed and said the programs should be managed to 100% of the target, but if an overage up to 110% occurs, those fish should be released. Murdoch recommended keeping 110% of the targeted level of fish, because some fish will die during the winter. Mackey agreed that the program should not purposefully release 110% of the target level of fish.

Mackey said the Twisp program has an overage of wild-by-wild fish, and asked if those fish should be kept even though the current number is above 110% of the target. Bill Gale asked if the Twisp program fish are different than other groups and said the Winthrop and Twisp programs have similar brood stock. Tonseth advocated maintaining the Twisp program at its current level (overage), in order not to disrupt tagging and smolt-to-adult return estimates. Murdoch asked if the permit for these programs is written such that the 100% target pertains to the program combined, or to each release group. Tonseth said the targets are for the program as a whole. Gale said he thinks it is acceptable to manage the program target with a combined approach this year, but the Hatchery Committees should not set the precedent of managing release groups in aggregate due to long-term unintended consequences. Tonseth said sufficient broodstock were collected for each release component, and the overage is due in part to collection of 2-salt fish, while the shortage is related to a water issue at the hatchery resulting in some steelhead dying. Tonseth said the situation in 2017 is unique, and the programs are not set up to automatically backfill each other. Mackey agreed and said there was no issue with broodstock collection, and if there had been, it would have been addressed earlier.

Mackey said one option is to maintain the Twisp program as-is with the overage, release all the Methow program fish that are available, and backfill the release up to 110% with the Columbia program overage. Tonseth said the broodstock collection protocols and BiOp are specific as to which broodstock comprise the safety-net program. He said due to the parental origin of surplus hatchery fish being unknown, those should not be used for safety-net releases. Tonseth said Mackey's proposition will likely meet the 100% target, though with a different make-up than planned. Murdoch asked if other steelhead programs are short. Tonseth said Okanogan and Ringold programs are not short, and Matt Cooper said the Winthrop program is also not short.

Tracy Hillman asked why the Methow program is short. Mackey said the shortage is due to a power outage at Wells Fish Hatchery that occurred in early summer 2017. When power was out, the water supply diminished and an airlock in the pipes resulted in steelhead fry (mostly Methow program) being siphoned out of start tanks.

Mackey summarized that the programs combined have a targeted release of 308,000 fish, not to exceed the 110% level of 338,800 fish. He said by keeping the Twisp overage, releasing all the Methow program fish available, and backfilling with Columbia program fish to meet the total mitigation obligation, the Hatchery Committees should discuss whether to maintain only the 308,000-targeted fish or to maintain 338,800 fish at a 10% overage. Gale suggested maintaining the 308,000 fish plus an estimate for winter mortality. Tonseth reminded the representatives that the estimates presented today are from the time the fish are tagged, and some will die before release. Tonseth estimated that if 338,800 fish are maintained, approximately 325,000 would be released, which he said is a reasonable buffer.

Gale said at those numbers, the Columbia program would be at an approximate 15% overage, and fish from that release that stray into the Methow River might be an issue and should be considered. Murdoch said with a year of poor steelhead survival, strays into the Methow River may not be an issue. Tonseth said the Columbia program has the greatest likelihood of adults being removed upon return, which also helps to minimize straying into the Methow River.

Brett Farman said overages are generally considered by each release location, not as an aggregate of programs. He said if the Hatchery Committees agree to the deviation as a group, that is acceptable for this occasion. Farman asked about the marking strategy for these releases, and if they can be differentiated upon return. Mackey said the Columbia program release is ad-clipped only, the Methow release is ad-clipped only, and the Twisp release is CWT only. Tonseth noted that the BiOp for Methow steelhead programs indicates that if shortages or overages occur in one component, the difference is made up by the Columbia release, as proposed today to meet the production obligation for Douglas PUD.

Mackey said surplus fish are usually put into non-anadromous waters as determined by WDFW. Douglas PUD, YN, WDFW, USFWS, and NMFS came to agreement about the surplus, and CCT provided input via email. Wells Hatchery Committee representatives agreed to the following items regarding the surplus of brood year 2017 steelhead for Douglas PUD's program:

- Release all Twisp no-net-impact and inundation program fish that are on-station at time of release (55,620 or fewer).
- Release all Methow inundation program fish that are on-station at time of release (72,768 or fewer).
- Retain 210,412 Columbia Safety-Net program fish on-station for release.
- Release the target of 160,000 Columbia Safety-Net program fish plus a surplus (50,412 or fewer) to make up the shortfall (27,232 or more fish) in the Methow inundation program release, for a total release of 338,800 fish or less.
- Remove additional surplus fish (37,034 or fewer) from the Columbia Safety-Net program and release in non-anadromous waters under direction of WDFW.

B. M&E Implementation Plan 2018 (Greg Mackey)

Greg Mackey said Douglas PUD has not yet received any substantial comments on their draft 2018 Implementation Plan, which is available for review until December 1, 2017.

C. Wells and Methow Fish Hatcheries Transition (Greg Mackey)

Greg Mackey said Douglas PUD has fully staffed both the Wells and Methow fish hatcheries. Mackey said the transition is on track to be complete within 90 days as planned, and Douglas PUD is working to finalize paperwork and responsibilities. Bill Gale asked if anyone has been hired for the fish health position. Mackey said not yet, and Douglas PUD has not decided yet to hire for the position or contract it with WDFW. Mike Tonseth asked if contracts for fish marking will also be decided soon. Mackey said the contracts would be separate [from fish health], and Douglas PUD has requested quotes from entities capable of marking fish for these hatcheries, including WDFW, CCT, USFWS, and others. Gale noted the 90-day transition period ends before the next Hatchery Committees meeting, and asked for an update on remaining items towards the end of the transition period. Mackey said he will provide an update.

IV. WDFW

A. Summer Chinook Salmon Spawning Update (Mike Tonseth)

Greg Mackey said Mike Tonseth asked for an update on spawning for the Douglas PUD summer Chinook salmon program. Mackey said staff acquired the full program egg take, with a possible surplus. He said staff collected an additional 18 females to augment losses during an outbreak of columnaris.The Yakima River restoration program receives eggs through the Wells broodstsock collection and spawning. YN staff participates in spawning on days when the Yakima River program receives eggs. He said because late females were not sexually maturing as expected, it is not currently known how many eggs went directly to the Yakima River restoration program. He said as of November 13, all fish were spawned and the remainder were killed because they were either gong to die form the Columnaris infection or were so sexually immature that they were not likely to mature at all. Tonseth asked for a second update when Douglas PUD has revised numbers. Mackey said he will provide an update.

V. Joint HCP-HC/PRCC HSC

A. NMFS Consultation Update (Emi Kondo)

Emi Kondo provided an update on consultation for the unlisted programs in the upper Columbia River. Kondo said she received the official initiation of consultation request, and now NMFS will respond with letters of sufficiency to the applicants. She confirmed to whom the letters should be addressed for Douglas PUD, Grant PUD, Chelan PUD, and WDFW.

She said the Draft Upper Columbia River summer/fall and fall Chinook salmon BiOp will go to General Counsel review soon, then back to the applicants for review. She said this BiOp is a regional priority to finish by the end of 2017, and asked for the Hatchery Committees to be aware that it will be available for review soon.

Alene Underwood asked for an update on the steelhead draft permit. Kondo said she is not sure on the status of the steelhead draft permit, and said Charlene Hurst would have more information about that permit.

B. USFWS Bull Trout Consultation Update (Matt Cooper)

Matt Cooper said Karl Halupka provided him an update on USFWS bull trout consultations, which he summarized as follows:

- Halupka is finalizing editorial pieces and working to get the BiOp for the batch of Wenatchee subbasin programs signed this week.
- Halupka is making progress on the Methow steelhead consultation, and is using the memorandum format developed for Methow spring Chinook salmon. He expects this to be complete by the end of November.
- Halupka received additional information for the unlisted programs in the upper Columbia River, which will inform the effects analysis. He said the schedule for completing a letter of concurrence depends on when NMFS is able to initiate consultation.

Mike Tonseth added that the USFWS consultation for the unlisted batch of Columbia River programs will likely only require a letter of concurrence.

C. Decision: M&E Plan for PUD Hatchery Programs, 2017 Update (Tracy Hillman)

Tracy Hillman shared the revised document, M&E Plan for PUD Hatchery Programs (2017 Update), which Sarah Montgomery distributed to the Hatchery Committees on October 19, 2017. Hillman said the sections about non-target taxa of concern and adaptive management have been recently updated, and Andrew Murdoch also provided edits to Appendix 1, Estimation of Carrying Capacity.

He asked if the Hatchery Committees approve the revised document. Chelan PUD, Douglas PUD, YN, USFWS, NMFS, and WDFW approved during the meeting, and CCT approved via email. Grant PUD (PRCC HSC) also indicated approval.

Hillman said he will finalize and distribute the document to the committees, Greer Maier, and the ISAB. (Note: Montgomery distributed the final version on October 17, 2017 [Attachment D]).

D. Timeline of Changes in Spring Chinook Salmon Programs (Tracy Hillman)

Tracy Hillman shared the document, Draft Hatchery Program Timelines, which Sarah Montgomery distributed to the Hatchery Committees on October 18, 2017 (Attachment E). Hillman said he received feedback from USFWS and Chelan PUD on the timelines. He said once the timelines have all the needed information, statistical break periods can be decided. Hillman said he will revise the timelines based on further input from Douglas PUD, and also prepare draft timelines for steelhead and summer Chinook salmon. Once the timelines are complete, the best way to complete the statistical and comprehensive reports can be decided.

Bill Gale asked if a timeline should be created for the Entiat. He said there is no PUD hatchery production there, but it could be related to analyses for statistical and comprehensive reports. Hillman said he will make a timeline for the Entiat and asked representatives to send him input for it. Mike Tonseth said spring and summer Chinook salmon programs have been in the Entiat River, and steelhead used to be released there too. Gale suggested developing a timeline for sockeye. Hillman said he can do that. Gale suggested also displaying the timelines by basin as well as species. Todd Pearsons suggested also displaying the timelines in table format, and also including exact dates as well as years whenever possible. Mackey suggested identifying year and brood year whenever possible. Hillman said he would incorporate these suggestions and continue revising the timelines.

E. Discuss UCSRB Hatchery Report (Greer Maier)

Tracy Hillman welcomed Greer Maier to the meeting, and said Maier will be discussing the UCSRB's draft Hatchery Summary. Maier shared a presentation, "Integrated Recovery" (Attachment F), which Sarah Montgomery distributed to the Hatchery Committees on November 15, 2017. Maier said the UCSRB implements the Upper Columbia Salmon and Steelhead Recovery Plan along with their partners, including the Integrated Recovery Technical Advisory Group (IRTAG), and the plan identifies actions across the four H's, hydropower, hatcheries, habitat, and harvest. Maier reviewed the process of writing the Habitat Report and Hatchery Summary, and discussed the contents of the Hatchery Summary.

Maier said the next steps for the Hatchery Report include a meeting next week to edit and review the report with the IRTAG, then it will hopefully be approved at the board meeting in December. In 2018, the UCSRB plans to share the report and knowledge from it through meetings and conferences. Then, the UCSRB will develop summaries for hydropower and harvest. Maier said the UCSRB is always looking to partner with other entities in order to move along initiatives that benefit recovery.

Questions and Comments

Bill Gale asked about the delineation between the hatchery report and the harvest report. He said with the Leavenworth programs, for example, there are unlisted hatchery programs that produce fish for harvest, but these programs are described in the Hatchery Summary. Maier said the harvest report has not been started yet, and the hatchery report focuses on hatchery fish interacting with listed species. She said there is overlap, and a clear line has not been drawn yet. She said she is open to suggestions on which programs to discuss in which report. Mike Tonseth suggested describing a clear linkage between the harvest and hatchery reports. He said harvest programs such as summer Chinook, fall Chinook, and sockeye salmon have impacts to listed fish. Maier agreed and said those will be addressed in the harvest report. Gale suggested being very clear about which programs and topics are included in each report.

Gale also suggested providing more clarity in the adult straying section, where he said hatchery escapement and straying are somewhat conflated. He said the Hatchery Committees discuss strays as out-of-population strays, and if a hatchery fish returns to its intended population (such as Wenatchee, Methow, or Okanogan), then it is not a stray; rather, it is a hatchery movement and escapement issue. Maier said the National Oceanic and Atmospheric Administration thinks that there are consequences to within-population straying, and within-population straying is reported in documents prepared by or for the Hatchery Committees. Gale suggested separating the types of straying more clearly. Greg Mackey said out-of-population straying is a genetic issue, and within-population straying is a management issue. Keely Murdoch said the level of concern for each type of stray depends on the program and species because they are all managed differently. Maier said the section discussing straying includes a general overview, and she will add more information about within-basin and out-of-basin strays. Mackey said that information is provided in PUD reports. Hillman suggested organizing that section by the recovery plan objectives and goals. He said the recovery plan mainly discusses out-of-population straying, but also discusses within-population straying. Maier liked this approach, and Hillman said she can find appropriate language and terms in the Hatchery M&E Plan. Gale said data for within-population straying are hard to compile, and so it might be best to show out-of-population stray data and describe that within-population straying also occurs. Maier said the document currently shows brood-year stray rates. Todd Pearsons said viable salmon population (VSP) criteria include within- and between-population stray rates, and said brood-year stray rates are different. He suggested focusing primarily on VSP-related stray rates. Hillman suggested reporting return-year stray rates instead of brood-year stray rates, because the recovery plan discusses return-year stray rates. Tonseth agreed and said examining brood-year stray rates can help determine if rearing practices or release strategies may contribute to stray rates, but it is more for management than evaluation. Mackey suggested reporting the number of fish along with the stray rate percentage, as percentages can be misleading depending on the size of the recipient program. Maier said she would consider these suggestions and review the Hatchery M&E Plan (2017 Update) for further content.

Mackey said for assessing habitat or hatchery performance, or for setting a management strategy, one could examine percent improvement for each generation or each year, then compile years and examine improvement over time. He said some improvements cannot be detected in year-to-year evaluations, but over a longer period of time they would be detected, as in a life cycle model. Maier said Jeff Jorgensen (NWFSC) included life cycle modeling scenarios with improvements over time (i.e., increasing natural-origin adults), and the results are included in the original Hatchery Summary draft, but not the most recent version. Mackey said the life cycle model will be useful for examining expected changes over time and will help with long-term planning and expectations. Hillman asked if Jorgensen's results showing that hatchery programs are very important to reducing the threat of extinction are included in the Hatchery Summary. Maier said those results are not included in the most recent version of the summary, but the life cycle model includes a robust hatchery module that should be considered especially considering realistic increases in natural-origin returns.

Hillman asked if non-target taxa of concern species are addressed in the Hatchery Summary. Tom Kahler said the BiOps contain information about non-target taxa of concern species that could be used in the summary. Mackey recommended contacting Craig Busack and Charlene Hurst for more information about non-target taxa of concern topics. Pearsons said there is published information about the non-target taxa of concern model, which could also be used in the summary.

Maier summarized that the UCSRB will start working on the hydro report next, then harvest. Peter Graf (Grant PUD) asked what the UCSRB's goals are for shared learning and discussions. He asked who will be participating in these discussions. Maier said shared learning will involve presentations to the Board from members of the IRTAG or Hatchery Committees. She said the Board should understand the relationship between management sections and recovery, and the goal is for the Board to engage on hatchery topics and understand the programs and management concepts.

Maier summarized that any further comments should be provided to her by Monday, November 20, 2017, so the IRTAG can address any outstanding issues. She asked representatives present for any further input on this summary. Catherine Willard said the summary is much improved from the previous draft, and Murdoch agreed. Maier asked what representatives think of this summary format, and said the hydro summary will likely focus on direct life stage interactions with the hydro system. Willard said she thinks the summaries will be useful for habitat and hydro managers.

Gale asked what the timeline is for reexamining the four H's once the reports are completed. Maier said for the Habitat Report, the UCSRB maintains a database of important information for tracking habitat projects. She said the Board tracks certain metrics and reports on them yearly. She said she expects the Hatchery Summary will also result in a database that is updated and reported annually. Gale suggested finalizing which data will be reported on and maintained before the report is finalized, so that the report points to and focuses on which data will be tracked.

Matt Cooper asked if there will be a report or modeling effort that will tie the four H reports together. Maier said the Board has discussed writing a synthesis report, but has not decided yet, and the discussion will likely continue during the sharing sessions when the most important data for interactions between the H's are identified.

Hatchery Committees representatives present thanked Maier for her presentation.

VI. HCP Administration

A. Next Meetings

Tracy Hillman asked if the Hatchery Committees plan to meet in December. Bill Gale said the committees might need to discuss consultations at the December meeting. Hillman summarized that the Hatchery Committees might have a conference call or meet in person in December, depending on what needs to be discussed.

The next Hatchery Committees meetings are on December 20, 2017 (TBD), and January 17, 2018 (Grant PUD), and February 14, 2018 (Grant PUD).

VII. List of Attachments

Attachment A List of Attendees
Attachment B Final SOA Regarding District's Coho Obligation
Attachment C Douglas PUD Steelhead Program Surplus BY 2017
Attachment D Final M&E Plan for PUD Hatchery Programs (2017 Update)
Attachment E Draft Hatchery Program Timelines
Attachment F Integrated Recovery

Attachment A
List of Attendees

Name	Organization
Tracy Hillman	BioAnalysts, Inc.
Sarah Montgomery	Anchor QEA, LLC
Catherine Willard*	Chelan PUD
Alene Underwood†	Chelan PUD
Greg Mackey*	Douglas PUD
Tom Kahler*	Douglas PUD
Todd Pearsons‡	Grant PUD
Peter Graf‡	Grant PUD
Deanne Pavlik-Kunkel‡	Grant PUD
Mike Tonseth*	Washington Department of Fish and Wildlife
Alf Haukenes†	Washington Department of Fish and Wildlife
Matt Cooper*	U.S. Fish and Wildlife Service
Bill Gale*	U.S. Fish and Wildlife Service
Brett Farman*†	National Marine Fisheries Service
Emi Kondo†	National Marine Fisheries Service
Keely Murdoch*	Yakama Nation
Greer Maier	Upper Columbia Salmon Recovery Board

Notes:
* Denotes Hatchery Committees member or alternate
† Joined by phone
‡ Joined for the joint HCP-HC/PRCC HSC discussion

Rocky Reach and Rock Island HCP Hatchery Committees
FINAL Statement of Agreement
Regarding District's Coho Obligation
November 15th, 2017

Approved as follows: CCT approved via email on November 14, 2017, and Chelan PUD, WDFW, USFWS, NMFS, and YN approved on November 15, 2017.

Statement

The Rocky Reach and Rock Island HCP Hatchery Committees (hereafter "Committees") agree that Chelan PUD shall provide coho compensation for the Methow River and Wenatchee River sub-basins at a rate equivalent to 7.0% at each project to meet Chelan PUD's No Net Impact hatchery obligations for brood years 2017 to 2021 (release years 2019 to 2023); therefore, 7.0% will be used as the coho hatchery compensation rate until the next scheduled hatchery compensation recalculation (2023). Methodology described in the SOA Regarding the 2013 No Net Impact Recalculation Methodology (dated July 20th, 2011) will be used to calculate hatchery compensation levels for coho.

Background

On June 20, 2007, the Committees agreed to implement coho hatchery compensation as detailed in Section 8.4.3.a of the Rocky Reach and Rock Island HCPs and agreed that the District shall begin providing hatchery compensation no later than October 1, 2007. On March 28, 2017, the Rocky Reach and Rock Island Coordinating Committees agreed to use Chelan PUD's yearling Chinook acoustic tag survival estimates and coho PIT-tag based survival estimates to estimate juvenile coho survival of 93.98% at Rock Island and 92.94% at Rocky Reach (Skalski and Townsend 2017) which culminated in a 93% survival value at both projects.

Calculations for the Methow Sub-basin Coho Reintroduction Project

Compensation for **hatchery-origin smolts** will be determined by multiplying the Program's annual release targets from the Methow sub-basin coho reintroduction project by the unavoidable project mortality (1-(0.93 x 0.93)) for Rocky Reach and Rock Island.

Compensation for **natural-origin smolts** produced is determined by:

- Mean NOR[1] to Rocky Reach (return years 2008 to 2011 and 2013 to 2015) = 43
- Mean NOR in absence of project mortality: 43/0.9300 = 46
- Adult equivalents to meet NNI: 46-43=3
- Mean 8-year SAR (release years 2008-2015 Methow sub-basin hatchery program) = 0.59%
- Compensation for natural-origin smolts: 3/0.0059 = 508 smolts

Calculations for the Wenatchee Sub-basin Coho Reintroduction Project

Compensation for **hatchery-origin smolts** will be determined by multiplying the Program's annual release targets from the Wenatchee sub-basin coho reintroduction project by the unavoidable project mortality (1-0.93) for Rock Island.

Compensation for **natural-origin smolts** is determined by:

- Mean NOR to Rock Island (return years 2007-2016) = 529
- Mean NOR in absence of project mortality: 529/0.9300 = 569
- Adult equivalents to meet NNI: 569-529 = 40
- Mean 10 year SAR[2] (release years 2006-2015 Wenatchee sub-basin hatchery program) = 0.75%
- Compensation for natural-origin smolts: 40/0.0075 = 5,333 smolts

[1]Natural-origin return=NOR
[2]SAR=releases from the Wenatchee hatchery programs and returns to Priest Rapids Dam (versus Rock Island Dam due to historic variable PIT tag detection efficiency at the adult ladders).

November 2017

HCP-HC

Douglas PUD Steelhead Program Surplus BY 2017

Quick Description:

The Twisp program has excess, the Methow Program is short, and the Columbia program has substantial excess fish. However, if the program + 10% overage is considered, the Twisp is 2,820 over and the Columbia is 71,232 over. The Methow is 27,232 under the 100,000 release target.

The Twisp includes 8,000 NNI (this obligation is met first). If we use the Columbia release to absorb the shortfall in the Methow Inundation and the overage in the Twisp Inundation, we can meet the mitigation obligations. This results in 37,034 surplus Columbia Inundation fish while maintaining +10 % across the DPUD programs in aggregate.

The 37,034 surplus would be provided to WDFW to release in non-anadromous waters.

Breakdown of the numbers:

	NNI	Inundation	Target	Target+10%	Difference	Diff at +10%
Twisp	8,000	47,620	48,000	52,800	7,620	2,820
Methow	0	72,768	100,000	110,000	-27,232	-37,232
Columbia	0	247,446	160,000	176,000	87,446	71,446
Total	8,000	367,834	308,000	338,800	67,834	37,034

Adjust Columbia to compensate for low Methow, high Twisp and High Columbia

Surplus Columbia = 37,034

Under this scenario the total release would be:

Twisp	55,620	
Methow	72,768	
Columbia	210,412	
Total	338,800	Matches the overall target of 308,000 + 10% = 338,800

Attachment D

MONITORING AND EVALUATION PLAN FOR PUD HATCHERY PROGRAMS

2017 UPDATE

November 16, 2017

Prepared by:

Tracy Hillman
Tom Kahler
Greg Mackey
Andrew Murdoch
Keely Murdoch
Todd Pearsons
Mike Tonseth
Catherine Willard

Prepared for:

HCPs and PRCC Hatchery Committees

Citation: Hillman, T., T. Kahler, G. Mackey, Andrew Murdoch, K. Murdoch, T. Pearsons, M. Tonseth, and C. Willard. 2017. Monitoring and evaluation plan for PUD hatchery programs: 2017 update. Report to the HCP and PRCC Hatchery Committees, Wenatchee and Ephrata, WA.

TABLE OF CONTENTS

SECTION 1: INTRODUCTION 1

SECTION 2: ADULT PRODUCTIVITY 9
2.1 Natural Replacement Rates of Supplemented Populations 9
2.2 Natural-Origin Recruits of Supplemented Populations 11

SECTION 3: JUVENILE PRODUCTIVITY 13
3.1 Freshwater Juvenile Productivity 13

SECTION 4: NATURAL ENVIRONMENT MONITORING INDICATORS 17
4.1 Hatchery Replacement Rates (HRRs) 17
4.2 Proportion of Hatchery-Origin Spawners (pHOS or PNI) 18
4.3 Run Timing, Spawn Timing, and Spawning Distribution 19
4.4 Stray Rates 22
4.5 Population Genetics 26
4.6 Phenotypic Traits 28

SECTION 5: HATCHERY ENVIRONMENT MONITORING INDICATORS 33
5.1 Release Targets 33

SECTION 6: HARVEST MONITORING INDICATORS 37
6.1 Harvest Rates 37

SECTION 7: REGIONAL OBJECTIVES 39
7.1 Incidence of Disease 39
7.2 Non-Target Taxa of Concern (NTTOC) 40

SECTION 8: ADAPTIVE MANAGEMENT 43

SECTION 9: REFERENCES 45

SECTION 10: GLOSSARY 47

APPENDIX 1: ESTIMATION OF CARRYING CAPACITY 51

APPENDIX 2: HATCHERY REPLACEMENT RATES 79

APPENDIX 3: PNI AND PHOS TARGETS AND SLIDING SCALES 81

APPENDIX 4: SPATIAL DISTRIBUTION OF SPAWNERS OR REDDS 85

APPENDIX 5: WITHIN HATCHERY REARING TARGETS 87

APPENDIX 6: IDENTIFYING AND ANALYZING REFERENCE POPULATIONS 89

LIST OF APPENDICES

Appendix 1: **Estimation of Carrying Capacity**

Appendix 2: **Hatchery Replacement Rates**

Appendix 3: **PNI and pHOS Management Targets and Sliding Scales**

Appendix 4: **Spatial Distribution of Spawners or Redds**

Appendix 5: **Within Hatchery Rearing Targets**

Appendix 6: **Identifying and Analyzing Reference Populations**

SECTION 1: INTRODUCTION

This document is an update of the monitoring and evaluation (M&E) plan of the salmon and steelhead hatchery programs funded by Douglas, Chelan, and Grant County Public Utility Districts (PUDs). Programmatic changes, evaluation of data collection methods, and M&E results from the past several years, along with shifting management paradigms affect M&E needs, all of which have occurred under advancing fish culture and monitoring techniques. As required by the programs, this document is a result of a five-year review intended to expand on and coalesce previous M&E documents (BAMP 1998; Cates et al. 2005; Murdoch and Peven 2005; Hays et al. 2006; Pearsons and Langshaw 2009a, 2009b; Hillman et al. 2013) with inclusion of new information.

Fishery management agencies developed the following general goal statements for hatchery programs, which were adopted by the HCPs Hatchery Committees and PRCC Hatchery Sub-Committee (hereafter, Hatchery Committees):

1. Support the recovery of ESA-listed species by increasing the abundance of the natural adult population, while ensuring appropriate spatial distribution, genetic stock integrity, and adult spawner productivity.
2. Increase the abundance of the natural adult population of unlisted plan species, while ensuring appropriate spatial distribution, genetic stock integrity, and adult spawner productivity. In addition, provide harvest opportunities in years when spawning escapement is sufficient to support harvest.
3. Provide salmon for harvest and increase harvest opportunities, while segregating returning adults from natural tributary spawning populations.

Following the development of Hatchery and Genetic Management Plans (HGMPs), artificial supplementation programs are now characterized into three categories. The first type, integrated conservation programs, are intended to support or restore natural populations. These programs focus on increasing the natural production of targeted fish populations. A fundamental assumption of this strategy is that hatchery fish returning to the spawning grounds are reproductively similar to naturally produced fish. The second type, safety-net programs, are extensions of conservation programs, but are intended to function as reserve capacity for conservation programs in years of low returns. The safety-net provides a demographic and genetic reserve for the natural population. That is, in years of abundant returns they function like segregated programs, and in low return years they can be managed as conservation programs. Lastly harvest augmentation programs are intended to increase harvest opportunities while limiting interactions with wild-origin counterparts.

Monitoring is needed to determine if the hatchery programs are meeting the intended management objectives of conservation, safety-net, or harvest augmentation programs. Objectives for hatchery programs are generally grouped into three categories of performance indicators:

1. In-Hatchery: Is the program meeting the hatchery production objectives?
2. In-Nature: How do fish from the program perform after release?
    a. Conservation Program:

- How does the program affect target population abundance and productivity?
- How does the program affect target population long-term fitness?

b. Safety-Net Program:
- How does the program affect target population long-term fitness?

c. Harvest Augmentation Program:
- Does the program provide harvest opportunities?

3. Risk Assessment: Does the program pose risks to other populations?

Objectives in this plan have been organized in a hierarchy where productivity indicators are the primary metrics used to assess if conservation and safety-net program goals have been met; harvest rates and effects on non-targeted populations are used for harvest programs. In cases where productivity indicators are not available or results are equivocal, monitoring indicators may be used to help evaluate the performance of the program. Evaluations of monitoring indicators may not provide sufficiently powerful conclusions on which to base management actions, although they may provide insight as to why a productivity indicator did or did not meet the program goal. Therefore, the relationship between hatchery programs and indicators can be viewed in a chain-of-causation: management actions within the hatchery programs affect the status of monitoring indicators, which in turn influence productivity indicators (Figure 1).

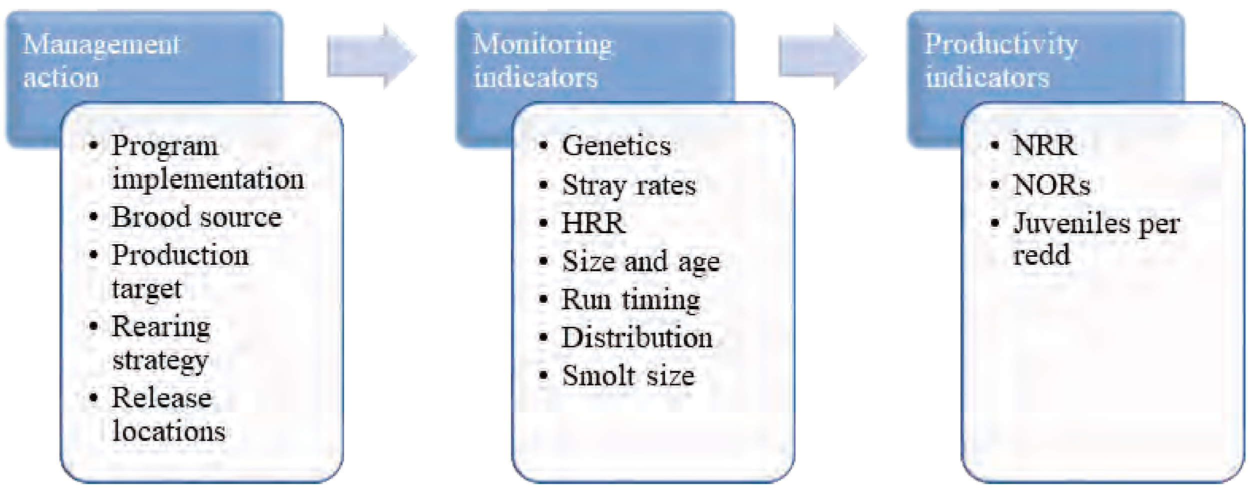

Figure 1. Relationship of indicators to the assessment of supplementation programs. Management actions affect monitoring indicators, which influence productivity indicators. Monitoring indicators may be used to hypothesize the magnitude of influence on productivity.

The primary goal of a conservation program is to contribute to the rebuilding and recovery of naturally reproducing populations within their native habitat. In this plan, natural replacement rates (NRR), recruitment of naturally-produced fish (NOR), and juvenile productivity (juveniles per redd) are important indicators for assessing the success of supplementation. These indicators are difficult to measure precisely and are quite variable in space and time. Therefore, monitoring indicators can be evaluated to help assess if productivity was related to the hatchery programs or other factors (Table 1).

Table 1. Program objectives, indicators, and goals for conservation hatchery programs including productivity and monitoring indicators (also applies to safety-net programs when used to support a conservation program).

	Objective	Indicator	Target	Program goals: Rebuild natural populations	Program goals: Maintain genetic diversity	Program goals: Opportunity for harvest
Productivity indicators	Determine if the program has increased the number of naturally spawning adults	Abundance of natural spawners	Increase	✓		✓
		Adult productivity (NRR)	No decrease	✓		
	Determine if the proportion of hatchery fish affects freshwater productivity	Residuals vs. pHOS	No relationship	✓		
		Juveniles per redd vs. pHOS	No relationship	✓		
Monitoring indicators	Determine if run timing and distribution meets objectives	Migration timing	No difference	✓	✓	
		Spawn timing[1]	No difference	✓	✓	
		Redd distribution[2]	No difference	✓	✓	
	Determine if program has affected genetic diversity and population structure	Allele frequency (hatchery vs. wild)	No difference		✓	
		Genetic distance between populations	No difference		✓	
		Effective population size	Increase		✓	
		Age and size at maturity	No difference		✓	
	Determine if hatchery survival meets expectations	HRR	HRR > NRR	✓		
		HRR	HRR ≥ Goal[3]	✓		
	Determine if recipient stray rate of hatchery fish is acceptable	Out of basin	≤ 5%	✓	✓	
		Within basin	≤ 10%	✓	✓	
	Determine if hatchery fish were released at program targets	Size and number	= Target[4]	✓		
	Provide harvest opportunities when appropriate	Harvest	Escapement goals			✓

[1] Hatchery and natural-origin fish should spawn at the same time across the range of elevations within the spawning distribution of each stock.

[2] Hatchery and natural-origin fish should spawn in the same locations. Exceptions are the Carlton and Dryden Summer Chinook programs (see Appendix 4).

[3] HRR targets are identified in Appendix 2.

[4] Number and size targets are identified in Table 3 and Appendix 5.

A flow of information following sequential, logical steps will be employed to evaluate supplementation programs, consistent with the indicators described in Table 1. For example, a hatchery program, at a minimum, must be able to produce more adults per spawner than would occur in the natural environment. Should the program fail this test, hatchery operations should be evaluated to determine if improvements can correct the problem. If a program successfully replaces the required number of adults, it is then evaluated against a reference population or condition, if available, to determine if it has increased the overall number of naturally spawning fish (including both hatchery- and natural-origin adults), increased the number of natural-origin spawners, and to test if productivity of the natural population has changed. When these goals are met, the program is considered successful. When these goals are not met, monitoring indicators may infer why the program is not achieving its goals

If suitable reference populations are not available, other comparisons can be used to help evaluate treatment responses. Evaluation of programs may pursue the following approaches:

- Comparison to reference population(s) that do not contain pre-treatment data.
- Before treatment and after treatment comparisons.
- Comparison to standard(s).
- Comparison to other suitable reference conditions.

Methodologies for selecting reference streams, analyzing data from treatment and reference stream comparisons, and other comparisons are presented in Hillman et al. (2012) (see Appendix 6).

The primary goals of a safety-net program are to provide demographic and genetic reserves for a population that is supplemented by a conservation program (Table 2). Harvest and adult management may be used to control escapement of spawners when appropriate. Monitoring focuses on estimating the number of fish that escape to spawn naturally and stray rates and in-hatchery performance evaluation.

Table 2. Program objectives, indicators, and goals for segregated harvest augmentation hatchery programs including monitoring indicators.

				Program goals		
	Objective	**Indicator**	**Target**	**Rebuild natural populations**	**Maintain genetic diversity**	**Opportunity for harvest**
Monitoring indicators	Determine if hatchery survival meets expectations	HRR	HRR > NRR			✓
		HRR	HRR ≥ Goal[1]			✓
	Determine if stray rate of hatchery fish is acceptable	Out of basin	≤ 5%		✓	
		Within basin	≤ 10%		✓	
	Determine if hatchery fish were released at program targets	Size and number	= Target[2]			✓
	Provide harvest opportunities when appropriate	Harvest	When greater than escapement goals			✓

[1] HRR targets are identified in Appendix 2.

[2] Number and size targets are identified in Table 3 and Appendix 5.

The primary goal of a harvest augmentation program is to increase harvest opportunities, while segregating adults from natural spawning populations. In this plan, harvest opportunity, survival rates, and stray rates are important indicators for assessing the success of harvest augmentation. These indicators are more readily quantified compared to productivity indicators (Table 2). A flow of information will be employed to evaluate harvest augmentation programs. Since harvest augmentation programs are typically segregated, monitoring indicators will be used to determine the success of a program.

Both monitoring and productivity indicators will be used to evaluate the success of hatchery programs. In the event that the statistical power of tests that involve productivity indicators is insufficient to inform sound management decisions, some of the monitoring indicators may be used to guide management. Figure 2 show the categories of indicators associated with each component of monitoring.

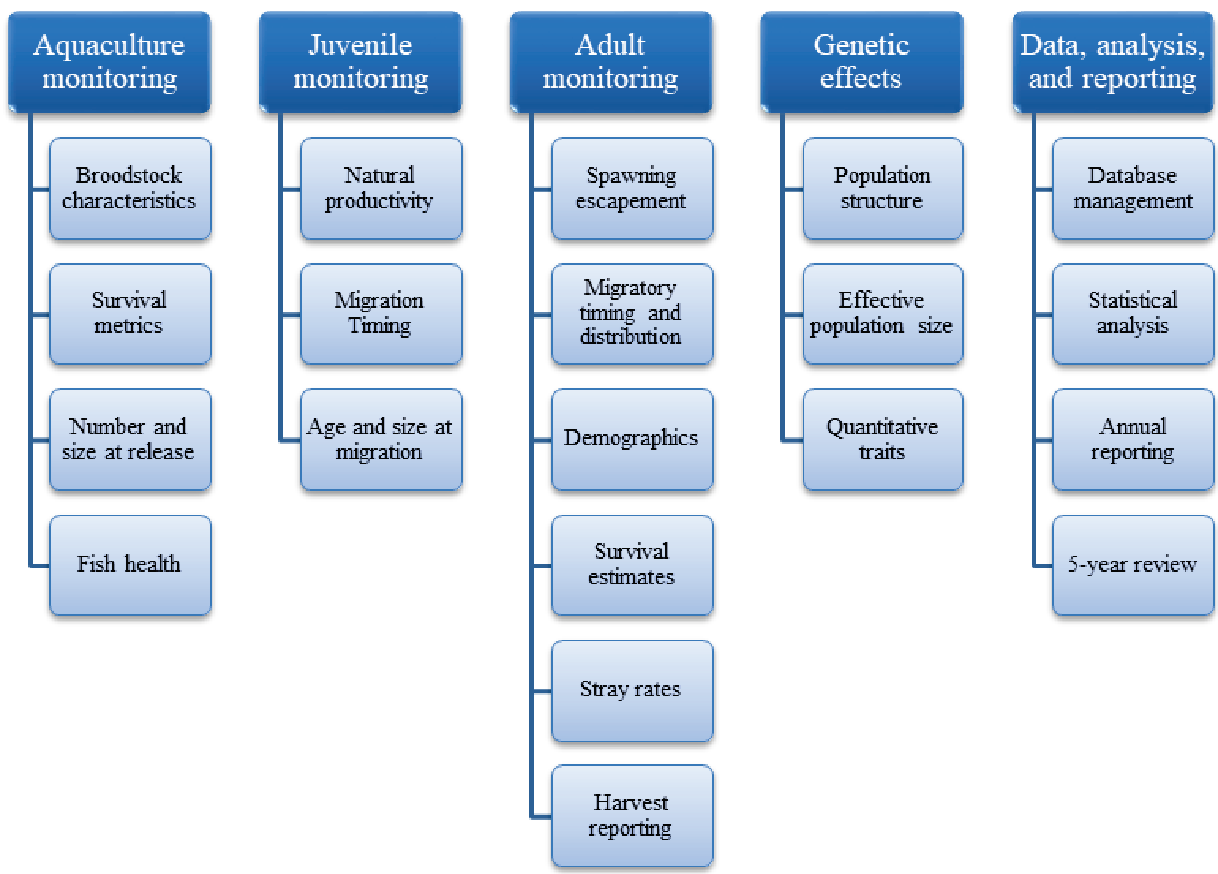

Figure 2. Overview of Monitoring and Evaluation Plan Categories and Components (not including regional objectives).

The overarching goals of conservation, safety-net, and harvest augmentation programs, as described above, are shown in detail in Figure 3. The flow chart (Figure 3) shows the relationship of overarching program goals, the strategies used to meet the goals, the monitoring and evaluation objectives used to evaluate the strategies and determine if goals are being met, and the adaptive

management cycle associated with the programs (see Tables 1 and 2 for the indicators under each objective). The logic depicted in this flow chart shall be used to assess M&E results and apply those results to management decisions. Table 3 presents the current hatchery programs releasing fish in the Upper Columbia Basin.

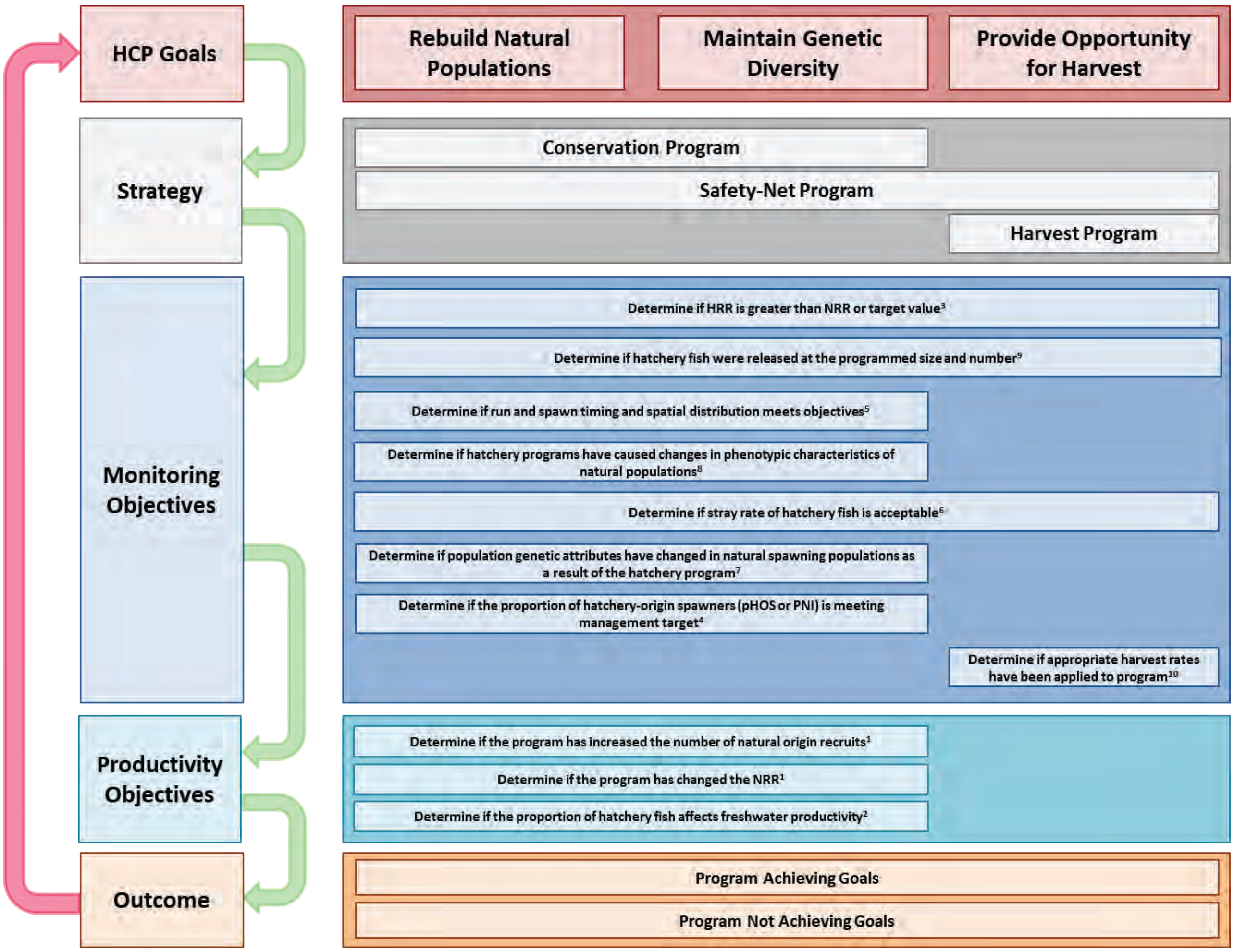

Figure 3. Adaptive management flow chart depicting HCP goals, associated strategies to meet the goals, the monitoring and evaluation objectives (indicated in superscript), and the adaptive management feedback cycle. The strategies, objectives, and outcomes are aligned vertically under the corresponding goals.

Table 3. Hatchery programs in the mid-Columbia River Basin, 2012. Funding entities included Douglas PUD (D), Chelan PUD (C), Grant PUD (G), Bonneville Power Administration (B), Bureau of Reclamation (O), and Army Corps of Engineers (A) and are listed in order of contribution. Total artificial production targets in the mid-Columbia River exceeds 20 million juveniles annually.

Program	Species	Basin	Purpose	Funding Entity	Production
Methow[5]	Spring Chinook [1]	Methow	NNI/Conservation	G, C, D	223,765
Chief Joseph[7]	Spring Chinook	Okanogan	Reintroduction/Harvest	B, G, C, D	900,000
Chiwawa[5]	Spring Chinook [1]	Wenatchee	NNI/Conservation	C	144,026
Nason[5]	Spring Chinook [1]	Wenatchee	NNI/Conservation	G	223,670
Winthrop[7]	Spring Chinook [2]	Methow	Safety-Net	O	400,000
Leavenworth	Spring Chinook [2]	Wenatchee	Harvest	O	1,200,000
Wells[5]	Steelhead [1]	Columbia	Inundation/Safety-Net	D	160,000
Winthrop[7]	Steelhead [1]	Methow	Conservation	O	100,000-200,000
Wells[5]	Steelhead [1]	Methow	Inundation/Safety-Net	D	100,000
Wells/Omak[5, 6]	Steelhead [1]	Okanogan	NNI/Conservation	G	100,000
Wells[5]	Steelhead [1]	Twisp	Inundation/Conservation	D	40,000
Wells[5]	Steelhead [1]	Twisp	NNI/Conservation	D	8,000
Chiwawa[5]	Steelhead [1]	Wenatchee	NNI/Conservation	C	22,000
Chiwawa[5]	Steelhead [1]	Wenatchee	Inundation/Harvest	C	165,000
Chiwawa[5]	Steelhead [1]	Wenatchee	Species trade	C	60,300
Ringold	Steelhead [9]	Columbia	Harvest	Mitchell Act	180,000
Wells[5]	Summer Chinook [2, 3]	Columbia	Inundation/Harvest	D	484,000
Chief Joseph[7]	Summer Chinook [3]	Okanogan	NNI/Cons./Harvest	B, C, D	700,000
Chelan Falls[5]	Summer Chinook [2]	Chelan	Inundation/Harvest	C	400,000
Chelan Falls[5]	Summer Chinook [2]	Chelan	NNI/Conservation	C	176,000
Wells[5]	Summer Chinook [2]	Columbia	Inundation/Harvest	D	320,000
Entiat	Summer Chinook	Entiat	Harvest	O	400,000
Carlton[5]	Summer Chinook	Methow	NNI/Conservation	G	200,000
Chief Joseph[7]	Summer Chinook	Okanogan	NNI/Cons./Harvest	B, G, C, D	1,300,000
Dryden[5]	Summer Chinook	Wenatchee	NNI/Conservation	C, G	500,000
Priest[5]	Fall Chinook[3]	Columbia	Inundation/Harvest	G	5,000,000
Priest[5]	Fall Chinook[3]	Columbia	NNI/Harvest	G	325,543
Priest[5]	Fall Chinook[4]	Columbia	Fry loss/Harvest	G	273,961
Priest[5, 7]	Fall Chinook[3]	Columbia	Harvest	A	1,700,000
Ringold[7]	Fall Chinook[3]	Columbia	Harvest	A	3,500,000
Yakama Nation	Coho	Wenatchee	Reintroduction/Harvest	B, G, C, D	1,000,000
Yakama Nation[8]	Coho	Methow	Reintroduction/Harvest	B, G, C, D	500,000
Skaha	Sockeye	Okanogan	Reintroduction/Harvest	C, G	≤ 5 M eggs

[1] Species listed under the Endangered Species Act.
[2] Segregated program.
[3] Sub-yearling production.
[4] Fry production.
[5] Program covered by this M&E Plan.
[6] Program also partially covered by CCT M&E Plan.
[7] Program affects PUD-funded programs covered by this plan.
[8] Planned to increase to 1,000,000.
[9] Part of the Mitchell Act suite of mitigation programs under the FCRPS BiOp.

SECTION 2: ADULT PRODUCTIVITY

2.1 Natural Replacement Rates of Supplemented Populations[1]

Objective 1: Determine if conservation programs have increased the number of naturally spawning and naturally produced adults of the target population and if the program has reduced the natural replacement rate (NRR) of the supplemented population.

At the core of a conservation program is the objective of increasing the number of spawning adults (i.e., the combined number of naturally produced and hatchery fish) in order to affect a subsequent increase in the number of returning naturally produced fish or natural-origin recruits (NOR). In order for the natural population to remain stable or to increase, the Natural Replacement Rate (NRR), or the ratio of NORs to the parent spawning population, must be at a level where parents are being replaced by their offspring as spawners in the next generation. It is possible to affect an increase in natural-origin spawners through supplementation with a stable or decreasing NRR. However, if the NRR is below replacement (NRR<1.0), termination of the supplementation program will result in a declining natural population should that state of NRR persist. The proportion of the hatchery-origin spawners (pHOS) that will increase natural production without creating adverse effects to the genetic diversity or reproductive success rate of the natural population is unknown, and may be dependent on how individual hatchery programs are operated, as well as available spawning and rearing habitat. Some programs restrict pHOS to reduce the risk to the natural population with the intent of optimizing productivity, concomitantly reducing the overall number of spawners. All other objectives of the M&E Plan either directly support this objective or seek to minimize negative effects of the conservation programs on non-target stocks of concern.

Differences in carrying capacities of supplemented and non-supplemented streams can confound the analysis of the effects of supplementation on total number of spawners returning to the streams. For example, if the supplemented population is at carrying capacity and the non-supplemented population is not, the total number of spawners returning to the non-supplemented population may show an increasing trend over time, while the supplemented population would show no increasing trend. To avoid concluding that the supplementation program has no effect or perhaps a negative effect on total spawners, density corrections should be included in the analyses. Hypotheses that may require density corrections are noted under each monitoring question. Appendix 1 describes methods for estimating carrying capacities.

Monitoring Questions:

Q1.1.1 Has the supplementation program changed the adult productivity (NRRs) of the supplemented populations?[2]

Target Species/Populations:

[1] Supplementation programs may include a safety-net component.

[2] Because adult productivity is affected by the abundance of the population (i.e., productivity decreases with increasing abundance), the goal of supplementation is to increase or maintain productivity, but not decrease it.

- Q1.1.1 applies to all conservation and safety-net stocks.

Statistical Hypotheses 1.1.1[3]:

- $Ho_{1.1.1.1}$: Slope in NRRs before supplementation ≤ slope in NRRs after supplementation.
- $Ho_{1.1.1.2}$: Differences in slopes in NRRs between supplemented and reference populations before supplementation ≤ differences in slopes in NRRs between supplemented and reference populations after supplementation.
- $Ho_{1.1.1.3}$: Mean NRRs before supplementation ≤ mean NRRs after supplementation.
- $Ho_{1.1.1.4}$: Mean ratio scores in NRRs before supplementation ≤ Mean ratio scores in NRRs during supplementation.
- $Ho_{1.1.1.5}$: Mean ratio scores in NRRs (adjusted for density dependence) before supplementation ≤ Mean ratio scores in NRRs (adjusted for density dependence) during supplementation. [This hypothesis adjusts NRRs for density-dependent effects (see Hillman et al. 2012 for details; Appendix 6).]
- $Ho_{1.1.1.6}$: There is no association between the proportion of hatchery-origin spawners (pHOS) and the residuals from the smooth hockey stick stock-recruitment curve; rho = 0. [If there is a significant negative association between pHOS and the residuals, then hatchery fish may be reducing the productivity of the wild population.]

Measured Variables:

- Number of hatchery and naturally produced fish on spawning grounds
- Number of naturally produced fish harvested

Derived Variables:

- Number of naturally produced recruits by brood year for both naturally produced parents and hatchery parents (≥age-3).
- NRRs (calculated as NORs/spawner).
- Stock-recruit models, parameters, and residuals.
- Includes ratio scores of NRRs (requires reference population[s]).
- Includes calculation of ratios NORs (requires reference population).
- Appendix 1: Spawning escapement and carrying capacity information (as applicable)

Spatial/Temporal Scale:

- Calculated annually based on brood year.
- Time series.

Possible Statistical Analysis:

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3 Quality and quantity of data will determine which hypotheses are evaluated. See Hillman et al. 2012 (Appendix 6) for details.

- These analyses shall be performed every 5-years. Use graphic analyses, trend analyses, t-tests, Aspin-Welch tests, and randomization tests to evaluate the statistical hypotheses (see Hillman et al. 2012; Appendix 6). The specific analysis used will depend on the availability of reference conditions.
- Correlation analysis will examine associations between hatchery adult composition and NRRs.
- On a five-year period, correlate productivity with extraneous factors such as ocean productivity indices.

Analytical Rules:

- This is a productivity indicator that will be used to assess the success of the supplementation program.
- Type I Error of 0.05.

2.2 Natural-Origin Recruits of Supplemented Populations

Monitoring Questions:

Q1.2.1: Has the supplementation program changed the abundance of NORs within the supplemented population?

Target Species/Populations:

- Q1.2.1 applies to all supplemented or safety net stocks.

Statistical Hypotheses 1.2.1[4]:

- $Ho_{1.2.1.1}$: Slope in NORs[5] before supplementation ≥ slope in NORs after supplementation.
- $Ho_{1.2.1.2}$: Differences in slopes in NORs between supplemented and reference populations before supplementation ≥ differences in slopes in NORs between supplemented and reference populations after supplementation.
- $Ho_{1.2.1.3}$: Mean NORs before supplementation ≥ mean NORs after supplementation.
- $Ho_{1.2.1.4}$: Mean ratio scores in NORs before supplementation ≥ Mean ratio scores in NORs during supplementation.
- $Ho_{1.2.1.5}$: Mean ratio scores in NORs/Maximum Recruitment before supplementation ≥ Mean ratio scores in NORs/Maximum Recruitment during supplementation. [This hypothesis adjusts NORs for the capacity of the habitat; it tests the fraction of the habitat saturated with NORs (see Hillman et al. 2012 for details).]
- $Ho_{1.2.1.6}$: There is no association between the proportion of hatchery-origin spawners (pHOS) and NORs; rho = 0. [If there is a significant negative association between

4 Quality and quantity of data will determine which hypotheses are evaluated. See Hillman et al. 2012 (Appendix 7) for details.

5 “Slope in NORS” refers to abundance of NORs across time (years).

pHOS and NORs, then hatchery fish may be reducing the reproductive success of the wild population.]

Measured Variables:

- Number of hatchery and naturally produced fish on spawning grounds.
- Number of hatchery and naturally produced fish taken for broodstock.
- Number of hatchery and naturally produced fish taken in harvest (if recruitment is to the Columbia).

Derived Variables:

- NORs (number of naturally produced recruits (total recruits) by brood year for both naturally produced parents and hatchery parents [≥age-3]).
- Stock-recruit models, parameters, and residuals.
- Includes ratio scores of NORs (requires reference population[s]).
- Estimates of carrying capacity (see Appendix 1).

Spatial/Temporal Scale:

- Calculate annually based on brood year.
- Time series.

Possible Statistical Analysis:

- These analyses shall be performed every 5-years. Use graphic analyses, trend analyses, t-tests, Aspin-Welch tests, and randomization tests to evaluate the statistical hypotheses (see Hillman et al. 2012). The specific analysis used will depend on the availability of reference conditions.
- Correlation analysis will examine associations between hatchery adult composition and NORs.
- On a five-year period, correlate NORs with extraneous factors such as ocean productivity indices.

Analytical Rules:

- This is a productivity indicator that will be used to assess the success of the supplementation program.
- Type I Error of 0.05.

SECTION 3: JUVENILE PRODUCTIVITY

3.1 Freshwater Juvenile Productivity

Objective 2: Determine if the proportion of hatchery fish on the spawning grounds affects the freshwater productivity of supplemented stocks.

Out-of-basin effects (e.g., smolt passage through the hydro system, harvest, and ocean productivity, etc.) influence the survival of smolts after they migrate from the tributaries. These effects introduce substantial variability into the adult-to-adult survival rates (NRRs and HRRs) and may mask in-basin effects (e.g., habitat quality, density-dependent mortality, and differential reproductive success of hatchery and naturally produced fish). Therefore, an estimate of freshwater productivity may help inform the performance of hatchery and natural-origin spawners.

The objective of estimating freshwater productivity in the Upper Columbia ESU/DPS is to estimate the survival from egg to a critical juvenile life stage(s) of target stocks. Smolt or juvenile production models generated from the information obtained through these programs will provide a level of predictability with greater sensitivity to in-basin effects than spawner-recruitment models that consider all effects.

Differences in the current carrying capacities of supplemented and non-supplemented streams can confound the effects of supplementation on numbers of juveniles per redd. For example, if the supplemented population is at or above carrying capacity and the non-supplemented population is not, numbers of juveniles per redd in the non-supplemented population may be significantly greater than the number of juveniles per redd in the supplemented population. In addition, pHOS may be correlated with overall spawner abundance. In these cases, it is difficult or impossible to separate density-dependent effects from the influence of pHOS on freshwater productivity. To avoid concluding that the supplementation program has no effect or perhaps a negative effect on juveniles per redd, the capacity of the habitats must be included in the analyses. The Supplementary Hypotheses presented below are designed to address the confounding effects of different densities on the analyses.

Monitoring Questions:

Q2.1.1: Has the supplementation program changed the number of juveniles (smolts, parr, and/or emigrants) per redd within the supplemented population?

Q2.2.1: Does the number of juveniles per redd decrease as the proportion of hatchery spawners increases?[6]

Target Species/Populations:

- Both Q2.1.1 and Q2.2.1 apply to all conservation stocks.

Statistical Hypotheses for 2.1.1[7]:

[6] Information is needed to estimate the effects of density dependence on these questions. Consider spatial distribution of redds.

[7] Quality and quantity of data will determine which hypotheses are evaluated. See Hillman et al. (2012) for details.

- $Ho_{2.1.1.1}$: Slope in juveniles/redd before supplementation ≤ slope in juveniles/redd after supplementation.
- $Ho_{2.1.1.2}$: Differences in slopes in juveniles/redd between supplemented and reference populations before supplementation ≤ differences in slopes in juveniles/redd between supplemented and reference populations after supplementation.
- $Ho_{2.1.1.3}$: Mean juveniles/redd before supplementation ≤ mean juveniles/redd after supplementation.
- $Ho_{2.1.1.4}$: Mean ratio scores in juveniles/redd before supplementation ≤ Mean ratio scores in juveniles/redd during supplementation.
- $Ho_{2.1.1.5}$: Mean ratio scores in juveniles/redd (adjusted for density dependence) before supplementation ≤ Mean ratio scores in juveniles/redd (adjusted for density dependence) during supplementation. [This hypothesis adjusts juveniles/redd for density-dependent effects (see Hillman et al. 2012 for details; Appendix 6).]
- $Ho_{2.1.1.6}$: There is no association between the proportion of hatchery-origin spawners (pHOS) and the residuals from the smooth hockey stick stock-recruitment curve; rho = 0. [If there is a significant negative association between pHOS and the residuals, then hatchery fish may be reducing the productivity of the wild population.]

Statistical Hypotheses for 2.2.1:

- $Ho_{2.2.1.1}$: There is no association between the proportion of hatchery-origin spawners (pHOS) and the residuals from the smooth hockey stick stock-recruitment curve; rho = 0. [If there is a significant negative association between pHOS and the residuals, then hatchery fish may be reducing the productivity of the wild population.]
- $Ho_{2.2.1.2}$: The slope between proportion of hatchery spawners and juveniles/redd is ≥ 0.

Measured Variables:

- Number of hatchery and naturally produced fish on spawning grounds.
- Numbers of redds.
- Number of juveniles (smolts, parr [where appropriate], and emigrants).

Derived Variables:

- Number of juveniles per spawner.
- Number of juveniles per redd.
- Carrying capacity (see Appendix 1).

Spatial/Temporal Scale:

- Calculate annually based on brood year.
- Time series.

Possible Statistical Analysis:

- These analyses shall be performed every five-years. Use graphic analyses, trend analyses, t-tests, Aspin-Welch tests, and randomization tests to evaluate the statistical hypotheses (see Hillman et al. 2012; Appendix 6). The specific analysis used will depend on the availability of reference conditions.
- Correlation analysis will examine associations between hatchery adult composition and juveniles/redd.

Analytical Rules:

- This is a productivity indicator that will be used to assess the success of the supplementation program.
- Type I Error of 0.05.

Attachment D

SECTION 4: NATURAL ENVIRONMENT MONITORING INDICATORS

4.1 Hatchery Replacement Rates (HRRs)

<u>Objective 3</u>: **Determine if the hatchery adult-to-adult survival (i.e., hatchery replacement rate, HRR) is greater than the natural adult-to-adult survival (i.e., natural replacement rate, NRR) and the target hatchery survival rate.**

The survival advantage from the hatchery (i.e., egg-to-smolt) must be sufficient to produce a greater number of returning adults than if broodstock were left to spawn naturally. If a hatchery program cannot produce a greater number of adults than naturally spawning fish, then the program should be modified or discontinued. Production levels were initially developed using historical run sizes and smolt-to-adult survival rates (BAMP 1998). Using the stock specific NRR and agreed upon target values (see Appendix 2), comparisons to actual survival rates will be made to ensure the expected level of survival has been achieved.

Monitoring Questions:

Q3.2.1: Is the adult-to-adult survival rate of hatchery fish (HRR) greater than or equal to the adult-to-adult survival rate (NRR) of naturally produced fish?

Q3.2.2: Is the adult-to-adult survival rate of hatchery fish (HRR) greater than or equal to the Target Value identified in Appendix 2[8]?

Target Species/Populations:

- Q3.2.1 applies to all conservation stocks.
- Q3.2.2 applies to all stocks.

Statistical Hypothesis 3.2.1:

- $Ho_{3.2.1.1}$: $HRR_{\text{Year x}} \geq NRR_{\text{Year x}}$

Statistical Hypothesis 3.2.2:

- $Ho_{3.2.2.1}$: HRR ≥ Target Value identified in Appendix 2

Measured Variables:

- Number of hatchery and naturally produced fish on spawning grounds.
- Number of hatchery and naturally produced fish harvested.
- Number of hatchery and naturally produced fish collected for broodstock.
- Number of broodstock used by brood year (hatchery and naturally produced fish).

Derived Variables:

- Number of hatchery and naturally produced adults by brood year (≥age-3).

[8] Target values may be adjusted by the hatchery committees.

- HRR (number of returning adults per brood year/broodstock)
- NRR (from Objective 1)
- Appendix 2: HRR targets identified in Appendix 2

Spatial/Temporal Scale:

- Calculate annually based on brood year.
- Time series.

Possible Statistical Analysis:

- For Q3.2.1 use graphic analysis and paired-sample quantile tests to compare HRR to NRR
- For Q3.2.2 use graphic analysis and one-sample quantile tests to compare HRR to the target value.
- On a five-year period, correlate HRRs with extraneous factors such as ocean productivity indices.

Analytical Rules:

- This is a monitoring indicator that will be used to support management decisions.
- Type I Error of 0.05.

4.2 Proportion of Hatchery-Origin Spawners (pHOS or PNI)

<u>Objective 4</u>: **Determine if the proportion of hatchery-origin spawners (pHOS or PNI) is meeting management target.**

Certain hatchery programs have pHOS or PNI targets, while other do not. HGMPs and permits inform the selection of targets, which are identified in Appendix 3.

Monitoring Questions:

Q4.1.1: Is the estimated proportion of hatchery-origin spawners (pHOS) less than or equal to the management target, and/or, is the estimated Percent Natural Influence (PNI) greater than or equal to the management target identified in Appendix 3?

Target Species/Populations:

- Q4.1.1 applies to all conservation and safety-net stocks that have a defined pHOS or PNI target or sliding scale (see Appendix 3).

Statistical Hypothesis 4.1.1:

- $Ho_{4.1.1.1}$: pHOS > target value or $PNI_{\text{Supplemented population}}$ < target value identified in Appendix 3

Measured Variables:

- Number of hatchery and naturally produced fish on spawning grounds

Derived Variables:

- pHOS or PNI
- Appendix 3: PNI and pHOS targets and sliding scales identified in Appendix 3

Spatial/Temporal Scale:

- Calculate annually.
- Analyzed as time series.

Possible Statistical Analysis:

- Use graphic analysis and summary statistics to compare pHOS or PNI to the target value in Appendix 3.

Analytical Rules:

- This is a monitoring indicator that will be used to support management decisions.

4.3 Run Timing, Spawn Timing, and Spawning Distribution

Objective 5: Determine if the run timing, spawn timing, and spawning distribution of the hatchery component is similar to the natural component of the target population or is meeting program-specific objectives.

Strategies for conservation programs typically intend that hatchery and natural-origin fish spawn together and in similar locations. However, in some cases, strategies may differ from this paradigm (e.g., summer Chinook salmon in the Wenatchee and Methow rivers; see Appendix 4). Phenotypic plasticity or selection resulting from the hatchery environment (i.e., domestication) may affect run (migration) timing, spawn timing, and spawning distribution. If conservation programs do not adequately represent the genetic diversity of the natural population, and if phenotypic traits in supplementation fish related to fitness deviate from the naturally produced spawning population, the goals of supplementation may not be achieved. Hatchery adults that migrate and/or spawn at different times or are spatially segregated from natural-origin fish may be subject to reduced fitness. Hatchery adults that spawn at different times or locations than natural-origin fish would be reproductively isolated from the natural population. The extent of such isolation, ranging from no isolation to substantial isolation, may be exploited for management purposes in some cases.

Migration Timing

Monitoring Questions:

Q5.1.1: Is the migration timing of hatchery and natural-origin fish from the same age class similar?

Target Species/Populations:

- Q5.1.1 applies to all conservation stocks.

Statistical Hypotheses 5.1.1:

- $Ho_{5.1.1.1}$: Migration timing $_{\text{Hatchery Age X}}$ = Migration timing $_{\text{Naturally produced Age X}}$

- $Ho_{5.1.1.2}$: The cumulative frequency of migration timing of hatchery-origin fish = the cumulative frequency of migration timing of natural-origin fish.
- $Ho_{5.1.1.3}$: The 10th percentile, 50th percentile (mode), 90th percentile, and mean migration timing of hatchery-origin fish = the 10th percentile, 50th percentile (median), 90th percentile, and mean migration timing of natural-origin fish.

Measured Variables:

- Ages of hatchery and natural-origin fish sampled via PIT tags or stock assessment monitoring.
- Time (Julian date) of arrival at mainstem projects and within tributaries (e.g., traps, PIT arrays) with the intent to identify biologically significant differences.

Derived Variables:

- Mean Julian date for a given age class.

Spatial/Temporal Scale:

- Calculate annually based on return year and age class.
- Time series.

Possible Statistical Analysis:

- Use graphic analyses (cumulative frequency polygons), paired t-tests, Aspin-Welch tests, and randomization tests.

Analytical Rules:

- This is a monitoring indicator that will be used to support management decisions.
- Type I Error of 0.05.

Spawn Timing

Monitoring Questions:

Q5.2.1: Is the timing of spawning similar for conservation hatchery and natural-origin fish?

Target Species/Populations:

- Q5.2.1: Applies to all semelparous species and populations supplemented by conservation programs. Steelhead can only be assessed for natural spawning in situations where hatchery and natural-origin fish can be appropriately marked and detected.

Statistical Hypotheses 5.2.1:

- $Ho_{5.2.1.1}$: The cumulative frequency of spawn timing of hatchery-origin fish = the cumulative frequency of spawn timing of natural-origin fish.
- $Ho_{5.2.1.2}$: The 10th percentile, 50th percentile (mode), 90th percentile, and mean spawn timing of hatchery-origin fish = the 10th percentile, 50th percentile (mode), 90th percentile, and mean spawn timing of natural-origin fish.

- $Ho_{5.2.1.3}$: The relationship between elevation and spawn timing of hatchery-origin fish = the relationship between elevation and spawn timing of natural-origin fish.

Measured Variables:

- Time (Julian date) and elevation (m) of hatchery and natural-origin salmon carcasses or marked steelhead detected on spawning grounds within defined reaches.
- Time (Julian date) of ripeness of hatchery and natural-origin steelhead captured for broodstock.

Derived Variables:

- Mean Julian date.

Spatial/Temporal Scale:

- Calculate annually based on return year.
- Time series.

Possible Statistical Analysis:

- Use graphic analyses (cumulative frequency polygons), paired t-tests, Aspin-Welch tests, and randomization tests.
- Use graphic analyses, ANCOVA, and/or regression analysis to assess relationships between elevation and spawn timing.

Analytical Rules:

- This is a monitoring indicator that will be used to support management decisions.
- Type I Error of 0.05.

Spatial Distribution of Redds

Monitoring Questions:

Q5.3.1: Is the distribution of redds similar for conservation hatchery and natural-origin fish?

Q5.3.2: Is the distribution of redds similar to defined management targets (see Appendix 4)?

Target Species/Populations:

- Q5.3.1 applies to all conservation program stocks.
- Q5.3.2 applies only to conservation program stocks with specific spawning distribution targets (Carlton and Dryden summer Chinook programs; Appendix 4).

Statistical Hypothesis 5.3.1:

- $Ho_{5.3.1.1}$: The distribution of hatchery-origin redds (hatchery females) = the distribution of natural-origin redds (natural-origin females).

Statistical Hypothesis 5.3.2:

- $Ho_{5.3.2.1}$: The distribution of hatchery-origin redds (hatchery females) = the target distribution identified in Appendix 4.

Measured Variables:

- Location (GPS coordinate) of female salmon carcasses observed on spawning grounds. The distribution of hatchery and naturally produced steelhead redds may be evaluated if marking or tagging efforts provide reasonable results.

Derived Variables:

- Location of female salmon carcass at the historic reach scale and at the 0.1 km scale.
- Calculate percent overlap in distribution across available spawning habitat or historical reaches.
- Appendix 4: Management targets for spatial distribution of spawners or redds (as applicable).

Spatial/Temporal Scale:

- Calculate annually based on return year.
- Time series.

Possible Statistical Analysis:

- Use graphic analysis and Yates' Chi-square analysis for both Q5.3.1 and Q5.3.2.

Analytical Rules:

- This is a monitoring indicator that will be used to support management decisions.
- Type I Error of 0.05.

4.4 Stray Rates

Objective 6: Determine if the recipient stray rate of hatchery fish is below the acceptable levels to maintain genetic variation among stocks.

Maintaining locally adapted traits among independent fish populations requires that returning hatchery fish have a high rate of site fidelity to the target population or stream. Hatchery practices (e.g., imprinting on water sources at key life history stages, release methodology, release location, age at return, broodstock used, spawner density, spawning habitat quality and access, and environmental conditions) are the main variables thought to affect stray rates. Regardless of the magnitude of homing of adult returns, if adult hatchery fish do not contribute to the natural population, the program will not meet the basic condition of a supplementation program.

Independent populations are populations that are genetically differentiated from other populations. In some cases, genetic differentiation may be assumed based on phenotypic traits or geographic isolation when molecular genetics analyses are not available. When populations are not independent, straying among them does not pose a risk of genetic homogenization. In addition, stray rates of hatchery-origin fish cannot be expected to be lower than for natural-origin fish. When estimates of stray rates for natural-origin fish are available and if they exceed the 5% among population stray rate or 10% within population stray rate thresholds identified in this plan, analysis

and interpretation of stray rates must take into account the concept that hatchery programs may be held to unattainable standards based on the natural stray rate. Current criteria established by the ICBTRT (2005) and the Upper Columbia Spring Chinook Salmon and Steelhead Recovery Plan (2007) indicate that fish that do stray to other non-target populations should not comprise greater than 5% of the non-target spawning population. Likewise, fish that stray into non-target spawning areas within an independent population should not comprise greater than 10% of the non-target spawning aggregate (see Tables 6.1 and 6.2).

This plan identifies three stray rate metrics; brood-year stray rate, among population return-year stray rate, and within population return-year stray rate. The return-year stray rates have specific targets that are from the ICBTRT (2005) and Upper Columbia Spring Chinook Salmon and Steelhead Recovery Plan (2007), and are linked to extinction risk. That is, hatchery strays from other populations cannot make up more than 5% of the spawning escapement within a non-target, recipient population. In addition, hatchery strays from other spawning aggregations within a population (e.g., Chiwawa spring Chinook) cannot make up more than 10% of the spawning escapement within a non-target, recipient spawning aggregate (e.g., White River). Brood-year stray rate, on the other hand, is not discussed in the Upper Columbia Spring Chinook Salmon and Steelhead Recovery Plan (2007) or ICBTRT (2005) and therefore has no specific target. Nevertheless, it is important to track brood-year stray rates to determine if hatchery operations affect the homing and straying of specific brood years. These data support the return-year stray metrics and are used to inform possible changes in genetic variation among stocks.

Brood-Year Stray Rates

Monitoring Questions:

Q6.1.1: What is the brood-year stray rate of hatchery fish?

Target Species/Populations:

- Q6.1.1 applies to all hatchery stocks.

Statistical Hypothesis 6.1.1:

- $Ho_{6.1.1.1}$: None.

Measured Variables:

- Number of hatchery carcasses found in non-target and target spawning areas or number of returning spawners counted via PIT-tag detection or at weirs in close temporal proximity to spawning areas.
- Number of hatchery fish collected for broodstock.
- Number of hatchery fish taken in fishery.
- Locations of live and dead strays (used to tease out overshoot).

Derived Variables:

- Total number of hatchery carcasses and take in fishery estimated from expansion analysis.
- Percent of the total brood return that strays.

Spatial/Temporal Scale:

- Calculate annually based on brood year.
- Time series.

Possible Statistical Analysis:

- Use graphical analysis to track brood-year stray rates over time.

Analytical Rules:

- This is a monitoring indicator that will be used to support management decisions.

Among-Population Return-Year Stray Rates

Monitoring Questions:

Q6.2.1: Do hatchery strays make up less than 5% of the spawning escapement within their non-target independent populations?

Target Species/Populations:

- Q6.2.1 applies to all hatchery stocks.

Statistical Hypothesis 6.2.1:

- $Ho_{6.2.1.1}$: Stray hatchery fish make up ≥ 5% of the spawning escapement (based on run year) within other independent populations [9]

Measured Variables:

- Number of hatchery carcasses (PIT-tagged steelhead) found in non-target and target spawning areas or number of returning spawners counted via PIT-tag detection or at weirs in close temporal proximity to spawning areas.

Derived Variables:

- Total number of hatchery salmon carcasses (PIT-tagged steelhead, spawners counted at weirs) estimated from expansion analysis.
- Percent of the non-target population that is made up of hatchery strays.

Spatial/Temporal Scale:

- Calculate annually based on return year.
- Time series.

Possible Statistical Analysis:

[9] This stray rate is suggested based on a literature review and recommendations by the ICBTRT (2005) and is identified in the Upper Columbia Spring Chinook Salmon and Steelhead Recovery Plan (2007). It can be re-evaluated as more information on naturally-produced Upper Columbia salmonids becomes available. This will be evaluated on a species and program specific basis and decisions made by the HCP HC and PRCC HSC. It is important to understand the actual spawner composition of the population to determine the potential effect of straying.

- Use graphical analysis and one-sample quantile tests to compare the estimated stray rate with the target (5%) stray rate.

Analytical Rules:

- This is a monitoring indicator that will be used to support management decisions.
- Type I Error of 0.05.

Within-Population Return-Year Stray Rates

Monitoring Questions:

Q6.3.1: Do hatchery strays make up less than 10% of the spawning aggregate within non-target spawning areas within the target population?

Target Species/Populations:

- Q6.3.1 applies to all hatchery stocks.

Statistical Hypothesis 6.3.1:

- $Ho_{6.3.1}$: Stray hatchery fish make up ≥ 10% of spawning escapement (based on run year) within non-target spawning areas within the target population

Measured Variables:

- Number of hatchery carcasses (possibly PIT-tagged steelhead) found in non-target and target spawning aggregates or number of returning spawners counted via PIT-tag detection or at weirs in close temporal proximity to spawning areas.

Derived Variables:

- Total number of hatchery salmon carcasses (possibly PIT-tagged steelhead or spawners counted at weirs) estimated from expansion analysis.
- Percent of the non-target spawning aggregate that is made up of hatchery strays.

Spatial/Temporal Scale:

- Calculate annually based on return year.
- Time series.

Possible Statistical Analysis:

- Use graphical analysis and one-sample quantile tests to compare the estimated stray rate with the target (10%) stray rate.

Analytical Rules:

- This is a monitoring indicator that will be used to support management decisions.
- Type I Error of 0.05.

4.5 Population Genetics

Objective 7: Determine if genetic diversity, population structure, and effective population size have changed in natural spawning populations as a result of the hatchery program.

The genetic component of the M&E Plan specifically addresses the potential for changes in genetic diversity in natural populations as a result of a hatchery program(s). The long-term fitness of populations is assumed to be related to maintaining the genetic diversity of natural populations. However, hatchery programs select a subset of individuals from the population to pass on genetic material to the next generation. This is often a relatively small number of individuals that produce a large number of offspring, and can result in changes in allele frequencies and reductions of effective population size. Therefore, it is important to monitor the genetic status of the natural populations to determine if there are signs of changes in genetic distance among populations, changes in allele frequencies, and to estimate effective population size. Assessing the genetic effects of the hatchery program does not require annual sampling, but does require regular sampling at generational scales. Meeting stray-rate targets (hypotheses tested under Objective 5) should reduce significant changes in population genetics. Stray rates may inform population genetic analyses. Testing statistical hypotheses associated with genetic components (Hypotheses 3.1, 3.2, and 3.3) should be conducted every ten years or two generations.

Allele Frequency

Monitoring Questions:

Q7.1.1: Is the allele frequency of hatchery fish similar to the allele frequency of naturally produced and donor (broodstock) fish?

Target Species/Populations:

- Q7.1.1 applies to all conservation stocks.

Statiscial Hypotheses 7.1.1:

- $Ho_{7.1.1.1}$: Allele frequency $_{\text{Hatchery}}$ = Allele frequency $_{\text{Naturally produced}}$ = Allele frequency $_{\text{Donor pop.}}$
- $Ha_{7.1.1.1}$: Allele frequency $_{\text{Hatchery}}$ ≠ Allele frequency $_{\text{Naturally produced}}$ = Allele frequency $_{\text{Donor pop.}}$ or
- $Ha_{7.1.1.1}$: Allele frequency $_{\text{Hatchery}}$ = Allele frequency $_{\text{Naturally produced}}$ ≠ Allele frequency $_{\text{Donor pop.}}$ or
- $Ha_{7.1.1.1}$: Allele frequency $_{\text{Hatchery}}$ ≠ Allele frequency $_{\text{Naturally produced}}$ ≠ Allele frequency $_{\text{Donor pop.}}$

Measured Variables:

- SNP genotypes

Derived Variables:

- Allele frequency

Spatial/Temporal Scale:

- Analyze as a time series, initially comparing pre- and post-hatchery samples and thereafter every 10 years.
- Compare samples within drainages.

Possible Statistical Analysis:

- Population differentiation tests, analysis of molecular variance (AMOVA), and relative genetic distances.

Analytical Rules:

- This is a monitoring indicator that will be used to support management decisions.
- Type I Error of 0.05.

Genetic Distance Between Populations

Monitoring Questions:

Q7.2.1: Does the genetic distance among subpopulations within a supplemented population remain the same over time?

Target Species/Populations:

- Q7.2.1 applies to all conservation and safety-net stocks.

Statistical Hypothesis 7.2.1:

- $Ho_{7.2.1.1}$: Genetic distance between subpopulations $_{\text{Year x}}$ = Genetic distance between subpopulations $_{\text{Year y}}$

Measured Variables:

- SNP genotypes

Derived Variables:

- Allele frequencies

Spatial/Temporal Scale:

- Analyze as a time series, initially comparing pre- and post-hatchery samples and thereafter every 10 years.
- Compare samples among spawning aggregates.

Possible Statistical Analysis:

- Population differentiation tests, AMOVA, and relative genetic distances.

Analytical Rules:

- This is a monitoring indicator that will be used to support management decisions.
- Type I Error of 0.05.

Effective Spawning Population

Monitoring Questions:

Q7.3.1: Is the ratio of effective population size (N_e) to spawning population size (N) constant over time?

Target Species/Populations:

- Q7.3.1 applies to all supplemented stocks.

Statistical Hypothesis 3.3:

- $Ho_{7.3.1.1}$: $(N_e/N)_{t0} = (N_e/N)_{t1}$ for each population

Measured Variables:

- SNP genotypes

Derived Variables:

- Allele frequencies

Spatial/Temporal Scale:

- Analyze as a time series, initially comparing pre- and post-hatchery samples and thereafter every 10 years.

Possible Statistical Analysis:

- Population differentiation tests, relative genetic distances, statistics to calculate effective population size (e.g., harmonic means).

Analytical Rules:

- This is a monitoring indicator that will be used to support management decisions.
- Type I Error of 0.05.

4.6 Phenotypic Traits

Objective 8: Determine if hatchery programs have caused changes in phenotypic characteristics of natural populations.

Fitness, or the ability of individuals to survive and pass on their genes to the next generation in a given environment, includes genetic, physiological, and behavioral components.[10] Maintaining the long-term fitness of supplemented populations requires a comprehensive evaluation of genetic and phenotypic characteristics. Evaluation of some phenotypic traits (i.e., run timing, spawn timing, spawning location, and stray rates) is addressed under Objective 5. Objective 8 assess the potential effects of domestication, including size at maturity, age at maturity, sex ratio, and fecundity. Age and size at maturity shall be assessed for both fish arriving in the Columbia system, and those recovered on the spawning grounds. Size (or age) selective mortality during migration through the Columbia system, such as through fisheries, could alter the age and size of fish on the spawning grounds.

[10] These metrics are difficult to measure, and phenotypic expression of these traits may be all we can measure and evaluate.

Age at Maturity

Monitoring Questions:

Q8.1.1: Is the age at maturity of hatchery and natural-origin fish similar at the time they enter the Columbia River and when they spawn?

Target Species/Populations:

- Q8.1.1 applies to all conservation program stocks.

Statistical Hypotheses 8.1.1:

- $Ho_{8.1.1.1}$: Age at Maturity $_{\text{Hatchery produced spawners Gender X}}$ = Age at Maturity $_{\text{Naturally produced spawners Gender X}}$
- $Ho_{8.1.1.2}$: Age at Maturity $_{\text{All hatchery produced adults Gender X}}$ = Age at Maturity $_{\text{All naturally produced adults Gender X}}$

Measured Variables:

- Total and salt (ocean) age of hatchery and natural-origin salmon carcasses collected on spawning grounds.
- Total and salt age of broodstock.
- Total and salt age of fish at stock assessment locations (e.g., Dryden, Tumwater, Wells, Priest Rapids).
- Whenever possible, age at maturity will be measured at weirs or dams near the spawning stream to avoid the size-related carcass recovery bias on spawning grounds (carcass sampling).
- Assess age of fish, including harvested fish.

Derived Variables:

- Total age and saltwater age
- Age of fish entering the Columbia River.

Spatial/Temporal Scale:

- Calculate annually based on brood year.
- Time series.

Possible Statistical Analysis:

- Use graphic analysis and Yates' Chi-square.

Analytical Rules:

- This is a monitoring indicator that will be used to support management decisions.
- Type I Error of 0.05.

Size at Maturity

Monitoring Questions:

Q8.2.1: Is the size (length) at maturity of a given age and sex of hatchery fish similar to the size at maturity of a given age and sex of natural-origin fish?

Target Species/Populations:

- Q8.2.1 applies to all conservation and safety-net stocks.

Statistical Hypothesis 8.2.1:

- $Ho_{8.2.1.1}$: Size (length) at Maturity $_{\text{Hatchery Age X and Gender Y}}$ = Size (length) at Maturity $_{\text{Naturally produced Age X and Gender Y}}$
- $Ho_{8.2.1.2}$: Size (length) at Maturity $_{\text{All hatchery adults Gender X}}$ = Size (length) at Maturity $_{\text{All naturally produced adults Gender X}}$

Measured Variables:

- Size (length), age, and gender of hatchery and natural-origin salmon carcasses collected on spawning grounds.
- Size (length), age, and gender of broodstock.
- Size (length), age, and gender of fish at stock assessment locations (e.g., Priest Rapids, Dryden, Tumwater, Wells, Twisp Weir).
- Whenever possible, size at maturity will be measured at weirs or dams near the spawning stream to avoid the size-related carcass recovery bias on spawning grounds (carcass sampling).

Derived Variables:

- Total age and saltwater age

Spatial/Temporal Scale:

- Calculate annually based on brood year.
- Time series.

Possible Statistical Analysis:

- Use graphic analysis and three-way ANOVA by origin, gender, and age

Analytical Rules:

- This is a monitoring indicator that will be used to support management decisions.
- Type I Error of 0.05.

Fecundity at Size[11]

Monitoring Questions:

Q8.3.1: Is the fecundity vs. size relationship of hatchery and natural-origin fish similar?

[11] May not apply to all programs.

Q8.3.2: Is the gonadal mass vs. size relationship of hatchery and natural-origin fish similar?

Target Species/Populations:

- Both Q8.3.1 and Q8.3.2 apply to all conservation stocks using both natural- and hatchery-origin broodstock.

Statistical Hypothesis 8.3.1:

- $Ho_{8.3.1.1}$: Slope of Fecundity vs. Size $_{\text{Hatchery}}$ = Slope of Fecundity vs. Size $_{\text{Naturally produced}}$

Statistical Hypothesis 8.3.2:

- $Ho_{8.3.2.1}$: Gonadal Mass vs. Size $_{\text{Hatchery}}$ = Gonadal Mass vs. Size $_{\text{Naturally produced}}$

Measured Variables:

- Length, weight, and age (covariate) of hatchery and natural-origin broodstock after eggs have been removed.
- Number and weight of eggs

Derived Variables:

- Total age and saltwater age.
- Mean weight per egg.

Spatial/Temporal Scale:

- Calculate annually based on brood year.
- Time series.

Possible Statistical Analysis:

- Use graphic analysis, regression, t-test, and ANCOVA.

Analytical Rules:

- This is a monitoring indicator that will be used to support management decisions.
- Type I Error of 0.05.

Sex Ratio

Monitoring Questions:

Q8.4.1: Is the sex ratio of hatchery and natural-origin fish similar?

Target Species/Populations:

- Q8.4.1 applies to all conservation stocks.

Statistical Hypothesis 8.4.1:

- $Ho_{8.4.1.1}$: Sex Ratio $_{\text{Hatchery}}$ = Sex Ratio $_{\text{Naturally produced}}$

Measured Variables:

- Age and sex of hatchery and natural-origin salmon carcasses collected on spawning grounds or sampled at dams or weirs.
- Whenever possible sex ratio will be measured at weirs or dams near the spawning stream to avoid the size-related carcass recovery bias on spawning grounds (carcass sampling or ultrasound on live fish).

Derived Variables:

- Ratio of sexes based on brood year returns

Spatial/Temporal Scale:

- Calculate annually based on brood year.
- Time series.

Possible Statistical Analysis:

- Use graphic analysis and Yates'Chi-square.

Analytical Rules:

- This is a monitoring indicator that will be used to support management decisions.
- Type I Error of 0.05.

SECTION 5: HATCHERY ENVIRONMENT MONITORING INDICATORS

5.1 Release Targets

Objective 9: Determine if hatchery fish were released at the programmed size and number.

The HCP outlines the number and size of fish that are to be released to meet NNI and inundation compensation levels. The size of the fish at release may be altered according to an adaptive management process in the Hatchery Committee(s), and the number of fish can be altered by survival study results and adjustment of hatchery production for population dynamics. Size of fish at release can affect survival, sex ratios, age at return, stray rate, and fecundity. In addition, the variation in size at release may affect performance of the fish.

The coefficient of variation (CV) will be evaluated to ascertain if program performance is related to variation in size at release. Note also that variation in a population is a natural condition and striving to control this variation could result in directional or stabilizing artificial selection that could have unforeseen long-term consequences. Attaining uniform or multi-modal growth in a hatchery environment may not be adaptive for fitness in the wild. Therefore, pursuit of a CV target should be seen as an informative exercise, but is not in itself indicative of success or failure of a hatchery program. Furthermore, growth regimes may prove to be important in affecting adult returns and age structure. Although many factors can influence both the size and number of fish released, past hatchery cultural experience with these stocks should assist in meeting program production levels. Appendix 5 presents the target size at release and CVs for the programs. These targets shall be assessed annually to ensure they are optimized to inform management decisions.

Size at Release of Hatchery Fish

Monitoring Questions:

Q9.1.1: Is the size (fish per pound; fpp) of hatchery fish released equal to the program goal identified in Appendix 5?

Target Species/Populations:

- Q9.1.1 applies to all hatchery stocks.

Statistical Hypothesis 9.1.1:

- $Ho_{9.1.1}$: Hatchery fish $_{\text{fpp at release}}$ = Programmed $_{\text{fpp at release}}$ (see Appendix 5)

Measured Variables:

- Fork length and weights of random samples of hatchery juveniles at release.

Derived Variables:

- Mean length (FL), mean weight, and fish per pound
- Appendix 5: Rearing targets

Spatial/Temporal Scale:

- Calculate annually.
- Time series.

Possible Statistical Analysis:

- Use graphic analysis and descriptive statistics to compare the estimated fpp of hatchery fish at time of release with the program goal.

Analytical Rules:

- This is a monitoring indicator that will be used to support management decisions.

Coefficient of Variation (CV) of Hatchery Fish Released

Monitoring Questions:

Q9.2.1: Is the CV of hatchery fish released equal to the program target identified in Appendix 5?

Target Species/Populations:

- Q9.2.1 applies to all hatchery stocks.

Statistical Hypothesis 9.2.1:

- $Ho_{9.2.1.1}$: Hatchery fish $CV_{\text{at release}}$ = Programmed CV in Appendix 5

Measured Variables:

- Length and weights of random samples of hatchery smolts.

Derived Variables:

- Coefficient of Variation: $cv = (1 + 1/4n) \times (s/x)$ (where s = standard deviation, x = estimated mean, n = sample size)
- Appendix 5: Rearing targets

Spatial/Temporal Scale:

- Calculate annually.
- Time series.

Possible Statistical Analysis:

- Use graphic analysis and descriptive statistics to compare the estimated CV of size of hatchery fish released with the program goal.

Analytical Rules:

- This is a monitoring indicator that will be used to support management decisions.

Condition Factor (K) of Hatchery Fish Released

Monitoring Questions:

Q9.3.1: Is the K of hatchery fish released equal to the program target identified in Appendix 5?

Target Species/Populations:

- Q9.3.1 applies to all hatchery stocks.

Statistical Hypothesis 9.3.1:

- $Ho_{9.3.1.1}$: Hatchery fish $K_{\text{at release}}$ = Programmed K identified in Appendix 5

Measured Variables:

- Monthly individual lengths and weights of random samples of hatchery juveniles.

Derived Variables:

- Condition Factor: $K = W/L^3 \times 10^5$

Spatial/Temporal Scale:

- Calculate annually.
- Time series.

Possible Statistical Analysis:

- Use graphic analysis and descriptive statistics to compare the estimated K of released hatchery fish with the program goal.

Analytical Rules:

- This is a monitoring indicator that will be used to support management decisions.
- Type I Error of 0.05.

Number of Hatchery Fish Released

Monitoring Questions:

Q9.4.1: Is the number of hatchery fish released equal to the program goal identified in Appendix 5?

Target Species/Populations:

- Q9.4.1 applies to all hatchery stocks.

Statistical Hypothesis 9.4.1:

- $Ho_{9.4.1.1}$: Hatchery Fish Number = Programmed Number identified in Appendix 5

Measured Variables:

- Numbers of smolts released from the hatchery.

Derived Variables:

- Appendix 5: Rearing targets

Spatial/Temporal Scale:

- Calculate annually.

- Time series.

Possible Statistical Analysis:

- Use graphic analysis and one-sample quantile tests to compare the estimated number of hatchery fish released with the program goal.

Analytical Rules:

- This is a monitoring indicator that will be used to support management decisions.
- Type I Error of 0.05.

SECTION 6: HARVEST MONITORING INDICATORS

6.1 Harvest Rates

<u>Objective 10</u>: **Determine if appropriate harvest rates have been applied to conservation, safety-net, and segregated harvest programs to meet the HCP/SSSA goal of providing harvest opportunities while also contributing to population management and minimizing risk to natural populations.**

Harvest will be applied to different types of programs in an effort to achieve the management objectives of those programs. Programs designed to augment harvest should routinely contribute to harvest at a rate that greatly reduces the incidence of straying to natural spawning grounds, but also allows the program to be sustained. Safety-net programs may be harvested as part of an adult management strategy to minimize excessive escapement of hatchery-origin fish to spawning grounds. Similarly, conservation programs may undergo harvest to manage returning adults, but the emphasis for these programs should be to achieve escapement goals. In all cases, harvest effort should not have the unintended consequence of removing excessive numbers of conservation or natural-origin fish. In years when the expected returns of hatchery adults are above the level required to meet program goals (i.e., supplementation of spawning populations and/or brood stock requirements), surplus fish may be available for harvest. The M&E Plan specifically addresses harvest and harvest opportunities upstream of Priest Rapids Dam. Harvest or removal of surplus hatchery fish from the spawning grounds may assist in reducing potential adverse ecological and genetic impacts to natural populations (e.g., loss of genetic variation within and between populations, loss of fitness, reduced effective population size, and density-dependent effects).

Monitoring Questions:

Q10.1.1: Conservation Programs: Is the harvest on conservation hatchery fish at an appropriate level to manage natural spawning of conservation hatchery fish but low enough to sustain the hatchery program?

Q10.1.2: Safety-Net Programs: Is the harvest on conservation hatchery fish at an appropriate level to manage natural spawning of safety-net hatchery fish but low enough to sustain the hatchery program?

Q10.1.3: Is the harvest on hatchery fish produced from harvest-augmentation programs high enough to manage natural spawning but low enough to sustain the hatchery program?

Q10.1.4: Is the escapement of fish from conservation and safety-net programs in excess of broodstock and natural production[12] needs to provide opportunities for terminal harvest?

Target Species/Populations:

- Q10.1.1 applies to conservation programs.
- Q10.1.2 applies to safety-net programs.

[12] The current best estimates of carrying capacity (maximum recruits) will be used, as available.

- Q10.1.3 applies harvest augmentation programs.
- Q10.1.4 applies to conservation and safety-net programs.

Statistical Hypothesis 10.1.1:

- $Ho_{10.1.1.1}$: Harvest rate ≤ Maximum level to meet program goals

Statistical Hypothesis 10.1.2:

- $Ho_{10.1.2.1}$: Harvest rate ≤ Maximum level to meet program goals

Statistical Hypothesis 10.1.3:

- $Ho_{10.1.3.1}$: Escapement ≤ Maximum level to meet supplementation goals

Statistical Hypothesis 10.1.4:

- $Ho_{10.1.4.1}$: Harvest rate ≤ Maximum level to meet program goals

Measured Variables:

- Numbers of hatchery fish taken in harvest.
- Numbers of natural-origin fish taken in harvest.

Derived Variables:

- Total harvest by fishery estimated from expansion analysis.

Spatial/Temporal Scale:

- Calculated annually.
- Time series.

Possible Statistical Analysis:

- Use graphic analysis and one-sample quantile tests to compare the estimated harvest of hatchery fish with the program goal.

Analytical Rules:

- This is a monitoring indicator that will be used to support management decisions.
- Type I Error of 0.05.

SECTION 7: REGIONAL OBJECTIVES

Hatchery programs have the potential to increase diseases that typically occur at low levels in the natural environment (Objective 9). In addition, hatchery fish can reduce the abundance, size, or distribution of non-target taxa through ecological interactions (Objective 10). In this section, we address incidence of disease and non-target taxa of concern.

7.1 Incidence of Disease

Objective 11: Determine if the incidence of disease has increased in the natural and hatchery populations.

The hatchery environment has the potential to amplify diseases that are typically found at low levels in the natural environment. Amplification could occur within the hatchery population (i.e., vertical and horizontal transmission) or indirectly from the hatchery effluent or commingling between infected and non-infected fish (i.e., horizontal transmission). Potential impacts to natural populations have not been extensively studied, but should be considered for programs in which the hatchery fish are expected to commingle with natural fish. This is particularly important for supplementation type programs. Specifically, the causative agent of bacterial kidney disease (BKD), *Renibacterium salmoninarum* (Rs), could be monitored at selected acclimation ponds, both in the water and fish, in which the risk and potential for transmission from the hatchery is highest. Although it is technologically possible to measure the amount of Rs in water or Rs DNA in smolts and adults non-lethally sampled, the biological meaning of these data are uncertain. Currently, the only metric available for M & E purposes is measuring the antigen level from kidney/spleen samples (i.e., ELISA, PCR). When available, non-lethal sampling may replace or be used in concert with lethal sampling.

Implementation of this objective will be conducted in a coordinated approach within the hatchery and natural environment. BKD management within the hatchery population (e.g., broodstock or juveniles) has the potential to reduce the prevalence of disease through various actions (e.g., culling or reduced rearing densities). BKD management must also take into account and support other relevant objectives of the M & E program (e.g., Hatchery Return Rate [HRR], number of smolts released). Hence, the goal of BKD management is to decrease the prevalence of disease and maintain hatchery production objectives (i.e., number and HRR).

As previously discussed, disease transmission from hatchery to naturally produced fish may occur at various life stages and locations. Of these, horizontal transmission from hatchery effluent, vertical transmission on the spawning grounds, and horizontal transmission in the migration corridor have been identified as disease interactions that could be examined under this objective, although others may also be relevant. Experimental designs addressing this objective may require technology not yet available, although in some instances samples may be collected, but not analyzed until a link can be established between bacteria levels in samples and disease prevalence.

Developing a complete set of questions and hypotheses statements for this objective may not be practical at this time, because there is currently no BKD Management Plan. However, while developing experimental designs for this objective, it may be feasible to incorporate both hatchery and natural environment monitoring under a single study design. Integration of the different

aspects of the objective would likely result in a more robust approach into understanding the effectiveness of disease management strategies.

Proposed Tasks:

T1: Assemble fish health data for fish used as brood (e.g., ELISA results).

T2: Conduct data exploration exercise to identify potential relationships between pathogen profiles and likely causative variables (e.g., rearing conditions and management actions).

T3: Develop hypotheses for potential testing to meet objective.

7.2 Non-Target Taxa of Concern (NTTOC)

Objective 12: Determine if the release of hatchery fish affects non-target taxa of concern (NTTOC) within acceptable limits.

Hatchery programs have the potential to affect non-target taxa through various types of interactions (e.g., competition and predation). These interactions can reduce the distribution, size, and abundance of non-target species. The non-target taxa of concern (NTTOC) ecological risk assessment was developed as a regional objective that would addressed ecological interactions on non-target taxa.

In 2008, the Wells HCP, Rocky Reach HCP, Rock Island HCP Hatchery Committees, and the Priest Rapids Hatchery Sub-Committee agreed to an approach to evaluate the potential effects of hatchery programs on NTTOC. The committees originally planned to convene a panel of experts to conduct a preliminary evaluation of the potential effects of Plan supplemented species on NTTOC. At the 15 October 2008 Hatchery Committees meeting, the members agreed to convene an expert panel to conduct a preliminary evaluation of potential effects of supplemented Plan Species on non-target taxa using an approach similar to that used in the Yakima Basin (Pearsons and Hopley 1999; Ham and Pearsons, 2001). The Committees agreed to convene the panel in spring or early summer 2009, and focus this initial effort on HCP Plan Species and the two non-Plan Species, westslope cutthroat trout and lamprey. The Committees identified species interactions, containment objectives for non-target species, and fisheries professionals who possessed the expertise to contribute as panel members. The Committees directed the Hatchery Evaluation Technical Team (HETT) to pursue assessment of the hatchery programs potential effects on NTTOC.

The HETT evaluated methods to conduct a risk assessment on NTTOC, and proposed using a combined modeling and a Delphi panel approach, whereby the modeling results would be compared and correlated with the Delphi panel results. The HETT identified the PCD Risk 1 model (Busack et al., 2005; Pearsons and Busack, 2012) to conduct the modeling evaluation. The PCD Risk 1 model is a data intensive, individual-based stochastic model. The HETT determined that the assembled data to be used as inputs for the PCD Risk 1 model would also serve to provide expert panelists the necessary data for them to conduct risk assessments. Hence, the HETT embarked on an extensive effort to gather, organize, and extract the required data from existing datasets, literature, and biologists familiar with the programs and/or particular NTTOC. Ultimately, the input data were assembled in a relational database that allowed the data to be output in user-friendly formats for modeling or Delphi panel use. The database also served to hold the modeling results, which could be extracted and summarized as needed. Following the modeling work, the Committees decided not to assemble the expert panel, because the panel would not be able to evaluate adequately the very large number of possible interactions.

A report titled *Ecological Risk Assessment of Upper-Columbia Hatchery Programs on Non-Target Taxa of Concern* was drafted in 2013 and finalized in 2014, which included the modeling results to date. The results in the report represent a very extensive effort to model the risk of all the upper Columbia hatchery programs for the identified NTTOC for which data and model runs were available. Should new information become available, the Committees agreed to assess the suitability of the data as it relates to conducting future NTTOC evaluations as a regional objective.

SECTION 8: ADAPTIVE MANAGEMENT

One of the challenges of evaluating PUD hatchery programs is that hatchery programs are modified resulting in hatchery treatments that are uneven throughout the duration of the hatchery program. Modifications occur as a result of recalculating hatchery release numbers every 10 years and also through adaptive management. To solve this evaluation challenge, we propose to conduct two scales of analysis. First, the entire duration of the program will be analyzed using the entire data set. This evaluation will analyze whether the overall adaptively managed program achieved objectives. Second, where appropriate, analyses will be compared across periods or programs to determine if major program changes have resulted in hypothesized changes to key response variables. We acknowledged that partitioning data into shorter periods will likely result in reduced statistical power so only the biggest changes will be evaluated. In the future, the hatchery committees will develop a table or figure that identifies major program changes in fish culture or M&E.

In the past, hatchery programs have been evaluated at the hatchery program scale (e.g., Nason Creek, Carlton summer Chinook). In some cases, it may be worthwhile to evaluate supplementation programs at different spatial scales. For example, the Nason Creek spring Chinook salmon program can be evaluated at the scale of Nason Creek, the combined effects of spring Chinook hatchery programs in the Wenatchee basin at the Wenatchee basin scale, and then all of the spring Chinook programs in the upper Columbia at the upper Columbia basin scale.

Comparisons of supplemented populations (treatments) to in-basin reference populations are the best way to evaluate whether treatments have caused changes to variables such as natural-origin recruits or productivity. Many suitable out-of-basin references are available (see Appendix 6), but these references do not control for unique factors that may be happening in the upper Columbia or areas outside the upper Columbia. For example, large fires that occur in the Upper Columbia may not occur at similar times in areas outside of this area. Candidate in-basin reference populations are not ideal for spring Chinook salmon because they are small and are above a lake (e.g., Little Wenatchee River) or they have had a long history of hatchery stocking (e.g., Entiat River). Every population of upper Columbia summer and fall Chinook is supplemented so in-basin references are not currently available. Without a suitable number of in-basin reference populations that are similar in size and distribution to treated populations, it will be difficult to unambiguously assess hatchery effects on certain variables. Although not ideal, the only way to increase in-basin reference comparisons is to strategically reduce the number of places where hatchery fish are released such as was done for the Entiat River.

Previous stocking history will lessen the value of reference populations; however, they can still be of value. For instance, the Committees can still test whether NORs are increased under supplementation compared to periods when other populations are not supplemented (i.e., a reverse BACI analysis).

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SECTION 10: GLOSSARY

Adult-to-Adult survival (Ratio)	The number of parent broodstock relative to the number of returning adults.
Age at maturity	The age of fish at the time of spawning (hatchery or naturally).
Augmentation	A hatchery strategy where fish are released for the sole purpose of providing harvest opportunities.
Broodstock	Adult salmon and steelhead collected for hatchery fish egg harvest and fertilization.
Donor population	The source population for supplementation programs before hatchery fish spawned naturally.
Effective population size (Ne)	The number of reproducing individuals in an ideal population (i.e., Ne = N) that would lose genetic variation due to genetic drift or inbreeding at the same rate as the number of reproducing adults in the real population under consideration (Hallerman 2003).
ESA	Endangered Species Act passed in 1973. The ESA-listed species refers to fish species added to the ESA list of endangered or threatened species and are covered by the ESA.
Expected value	The number of smolts or adults derived from survival rates agreed to in the Biological Assessment and Management Plan (BAMP 1998).
Extraction rate	The proportion of the spawning population collected for broodstock.
Genetic diversity	All the genetic variation within a species of interest, including both within and between population components.
Genetic stock structure	A type of assortative mating, in which the gene pool of a species is composed of a group of subpopulations, or stocks, that mate panmictically within themselves.
Genetic variation	All the variation due to different alleles and genes in an individual, population, or species.
HCP	Habitat Conservation Plan is a plan that enables an individual or organization to obtain a Section 10 Permit which outlines what will be done to “minimize and mitigate” the impact of the permitted take on a listed species.

HCP-HC	Habitat Conservation Plan Hatchery Committee is the committee that directs actions under the hatchery program section of the HCP's for Chelan and Douglas PUDs.
HRR	Hatchery Replacement Rate is the ratio of the number of returning hatchery adults relative to the number of adults taken as broodstock, both hatchery and naturally produced fish (i.e., adult-to-adult replacement rate).
Long-term fitness	Long-term fitness is the ability of a population to self-perpetuate over successive generation.
Naturally produced	Progeny of fish that spawned in the natural environment, regardless of the origin of the parents.
Mean Ratio	The ratio between a treatment and control population, with the mean taken across a time period, such as years. Used in analysis in Before-After-Control-Impact studies.
Ne	Effective population size.
Non-target taxa of concern (NTTOC)	Species, stocks, or components of a stock with high value (e.g., stewardship or utilization) that may suffer negative effects because of a hatchery program.
NRR	Natural replacement rate is the ratio of the number of returning naturally produced adults relative to the number of adults that naturally spawned, both hatchery and naturally produced.
NTTOC	Non-target taxa of concern.
pHOS	Proportion of Hatchery Origin Spawners.
PNI	Proportionate Natural Influence.
pNOB	Proportion of Natural Origin Broodstock.
PRCC HSC	Priest Rapids Coordinating Committee Hatchery Subcommittee.
Productivity	The capacity in which juvenile fish or adults can be produced.
Reference population	A population in which no directed artificial propagation is currently directed, although may have occurred in the past. Reference populations are used to monitor the natural variability in survival rates and out of basin impacts on survival.
Smolt-to-adult survival rate (SAR)	Smolt-to-adult survival rate is a measure of the number of adults that return from a given smolt population.
Segregated	A type of hatchery program in which returning adults are spatially or temporally isolated from other populations.

Size at maturity	The length or weight of a fish at a point in time during the year in which spawning will occur.
Smolts per redd	The total number of smolts produced from a stream divided by the total number of redds from which they were produced.
SNP or single-nucleotide polymorphism	A single-nucleotide polymorphism is a variation in a single nucleotide that occurs at a specific position in the genome, where each variation is present to some appreciable degree within a population.
Spawning Escapement	The number of adult fish that survive to spawn.
Stray rate	The rate at which fish spawn outside of natal rivers or the stream in which they were released.
Supplementation	A hatchery strategy where the main purpose is to increase the relative abundance of natural spawning fish without reducing the long-term fitness of the population.
Target population	A specific population in which management actions are directed (e.g., artificial propagation, harvest, or conservation).

APPENDIX 1: ESTIMATION OF CARRYING CAPACITY

In the ecological literature, carrying capacity is often defined as the maximum population size that can be supported indefinitely by the environment (Cain et al. 2014). Said another way, carrying capacity is the maximum number or biomass of a species that a given habitat can support. This maximal environment load is often referred to as "habitat capacity" and is identified with the letter "C." In contrast, the carrying capacity parameter "K" in population models (e.g., logistic equation, Beverton-Holt model, hockey stick model, and the Ricker model) defines a maximum equilibrium population size. Maximum equilibrium population size is generated from density dependent mechanisms that reduce population growth rates as population size increases (negative density dependence). This is referred to as compensation. Population size fluctuates about the maximum equilibrium size because of variability in vital rates that are unrelated to density (density independent factors) and measurement error. Maximum equilibrium population size is often referred to as "population capacity." The two capacities (habitat capacity and population capacity) are related but not identical and therefore should not be confused. Habitat capacity will usually be greater than population capacity.

Estimation of carrying capacity is important because hatchery managers use it to inform supplementation programs, harvest managers use it to set appropriate harvest and escapement levels, modelers use it in life-cycle models to predict the effects of different recovery scenarios, and restoration practitioners use it to guide restoration actions. The purpose of this paper is to describe methods that can be used to estimate carrying capacity for stocks within the Upper Columbia River basin. We apply these methods to Wenatchee and Chiwawa River spring Chinook salmon.[13] Data used in this exercise are shown in Tables 1 and 2 and come from Hillman et al. (2017). We begin by identifying simple methods used to detect density dependence. We then describe the use of population models to estimate population capacity. We also discuss the use of habitat models and quantile regression to estimate habitat capacity. We end by comparing results of different methods and offering recommendations for estimating carrying capacity.

Table 1. Numbers of redds, adult spawners (estimated from redd surveys), eggs (estimated as the number of redds times average brood-year fecundity), summer parr (estimated using snorkel surveys), and yearling smolts (estimates using a rotary screw trap) by brood year for spring Chinook salmon in the Chiwawa River watershed. Smolts represent the number of yearling Chinook produced entirely within the Chiwawa River watershed. Date are from Hillman et al. (2017). NS = not sampled.

Brood year	Numbers of Chiwawa spring Chinook				
	Redds	Spawners	Eggs	Parr	Smolts
1991	104	242	478,400	45,483	42525
1992	302	676	1,570,098	79,113	39723
1993	106	233	556,394	55,056	8662
1994	82	184	485,686	55,241	16472
1995	13	33	66,248	5,815	3830

[13] Technically, Wenatchee River spring Chinook are one population. Chiwawa River spring Chinook are a subgroup of the Wenatchee spring Chinook population.

Brood year	Numbers of Chiwawa spring Chinook				
	Redds	Spawners	Eggs	Parr	Smolts
1996	23	58	106,835	16,066	15475
1997	82	182	374,740	68,415	28,334
1998	41	91	218,325	41,629	23,068
1999	34	94	166,090	NS	10,661
2000	128	346	642,944	114,617	40,831
2001	1,078	1,725	4,984,672	134,874	86,482
2002	345	707	1,605,630	91,278	90,948
2003	111	270	648,684	45,177	16,755
2004	241	851	1,156,559	49,631	72,080
2005	332	599	1,436,564	79,902	69,064
2006	297	529	1,284,228	60,752	45,050
2007	283	1,296	1,256,803	82,351	25,809
2008	689	1,158	3,163,888	106,705	35,023
2009	421	1,347	1,925,233	128,220	30,959
2010	502	1,094	2,165,628	141,510	47,511
2011	492	2,032	2,157,420	103,940	37,185
2012	880	1,478	3,716,240	149,563	34,334
2013	714	1,378	3,367,224	121,240	39,396
2014	485	999	1,961,825	111,224	37,170
2015	543	967	2,631,921	140,172	

Table 2. Numbers of redds, adult spawners (estimated from redd surveys), eggs (estimated as the number of redds times average brood-year fecundity), and yearling smolts (estimates using a rotary screw trap) by brood year for spring Chinook salmon in the Wenatchee River basin. Smolts represent the number of yearling Chinook produced entirely within the Wenatchee River basin. Date are from Hillman et al. (2017). NS = not sampled.

Brood year	Numbers of Wenatchee spring Chinook			
	Redds	Spawners	Eggs	Smolts*
2000	350	830	1,758,050	76,643
2001	2,109	3,217	8,674,624	243,516
2002	1,139	1,965	5,300,906	165,116
2003	323	673	1,887,612	70,738
2004	574	1,686	2,663,445	55,619
2005	830	1,484	3,587,083	302,116
2006	588	1,000	2,542,512	85,558
2007	466	2,035	2,069,506	60,219
2008	1,411	2,278	6,479,312	82,137
2009	733	2,299	NS	NS

Brood year	Numbers of Wenatchee spring Chinook			
	Redds	Spawners	Eggs	Smolts*
2010	968	1,921	NS	NS
2011	872	3,139	3,823,720	89,917
2012	1,704	2,720	7,195,992	67,973
2013	1,159	2,133	5,512,204	58,595
2014	885	1,600	3,894,000	36,752

* From 2000-2010 the smolt trap operated near the Town of Monitor; from 2013 to present the trap operated near the Town of Cashmere.

Evidence of Density Dependence

To calculate population capacity, the size of the population or stock must be influenced to a large degree by density-dependent factors. That is, population growth is affected by mechanisms whose effectiveness increases as population size increases. As population density increases, factors such as competition, predation, and disease (and parasites) cause birth rates to decrease, death rates to increase, and dispersal to increase. When densities decrease, the opposite occurs; birth rates increase and death and emigration rates decrease. In general, when the density of the population becomes high enough, density-dependent factors decrease population size because food or space are in short supply (Chapman 1966). In the ecological literature, this is referred to as “population regulation.”

A simple way to determine if density-dependent factors regulate population size is to plot population growth rate (or appropriate surrogate) against population size. If population regulation is occurring, the relationship between population size and population growth rate decreases exponentially (decreases linearly if data are log-transformed). Surrogates for population growth rate include survival rates, natality (birth rates), productivity, recruits, individual growth rates, and movement. Figure 1 shows the relationship between productivity (parr/spawner and smolts/spawner) and spawning escapement for Wenatchee River and Chiwawa River spring Chinook. One could use redd counts as a surrogate for spawning abundance. Because most female spring Chinook construct only one redd (Murdoch et al. 2009), redd counts reflect the number of female spawners in the population. In this report, we use number of spawners (spawning escapement) because most management decisions are based on spawning escapement.

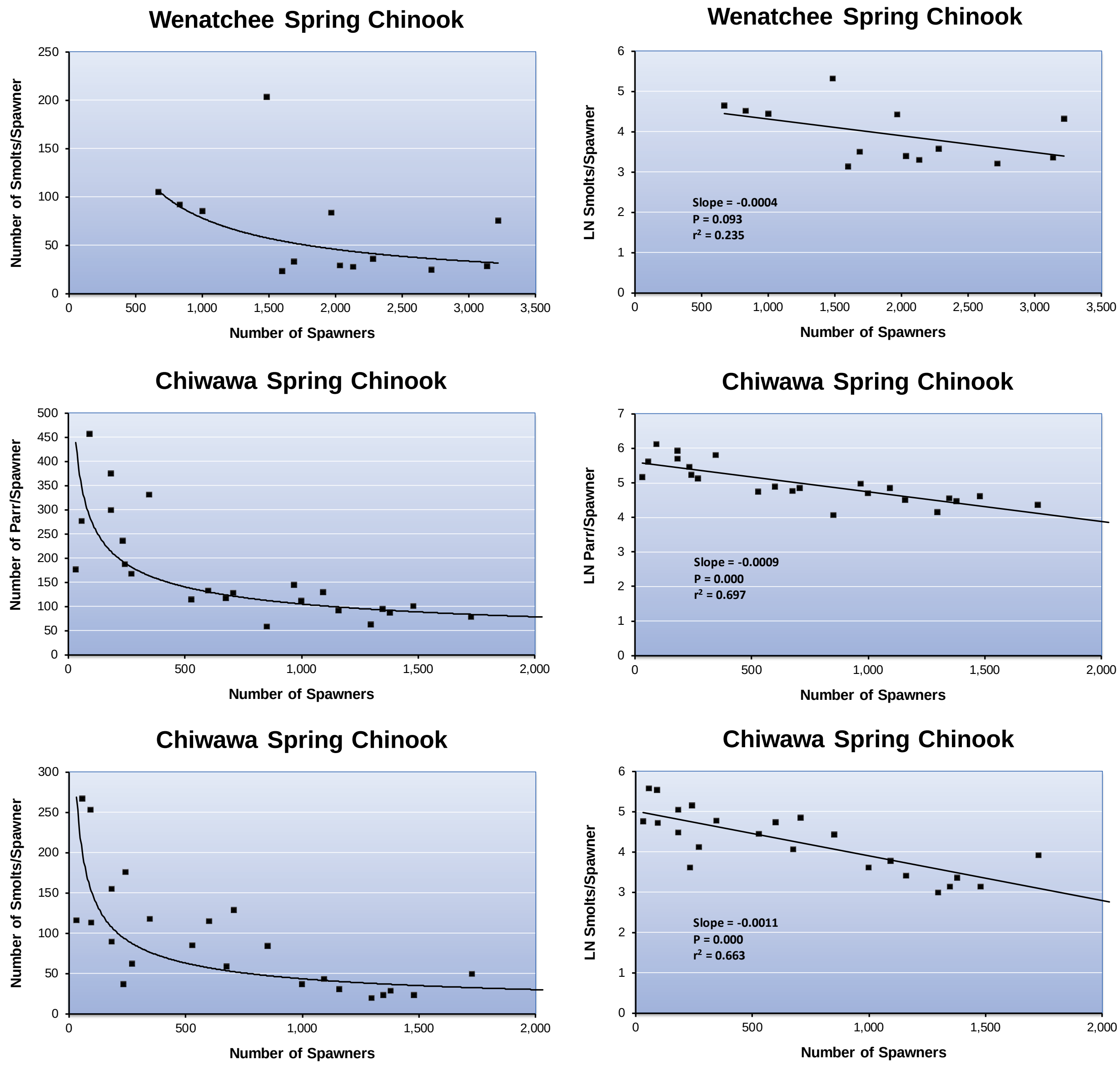

Figure 1. Relationship between spawner abundance and smolts/spawner for Wenatchee spring Chinook (top figures), spawner abundance and parr/spawner for Chiwawa spring Chinook (middle figures), and spawner abundance and smolts/spawner for Chiwawa spring Chinook (bottom figures). Figures on the right show natural log transformed productivity data.

The negative relationship between spawner abundance and juvenile productivity indicates the presence of density dependence in Chiwawa spring Chinook. Although there is a hint of density dependence in the Wenatchee River productivity data, the relationship was not significant statistically. This in part may be related to changes in sampling over the 13-year period. The negative relationship was significant for both summer parr and yearling smolts in the Chiwawa River watershed. We caution, however, that there may be a bias in the simple regression analysis presented in the figures. That is, the dependent (productivity) and independent (abundance) variables are not independent and this can produce a negative bias in regression estimates of slope. Nevertheless, the decline in juvenile productivity with increasing spawner abundance indicates the

presence of density dependence. Given the presence of density dependence, we should be able to estimate population capacity.

Estimating Carrying Capacity

Several different methods can be used to estimate population capacity. For example, time series analyses, including the logistic or Gompertz functions, or stock-recruitment models can be used to estimate population capacity. Common stock-recruitment models include Ricker, Beverton-Holt, and smooth hockey stick models. These models incorporate environmental variability and can be used to estimate the size of the spawning population needed to produce the maximum number of recruits. Habitat capacity, on the other hand, can be estimated using fish-habitat models. In general, these models estimate habitat capacity as the product of habitat area and fish/habitat relationships. These range from simple models such as percent habitat saturation models to more complex models including habitat suitability, quantile regression forest models, dynamic food-web models, and bioenergetic or net rate of energy intake models. In this report, we explore the use of stock-recruitment models to estimate population capacity. We apply quantile regression to stock-recruitment models to estimate habitat capacity and compare those results to a habitat model, the quantile regression forest model.

Population Capacity

To estimate population capacity, we evaluated the fit of three different stock-recruitment models to Chiwawa and Wenatchee River spring Chinook data: Ricker, Beverton-Holt, and smooth hockey stick models. In using these models, we assume:

- *Density-dependent mortality*—For some time period before recruitment, the brood instantaneous mortality rate is proportional to the number of parent spawners (Ricker 1954).
- *Lognormal variation*—At any particular spawning stock size, the variation in recruitment is log-normally distributed about its average, and acts multiplicatively (Quinn and Deriso 1999).
- *Measurement error*—Error in spawning stock size estimates (measurement error) is small relative to the range of spawning stock sizes observed (Hilborn and Walters 1992). Variation in realized recruitment at any particular spawning stock size (process error) dominates recruitment measurement error.
- *Stationarity*—The average stock-recruitment relationship is constant over time (Hilborn and Walters 1992). That is, environmental conditions randomly affect survival independent of stock size or time.

In general, the methods we used to fit the models to the data followed those outlined in Hilborn and Walters (1992) and Froese (2008). The Ricker model, which assumes that the number of recruits increases to a maximum and then declines as the number of spawners increases, takes the form:

$$\boldsymbol{E(R) = \alpha S e^{-\beta S}}$$

where E(R) is the expected recruitment, S is spawner abundance, α is the number of recruits per spawner at low spawning levels, and β describes how quickly the recruits per spawner drop as the number of spawners increases. We estimated population capacity (K) as:

$$K = \left(\frac{\alpha}{\beta}\right) e^{-1}$$

and the number of spawners (SP) needed to produce the maximum number of recruits as:

$$SP = \frac{1}{\beta}$$

The Beverton-Holt model assumes that the number of recruits increases constantly toward an asymptote as the number of spawners increases. After the asymptote is reached, the number of recruits neither increases nor decreases. The asymptote represents the maximum number of recruits the system can support (i.e., population capacity for the system; K). The Beverton-Holt curve takes the form:

$$E(R) = \frac{(\alpha S)}{(\beta + S)}$$

where E(R) and S are as above, α is the maximum number of recruits produced (i.e., α = K), and β is the number of spawners needed to produce (on average) recruits equal to one-half the maximum number of recruits. The number of spawners needed to produce the maximum number of recruits is ∞ in the Beverton-Holt model.

Like the Beverton-Holt model, the smooth hockey stick model assumes that the number of recruits increases toward an asymptote (population capacity; K) as the number of spawners increases. After the carrying capacity is reached, the number of recruits neither increases nor decreases. The carrying capacity represents the maximum equilibrium number of recruits the system can support. This curve takes the form (Froese 2008):

$$E(R) = R_{\infty}\left(1 - e^{-\left(\frac{\alpha}{R\infty}\right)S}\right)$$

where E(R) and S are as above, α is the slope at the origin of the spawner-recruitment curve, and R_{∞} is the carrying capacity of recruits (i.e., $R_{\infty} = K$). There is no direct estimate of SP in the smooth hockey stick model. Therefore, we estimated SP as the number of spawners needed to produce 0.95(K).

We used non-linear regression to fit the three models to spawner-recruitment data. Before fitting the models, we transformed recruitment data using natural logs. We estimated bias and uncertainty measures (95% CI) for the model parameters using bootstrap procedures, which assumed that the {R, S} sample represented or approximated the population. The number of bootstrap samples was 3,000. We computed and stored the non-linear regression results for each bootstrap sample. We then calculated the bootstrap 95% CI by arranging the 3,000 bootstrap parameter values in sorted order and selected the 2.5 and 97.5 percentiles from the list.

We used Akaike's Information Criterion for small sample size (AIC_c) to determine which model(s) best explained the relationship between spawners and recruitment in the supplemented and reference populations. AIC_c was estimated as:

$$AIC_c = -2log\left(£(\theta|data)\right) + 2K + \left(\frac{2K(K+1)}{n-K-1}\right)$$

where $log(£(\theta|data))$ is the maximum likelihood estimate, K is the number of estimable parameters (structural parameters plus the residual variance parameter), and n is the sample size (Burnham and Anderson 2002). We used least-squares methods to estimate $log(£(\theta|data))$, which was calculated as $log(\sigma^2)$, where σ^2 = residual sum of squares divided by the sample size ($\sigma^2 = RSS/n$). AIC_c assessed model fit in relation to model complexity (number of parameters). The model with the smallest AIC_c value represented the "best approximating" model within the model set. Remaining models were ranked relative to the best model using AIC_c difference scores (ΔAIC_c), Akaike weights (w_i), and evidence ratios. Models with ΔAIC_c values less than 2 indicated that there is substantial support for these models as being the best-fitting models within the set (Burnham and Anderson 2002). Models with values greater than 2 had less support. Akaike weights are probabilities estimating the strength of the evidence supporting a particular model as being the best model within the model set. Models with small w_i values are less plausible as competing models (Burnham and Anderson 2002). If no single model could be specified as the best model, a "best subset" of competing models was identified using (1) AIC_c differences to indicate the level of empirical support each model had as being the best model, (2) evidence ratios based on Akaike weights to indicate the relative probability that any model is the best model, and (3) coefficients of determination (R^2) assessing the explanatory power of each model.

Chiwawa River Spring Chinook Parr

We successfully fit the three stock-recruitment curves to the Chiwawa spring Chinook parr data (Figure 2).

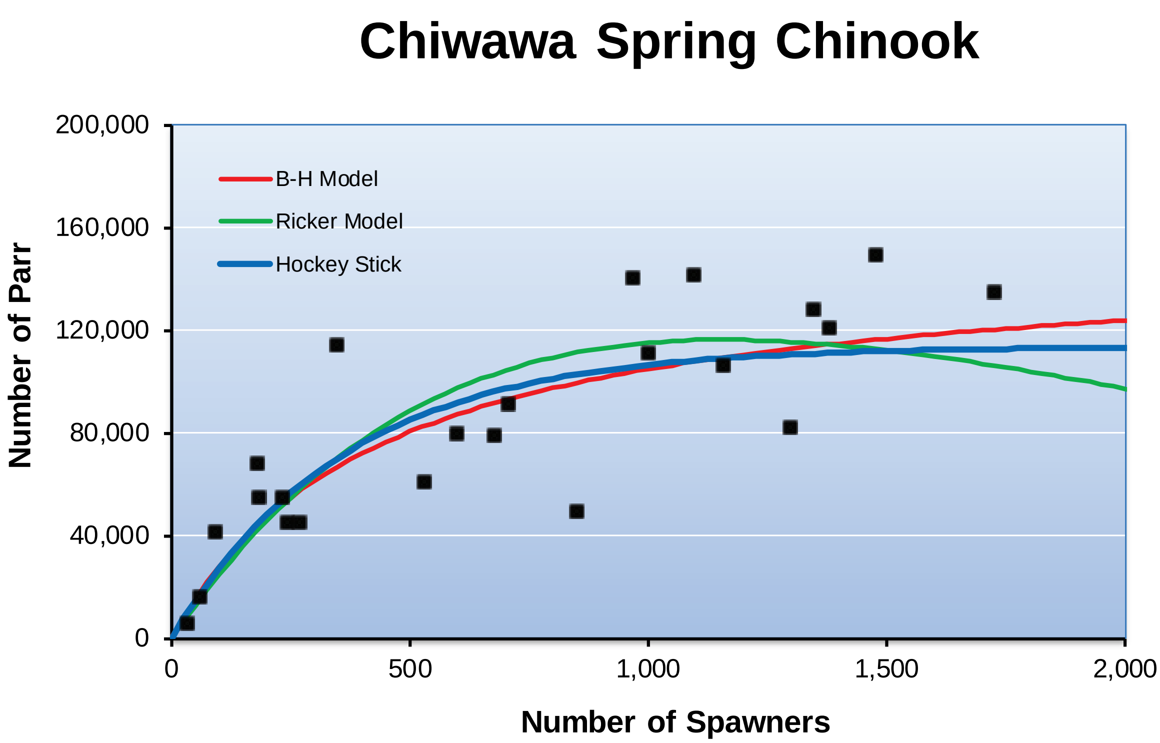

Figure 2. Relationship between numbers of spring Chinook parr and numbers of spawners in the Chiwawa River watershed, 1992-2016 (no sampling occurred in 2000). Figure shows the fit of the Beverton-Holt, Ricker, and smooth hockey stick models to the data.

For summer parr, the use of AIC_c indicated that the Beverton-Holt model best approximated the information in the productivity data. The estimated structural parameters for this model were:

$$Parr = \frac{(150{,}902 \times Spawners)}{(438 + Spawners)}$$

where the bootstrap estimated standard errors for the two parameters were 21,142 and 145, respectively. The adjusted $R^2 = 0.812$.

The second-best model was the smooth hockey stick model, which was 0.245 AIC_c units from the best model. The estimated parameters for this model were:

$$LN(Parr) = 11.6 + LN\left(1 - e^{-\left(\frac{312.9}{113{,}801}\right)Spawners}\right)$$

where the bootstrap estimated standard errors of the two parameters were 0.097 and 57.578, respectively, and the $R^2 = 0.810$.

The AIC_c difference scores, Akaike weights, and evidence ratios indicated that there was substantial support for both the Beverton-Holt and smooth hockey stick models. There was less support for the Ricker model, which was > 2 AIC_c units from the best models. This was further supported by the fact that, relative to the best models, the Ricker model had an evidence ratio greater than 3.

Depending on the stock-recruitment model used, population capacity ranged from 113,801 to 150,902 parr (Table 3). The Beverton-Holt model estimated the highest capacity, while the smooth hockey stick model estimated the lowest. The number of spawners needed to produce the population capacity of parr ranged from 1,089 to 1,163 (Table 3).

Table 3. Estimates of Beverton-Holt, smooth hockey stick, and Ricker model parameters, parr capacity (K), parr productivity (parr per spawner), and the number of spawners needed to produce the maximum number of parr for Chiwawa River spring Chinook.

Model	**Parameter**		**Population capacity (K)**	**Intrinsic productivity**	**Spawners**
	A	**B**			
Beverton-Holt	150,902.145	437.655	150,902	345	∞
Smooth Hockey Stick	11.642	312.913	113,801	313	1,089
Ricker	272.696	0.0009	116,650	273	1,163

It is important to note that the population capacity estimates are based on the number of parr counted in the Chiwawa River watershed during August. There are spring Chinook fry and parr that move out of the Chiwawa River watershed during spring and early summer (Hillman et al. 2017). It is unknown if these fish leave because of density-dependent pressures, they are flushed out during high flows, it is a life-history characteristic, or a combination of these. Regardless of the mechanism or reason, some of these fish may survive and rear in the Wenatchee or Columbia rivers. These emigrants are not included in the capacity estimates shown in Table 3.

The capacity estimates for spring Chinook parr apply only to the Chiwawa River watershed, a watershed within the Wenatchee River basin. Estimating parr capacity for the entire Wenatchee River basin using stock-recruitment models is difficult because there is no long-term time series of parr data for the entire basin. However, we can extrapolate parr capacity estimates from the

Chiwawa River watershed to the entire Wenatchee River basin using intrinsic potential (IP). Multiplying the parr capacity per intrinsic potential within the Chiwawa River watershed by the total intrinsic potential within the Wenatchee River basin yields an estimate of parr capacity for the Wenatchee River basin (Table 4). The Interior Columbia Basin Technical Recovery Team estimated IP based on wetted width, valley width (confinement), and gradient (see Cooney and Holzer 2006). They used sedimentation and temperature to refine IP for each 200-m long reach. We used the total stream area (km^2) weighted by intrinsic potential and temperature limited to extrapolate parr capacity to the entire Wenatchee River basin.

Table 4. Estimates of Wenatchee River basin parr capacity based on intrinsic potential (IP). The amount of IP within the Chiwawa River watershed is 0.481 km^2; the total amount of IP within the Wenatchee River basin is 1.798 km^2.

Model	Chiwawa parr capacity	Chiwawa parr/IP	Wenatchee parr capacity
Beverton-Holt	150,902	313,726	564,079
Smooth Hockey Stick	113,801	236,593	425,395
Ricker	116,650	242,516	436,043

Using this simple method, we estimate the Wenatchee River basin supports about 425,395-564,079 parr depending on which model is used. An important assumption of this simple method is that each unit of IP supports the same number of parr. This is clearly not true given that the quality of habitat within each unit of IP can vary greatly. That is, one unit of IP may contain more habitat structure (e.g., wood and cover) than another unit of IP. Importantly, the ratio of parr to IP comes from the Chiwawa River watershed, which contains some of the highest quality habitat within the Wenatchee River basin. Therefore, the estimated total parr capacity for the entire Wenatchee River basin is likely biased high. If habitat conditions throughout the Wenatchee River basin are enhanced to conditions similar to those in the Chiwawa River watershed, we may expect parr abundance to approach those estimated with this simple method.

Chiwawa River Spring Chinook Smolts

We successfully fit the three stock-recruitment curves to the Chiwawa spring Chinook smolt data (Figure 3). This information allows us to better understand the quality and quantity of overwintering habitat in the Chiwawa River basin.

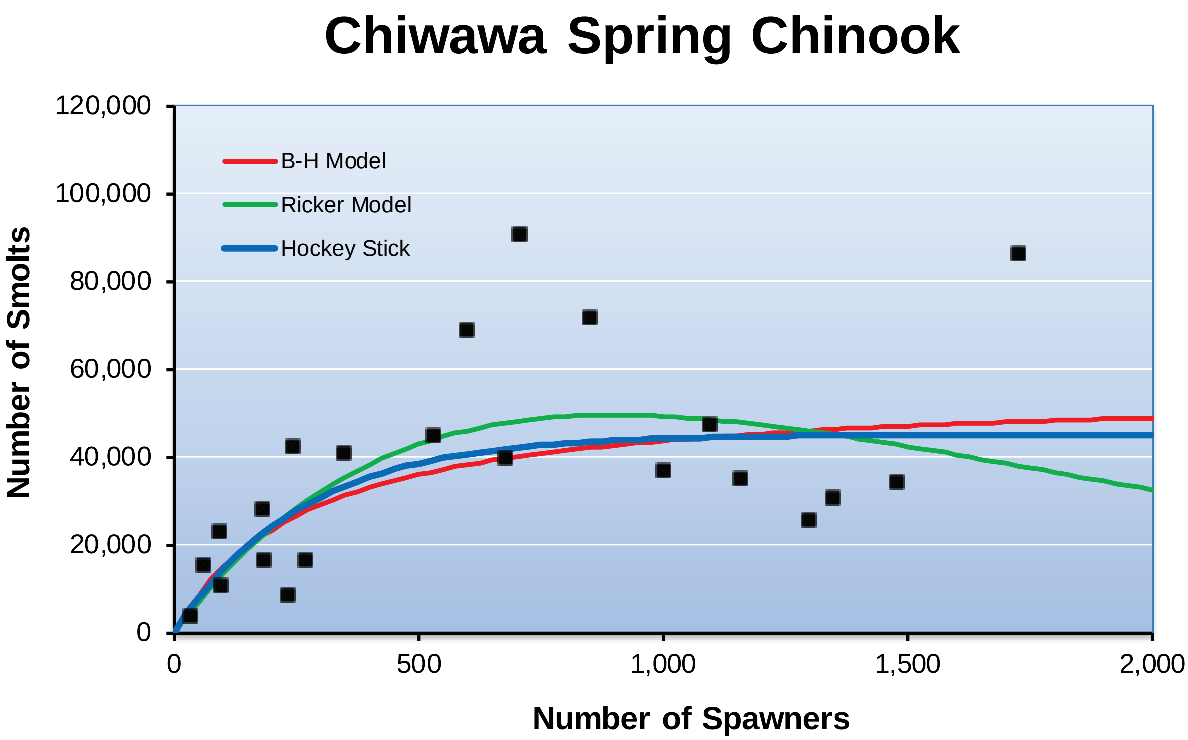

Figure 3. Relationship between numbers of spring Chinook smolts and numbers of spawners in the Chiwawa River watershed, 1992-2015. Figure shows the fit of the Beverton-Holt, Ricker, and smooth hockey stick models to the data.

For yearling smolts produced entirely within the Chiwawa River watershed, the use of AIC_c indicated that the smooth hockey stick model best approximated the information in the productivity data. The estimated structural parameters for this model were:

$$LN(Smolts) = 10.7 + LN\left(1 - e^{-\left(\frac{174.1}{45,161}\right)Spawners}\right)$$

where the bootstrap estimated standard errors for the two parameters were 0.13 and 41.29, respectively. The adjusted $R^2 = 0.569$.

The second-best model was the Ricker model, which was 0.234 AIC_c units from the best model. The estimated parameters for this model were:

$$Smolts = 149.45 \times Spawners(\mathrm{e}^{-0.00111 \times Spawners})$$

where the bootstrap estimated standard errors of the two parameters were 26.23 and 0.00018, respectively, and the $R^2 = 0.573$.

The third-best model was the Beverton-Holt model, which was 0.725 AIC_c units from the best model. The estimated parameters for this model were:

$$Smolts = \frac{(55,702 \times Spawners)}{(273 + Spawners)}$$

where the bootstrap estimated standard errors of the two parameters were 10,421.9 and 123.0, respectively, and the $R^2 = 0.560$.

The AIC_c difference scores, Akaike weights, and evidence ratios indicated that there was substantial support for all three models. Relative to the best model, the other two models had evidence ratios less than 1.5.

Depending on the stock-recruitment model used, population capacity ranged from 45,161 to 55,702 smolts (Table 5). The Beverton-Holt model estimated the highest capacity, while the smooth hockey stick model estimated the lowest. The number of spawners needed to produce the population capacity of smolts ranged from 777 to 901 (Table 5).

Table 5. Estimates of Beverton-Holt, smooth hockey stick, and Ricker model parameters, smolt capacity (K), smolt productivity (smolts per spawner), and the number of spawners needed to produce the maximum number of smolts for Chiwawa River spring Chinook.

Model	Parameter		Population capacity (K)	Intrinsic productivity	Spawners
	A	B			
Smooth hockey stick	10.718	174.077	45,161	174	777
Ricker	149.452	0.00111	49,532	149	901
Beverton-Holt	55,702.281	273.910	55,702	203	∞

It is important to note that the population capacity estimates are based on the number of smolts produced entirely within the Chiwawa River watershed. As noted earlier, there are spring Chinook fry and parr that move out of the Chiwawa River watershed during spring, early summer, and fall (Hillman et al. 2017). Fall emigration is common and occurs even when densities of juveniles are very low, indicating that fall emigration is a life-history characteristic. Regardless of why the fish emigrate as fry and parr, some of these fish survive and rear in the Wenatchee or Columbia rivers. Some survive to smolt (unpublished WDFW data), but are not included in the smolt capacity estimates shown in Table 5.

As with parr, the capacity estimates for spring Chinook smolts apply only to the Chiwawa River watershed. As before, we can extrapolate smolt capacity estimates from the Chiwawa River watershed to the entire Wenatchee River basin using intrinsic potential (IP). In this case, we multiply the smolt capacity per intrinsic potential within the Chiwawa River watershed by the total intrinsic potential within the Wenatchee River basin. This yields an estimate of smolt capacity for the Wenatchee River basin (Table 6).

Table 6. Estimates of Wenatchee River basin smolt capacity based on intrinsic potential (IP). The amount of IP within the Chiwawa River watershed is 0.481 km^2; the total amount of IP within the Wenatchee River basin is 1.798 km^2.

Model	Chiwawa smolt capacity	Chiwawa smolts/IP	Wenatchee smolt capacity
Beverton-Holt	55,702	115,805	208,218
Smooth Hockey Stick	45,161	93,891	168,816
Ricker	49,532	102,976	185,152

Using this simple method, we estimate the population capacity for the Wenatchee River basin at 168,816-208,218 smolts depending on which model is used. Based on smolt trapping in the lower Wenatchee River over a 13-year period, total smolt abundance has ranged from 36,752 to 302,116 smolts (average = 107,300 smolts) (Table 2).[14] Thus, recent (2000-2014) smolt production appears to be below capacity estimates for most years but higher in some years.

An important assumption of this simple method is that each unit of IP supports the same number of smolts. As we noted earlier, this is not the case given that the quality of habitat within each unit of IP can vary greatly. Nevertheless, the ratio of smolts to IP comes from the Chiwawa River watershed, which contains some of the highest quality habitat within the Wenatchee River basin. Therefore, the estimated total smolt capacity for the entire Wenatchee River basin is likely biased high. If habitat conditions throughout the Wenatchee River basin are enhanced to conditions similar to those in the Chiwawa River watershed, we may expect smolt abundance to approach those estimated with this simple method.

Wenatchee River Spring Chinook Smolts

Rather than extrapolate results from the Chiwawa River watershed to the entire Wenatchee River basin, we can fit stock-recruitment models to the smolt data collected in the lower Wenatchee River and estimate population capacity directly from the population models. We successfully fit the three stock-recruitment curves to the Chiwawa spring Chinook smolt data; although, the models explained little of the variation in the stock-recruitment data ($R^2 < 0.05$) (Figure 3).

[14] It is important to point out that the trapping location has changed over time. During the period 2000-2008 and 2011-2012, the trap was located near the Town of Monitor. During the period 2013-present, the trap was located near the Town of Cashmere.

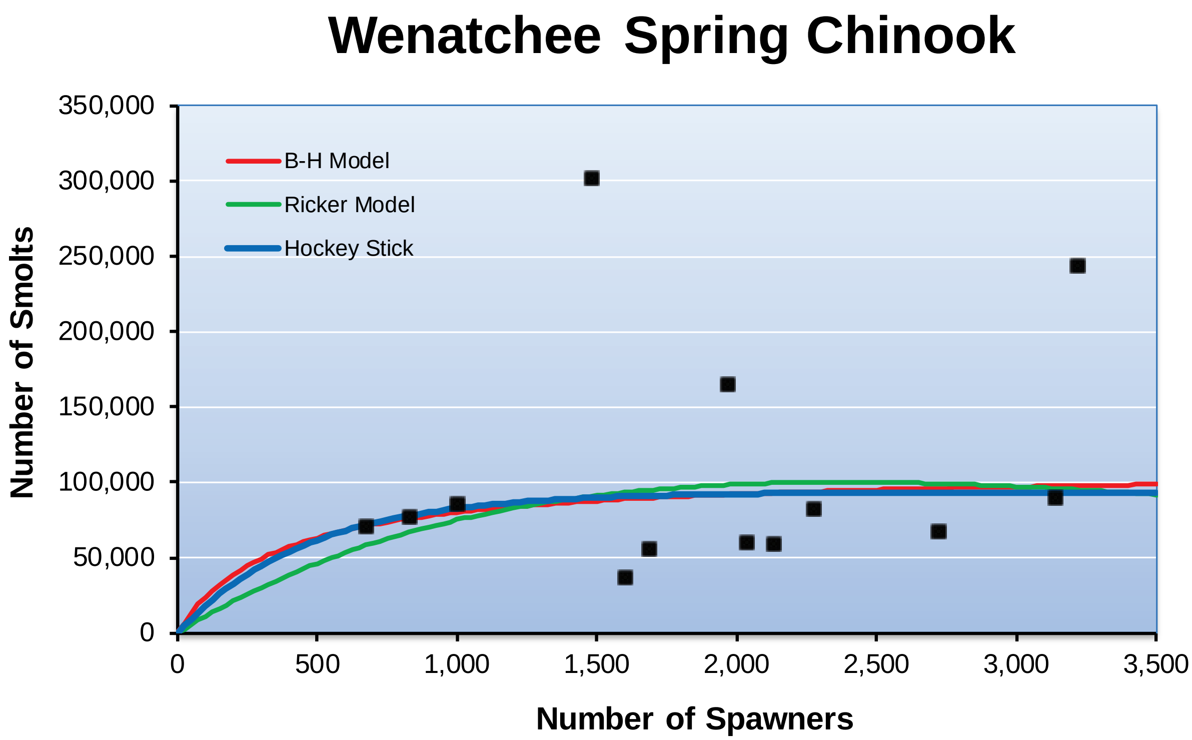

Figure 4. Relationship between numbers of spring Chinook smolts and numbers of spawners in the Wenatchee River basin, 2000-2014 (no data were collected in 2009 or 2010). Figure shows the fit of the Beverton-Holt, Ricker, and smooth hockey stick models to the data.

For yearling smolts produced within the Wenatchee River basin, the use of AIC$_c$ indicated that the Beverton-Holt model best approximated the information in the productivity data. The estimated structural parameters for this model were:

$$Smolts = \frac{(108{,}696 \times Spawners)}{(359 + Spawners)}$$

where the bootstrap estimated standard errors for the two parameters were 49,948 and 836, respectively. The adjusted $R^2 = 0.026$.

The second-best model was the smooth hockey stick model, which was 0.112 AIC$_c$ units from the best model. The estimated parameters for this model were:

$$LN(Smolts) = 11.4 + LN\left(1 - e^{-\left(\frac{20.72}{93{,}560}\right)Spawners}\right)$$

where the bootstrap estimated standard errors of the two parameters were 30.74 and 225.43, respectively, and the $R^2 = 0.017$.

The third-best model was the Ricker model, which was 0.0.808 AIC$_c$ units from the best model. The estimated parameters for this model were:

$$Smolts = 114.10 \times Spawners(\mathrm{e}^{-0.00042 \times Spawners})$$

where the bootstrap estimated standard errors of the two parameters were 56.16 and 0.00021, respectively, and the $R^2 = 0.001$.

The AIC_c difference scores, Akaike weights, and evidence ratios indicated that there was substantial support for all three models. Relative to the best model, the other two models had evidence ratios less than 2.0.

Depending on the stock-recruitment model used, population capacity for the Wenatchee River basin ranged from 93,560 to 108,696 smolts (Table 7). The Beverton-Holt model estimated the highest capacity, while the smooth hockey stick model estimated the lowest. The number of spawners needed to produce the population capacity of smolts ranged from 1,389-2,381 (Table 7).

Table 7. Estimates of Beverton-Holt, smooth hockey stick, and Ricker model parameters, smolt capacity (K), smolt productivity (smolts per spawner), and the number of spawners needed to produce the maximum number of smolts for Wenatchee River spring Chinook.

Model	Parameter		Population capacity (K)	Intrinsic productivity	Spawners
	A	B			
Smooth hockey stick	11.446	201.724	93,560	202	1,389
Ricker	114.104	0.00042	99,944	114	2,381
Beverton-Holt	108,696.009	358.616	108,696	303	∞

The population capacity estimates reported here are based on the number of smolts produced within the Wenatchee River basin. It is likely that some juvenile spring Chinook rear in the Columbia River and survive to smolt. Those fish are not included in these estimates of capacity.

Habitat Capacity

Habitat capacity can be estimated using fish-habitat models and creative modeling of stock-recruitment data. As we noted earlier, there are several different fish-habitat models that can be used to estimate habitat capacity. In this paper, we explore the use of two different methods, quantile regression applied to stock-recruitment functions and the Quantile Regression Random Forest model. The former relies on simple stock and recruitment data, while the latter requires estimates of habitat quality and quantity, and functional relationships between maximum fish density and habitat conditions.

Quantile Regression Analysis of Stock-Recruitment Data

To estimate population capacity, we used non-linear regression techniques to fit stock-recruitment functions to the data. These techniques approximate the conditional mean of the recruitment data given the range of stock sizes. As such, the functions (curves) estimated from the analyses lie near the center of the distribution of data resulting in data points above and below the curve. Although this technique is useful for estimating population capacity, it is not appropriate for estimating habitat capacity. The fact that there are actual recruitment data above the estimated population capacity indicates that habitat capacity must be greater than the population capacity, or that measurement error is high. The former explanation is more likely than the latter.

One way to possibly estimate habitat capacity with stock-recruitment data is to fit stock-recruitment functions to the juvenile spring Chinook data using quantile regression techniques. Quantile regression estimates quantiles of the recruitment data given the range of stock sizes. Thus,

we can use quantile regression to fit a stock-recruitment function to, say, the upper 90% or 95% of the recruitment distribution. In other words, we fit a stock-recruitment function to the upper limits of the recruitment data given the range of stock sizes. In this case, the resulting stock-recruitment curve is above most of the recruitment data and therefore few data points lie above the curve. Calculation of capacity from these functions should more closely represent habitat capacity, provided there is an adequate range of stock sizes. Quantile regression gives results similar to those obtained from calculating reference intervals (RI).

In this exercise, we calculated the upper 90% RI for the Beverton-Holt and Ricker functions. We assume the 90% RI will closely represent the habitat capacity for juvenile spring Chinook. We calculated the 90% RI only for the Beverton-Holt and Ricker models, because these functions can be transformed into linear function (see Hilborn and Walters 1992). RIs are easier to calculate on linear functions than non-linear functions. We were unable to transform the smooth hockey stick model into a linear function and therefore we did not calculate RIs for this function.

Chiwawa River Spring Chinook Parr—We calculated 90% RIs for Chiwawa Chinook parr data for both the Ricker and Beverton-Holt models (Figure 5). The estimated parameters for the 90% RI for the Ricker model were:

$$\log\left(\frac{Parr}{Spawners}\right) = 6.152 - \frac{6.152}{5{,}984.436}(Spawners)$$

This resulted in an estimated habitat capacity of 168,071 parr, which is about 1.4 times greater than the population capacity estimated with the Ricker model.

The estimated parameters for the 90% RI for the Beverton-Holt model were:

$$\frac{Spawners}{Parr} = \frac{196.91}{181{,}818} + \frac{1}{181{,}818}(Spawners)$$

This function resulted in an estimated habitat capacity of 181,818 parr, which was about 1.2 times greater than the population capacity estimated with the Beverton-Holt model.

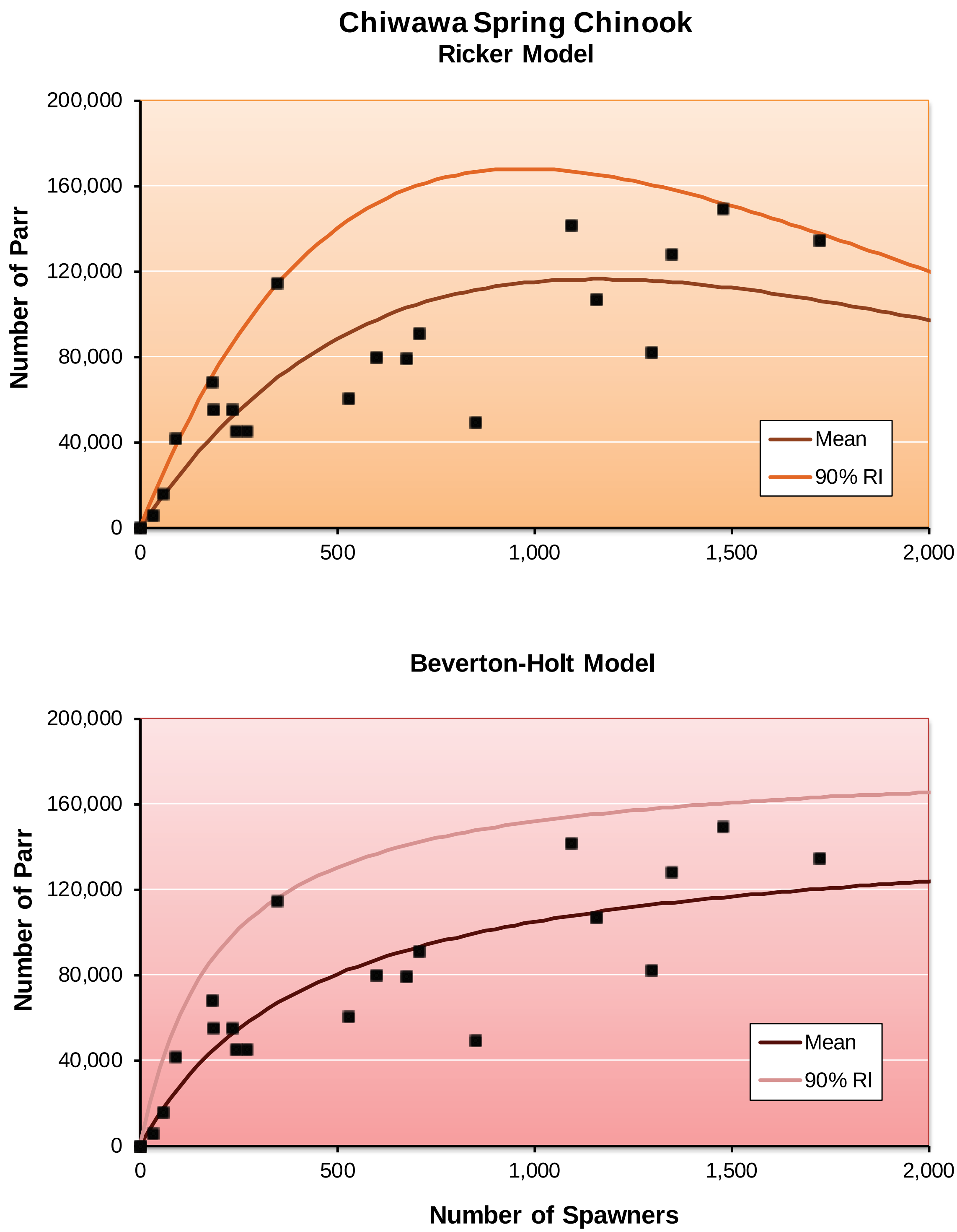

Figure 5. Relationship between numbers of spring Chinook parr and numbers of spawners in the Chiwawa River watershed, 1992-2016. Upper figure shows the fit of the Ricker model and its 90% reference interval to the data; lower figure shows the fit of the Beverton-Holt model and its 90% reference interval.

If we extrapolate the habitat capacity estimates for Chiwawa spring Chinook parr to the entire Wenatchee River basin (using the IP method described earlier), we estimate the habitat capacity for the Wenatchee River basin to be 628,256 parr from the Ricker model and 679,645 parr from the Beverton-Holt model.

Chiwawa River Spring Chinook Smolts—As with parr, we calculated 90% RIs for Chiwawa Chinook smolt data for both the Ricker and Beverton-Holt models (Figure 6). The estimated parameters for the 90% RI for the Ricker model were:

$$\log\left(\frac{Smolts}{Spawners}\right) = 5.687 - \frac{5.687}{4{,}687.964}(Spawners)$$

This resulted in an estimated habitat capacity of 89,425 smolts, which is about 1.8 times greater than the population capacity estimated with the Ricker model.

The estimated parameters for the 90% RI for the Beverton-Holt model were:

$$\frac{Spawners}{Smolts} = \frac{102.129}{64{,}516} + \frac{1}{64{,}516}(Spawners)$$

This function resulted in an estimated habitat capacity of 64,516 smolts, which was about 1.2 times greater than the population capacity estimated with the Beverton-Holt model.

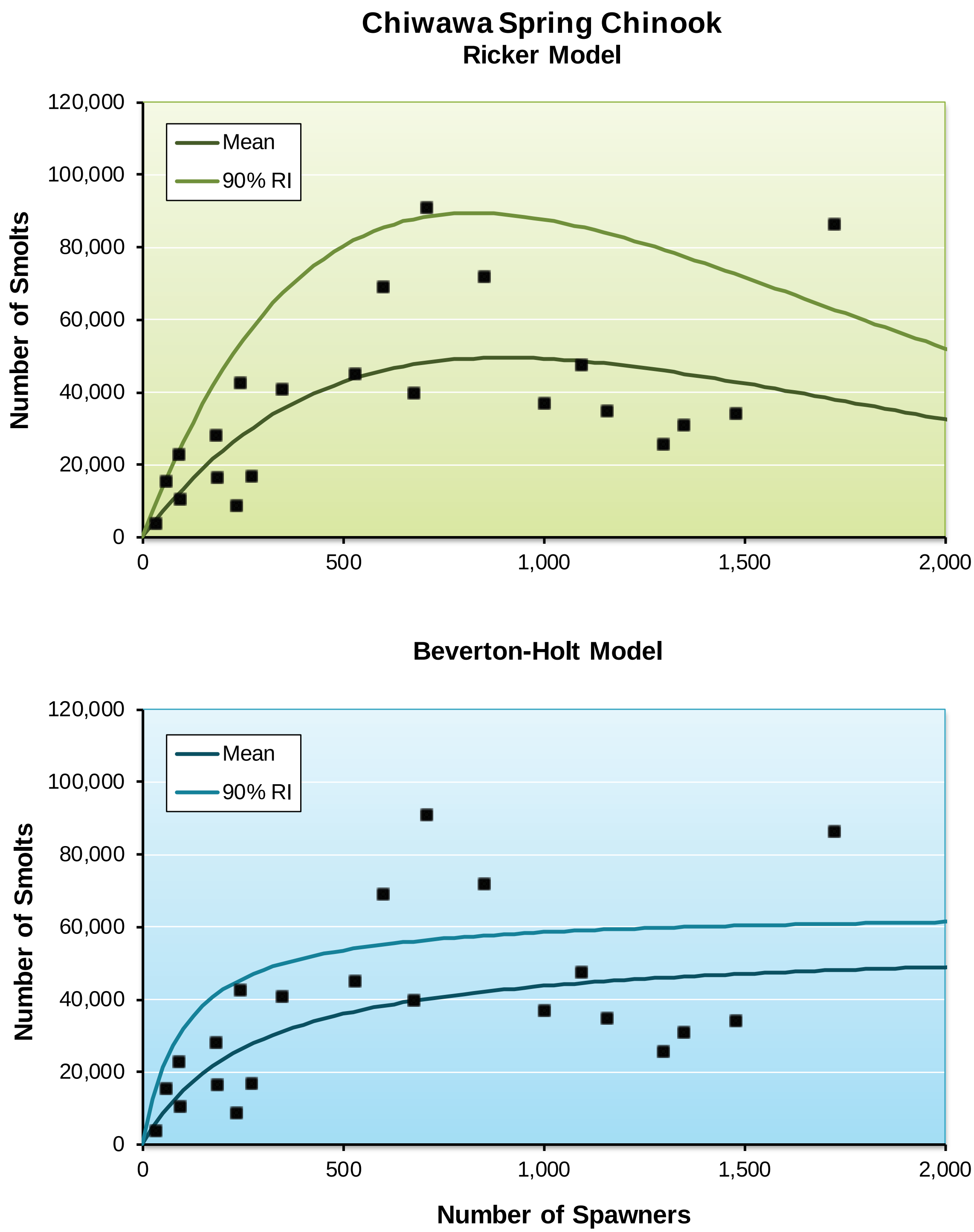

Figure 6. Relationship between numbers of spring Chinook smolts and numbers of spawners in the Chiwawa River watershed, 1992-2015. Upper figure shows the fit of the Ricker model and its 90% reference interval to the data; lower figure shows the fit of the Beverton-Holt model and its 90% reference interval.

If we extrapolate the habitat capacity estimates for Chiwawa spring Chinook smolts to the entire Wenatchee River basin (using the IP method described earlier), we estimate the habitat capacity

for the Wenatchee River basin to be 334,276 smolts based on the Ricker model and 241,164 smolts from the Beverton-Holt model.

Wenatchee River Spring Chinook Smolts—We calculated 90% RIs for Wenatchee River Chinook smolt data for both the Ricker and Beverton-Holt models (Figure 7). The estimated parameters for the 90% RI for the Ricker model were:

$$\log\left(\frac{Smolts}{Spawners}\right) = 5.320 - \frac{5.320}{16{,}642.420}(Spawners)$$

This resulted in an estimated habitat capacity of 235,131 smolts, which is about 2.4 times greater than the population capacity estimated with the Ricker model.

The estimated parameters for the 90% RI for the Beverton-Holt model were:

$$\frac{Spawners}{Smolts} = \frac{357.593}{186{,}567} + \frac{1}{186{,}567}(Spawners)$$

This function resulted in an estimated habitat capacity of 186,567 smolts, which was about 1.7 times greater than the population capacity estimated with the Beverton-Holt model.

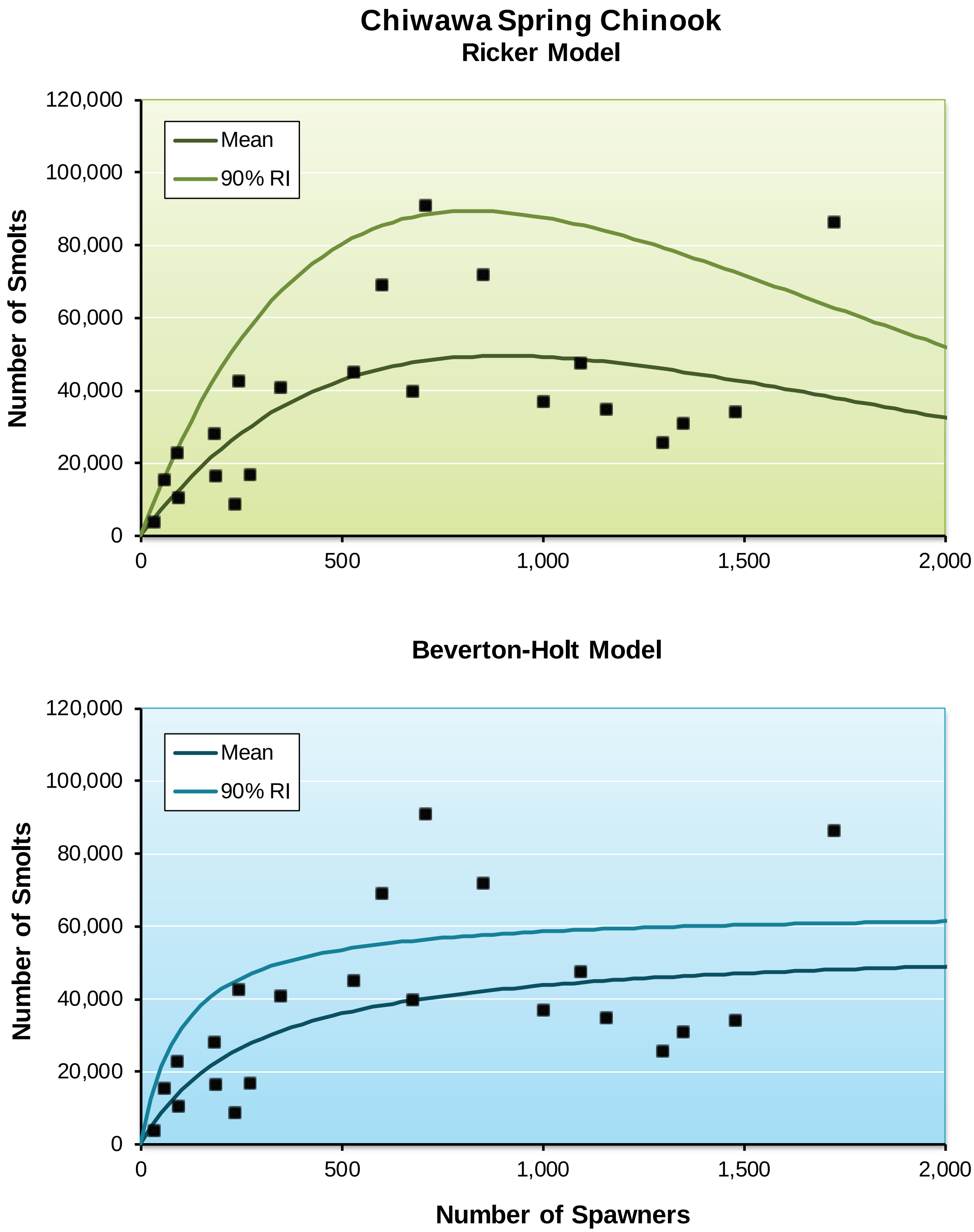

Figure 7. Relationship between numbers of spring Chinook smolts and numbers of spawners in the Wenatchee River basin, 2000-2015 (no data were collected in 2009 or 2010). Upper figure shows the fit of the Ricker model and its 90% reference interval to the data; lower figure shows the fit of the Beverton-Holt model and its 90% reference interval.

Quantile Regression Random Forest Model

Researchers with the Integrated Status and Effectiveness Monitoring Program (ISEMP) developed a model that estimates Chinook parr habitat capacity based on fish-habitat relationships (ISEMP/CHaMP 2015). Based on extensive sampling throughout the Columbia River basin, these researchers developed relationships between maximum densities of Chinook parr (summer estimates) and various habitat variables. Quantile regression forest (QRF) models use these relationships to estimate carrying capacities for juvenile Chinook. Very simply, QRF analysis develops non-linear relationships between fish density and different habitat variables. In this case, however, QRF analysis predicts the 90% quantile of fish density rather than the mean or median density. The researchers assume that the 90% quantile represents habitat capacity. This is important because the numbers of fish counted in some field sampling sites may not have been at maximum capacity. That is, it is likely that not all sites sampled were fully "seeded" with Chinook salmon. Thus, using the mean or median (50% quantile) would not represent habitat capacity, but some level below habitat capacity.

Researchers fit the QRF model to parr density data and 12 habitat variables that were collected from 227 sites within the distribution of Chinook throughout the Columbia River basin (within CHaMP/ISEMP watersheds). These variables were selected to represent a variety of types of habitat variables (e.g., substrate, riparian, complexity, temperature, etc.), contain the most "fish information," and be as uncorrelated as possible (ISEMP/CHaMP 2015). The 12 habitat variables and their relative importance are shown in Figure 8.

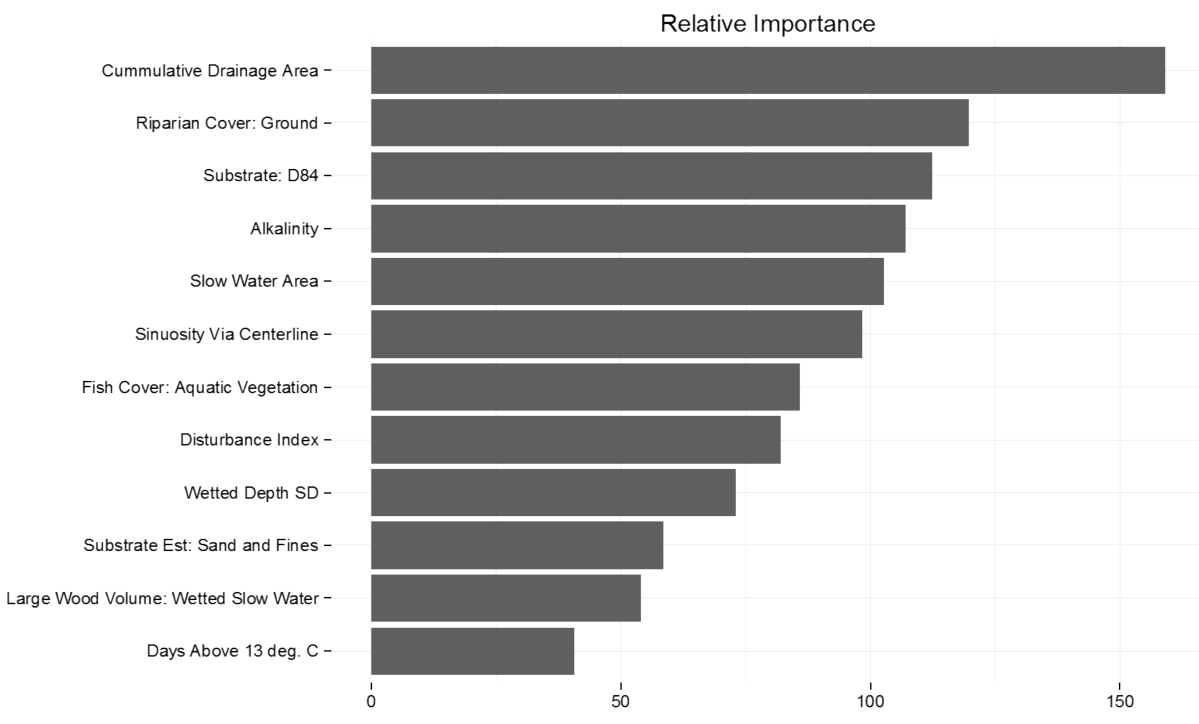

Figure 8. Relative importance of habitat variables included in juvenile Chinook salmon quantile regression forest models (Figure is from ISEMP/CHaMP 2015).

As a way of testing the model, ISEMP researchers used their QRF model to estimate Chinook parr capacities in different watersheds, including the Chiwawa River watershed, and compared their

estimates to those generated from fish population data using stock-recruitment modeling. Figure 9 shows the relationship between the QRF model results and population model results for the Chiwawa River watershed. The red curve was generated using the QRF model and the blue curve was generated using the Beverton-Holt model. At the time of this analysis, the Beverton-Holt model was fit to 21 years of parr data, not the 24 years of data used in the analyses above.

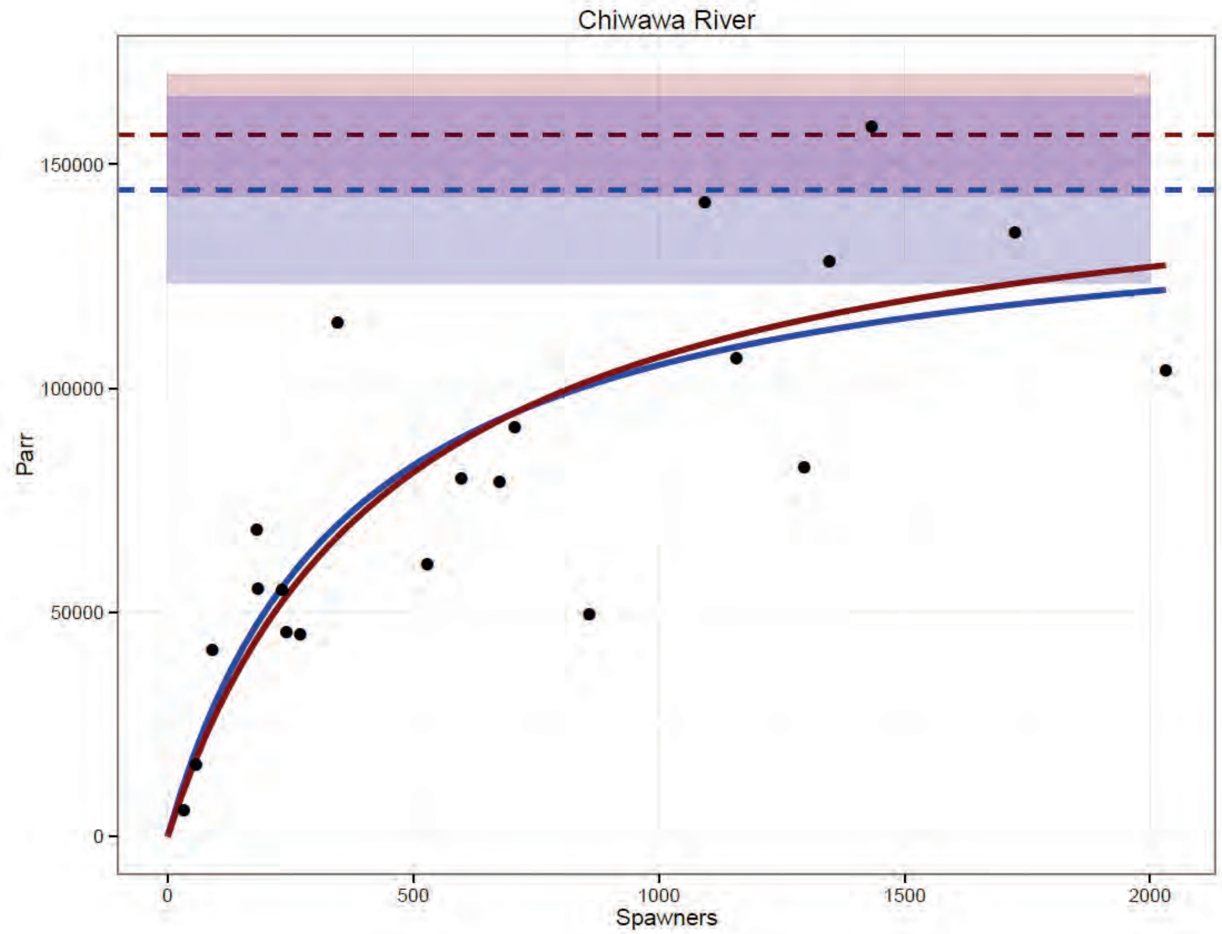

Figure 9. Comparison of productivity curves for Chiwawa spring Chinook parr generated from the QRF model (red line) and Beverton-Holt model (blue line). Dashed horizontal lines represent carrying capacity estimates. Shading about the capacity estimates represent the 95% confidence bounds. Figure is from ISEMP/CHaMP (2015).

The comparison shows that although the curves are very similar, the carrying capacity estimates (dashed horizontal lines) differed, with the habitat capacity generated from the QRF model being larger than the population capacity generated from the population data. That is, the QRF model estimated a habitat capacity of about 164,000 spring Chinook parr, while the population model estimated a population capacity of about 145,000 parr. Including more recent parr data in the Beverton-Holt model indicates that the population capacity estimate is about 151,000 parr for the Chiwawa River watershed. The 90% RI for the Beverton-Holt model estimated a habitat capacity of about 182,000, which is 1.1 times greater than the estimate from the QRF model. Note that the 90% RI for the Ricker model estimated a habitat capacity of about 168,000, which is close to the QRF model estimate.

Comparing Results

We estimated capacities for both spring Chinook parr and smolts for the Chiwawa River watershed and the entire Wenatchee River basin using different analytical tools. In this section, we compare the results from the different approaches.

Parr Capacity

Depending on the population model used, population capacity estimates for the Chiwawa River watershed ranged from 113,801 to 150,902 parr (Table 8). Not surprisingly, the Beverton-Holt model generally predicts the highest capacity estimates, while the smooth hockey stick model predicts the lowest. As expected, the population capacity estimates for Chiwawa parr were less than the habitat capacity estimates for parr. Habitat capacity estimates were about 1.2 to 1.5 times greater than the population capacity estimates (Table 8). Importantly, the fish-habitat model (QRF model) calculated a habitat capacity estimate that was close to that estimated from calculating 90% RI for the population models. Extrapolating Chiwawa capacity estimates to the entire Wenatchee River basin resulted in population capacities of 425,395 to 564,079 parr and habitat capacity estimates of 613,040 to 679,645 parr (Table 8).

Table 8. Comparison of spring Chinook parr capacity estimates for the Chiwawa River watershed and the Wenatchee River basin. Population capacities were estimated directly from the stock-recruitment functions; habitat capacities were estimated by calculating 90% reference intervals (using quantile regression; QR) for the stock-recruitment models and using a fish-habitat model (Quantile Regression Forest Model; QRF). Capacities for the Wenatchee River basin were estimated by extrapolating Chiwawa capacities using intrinsic potential.

Capacity type	Model	Chiwawa parr capacity	Wenatchee parr capacity
Population capacity	Beverton-Holt	150,902	564,079
	Smooth Hockey Stick	113,801	425,395
	Ricker	116,650	436,043
Habitat capacity	QR Beverton-Holt	181,818	679,645
	QR Ricker	168,071	628,256
	QRF Model	164,000	613,040

The number of spawners needed to achieve parr capacity also varied depending on the population model used (Table 9). For the Chiwawa River watershed, maximum spawners needed to achieve population capacity for parr ranged from 1,089 to 1,163 adults. Extrapolating Chiwawa results to the entire Wenatchee River basin resulted in maximum spawner estimates of 4,070 to 4,347 adults. We were able to estimate habitat capacity only with the Ricker model (Table 9). Using quantile regression to calculate the 90% RI for the Ricker model resulted in a maximum spawner abundance of 973 adults, which is less than the number needed to achieve population capacity. This is because the 90% RI for the Ricker function estimates a higher intrinsic productivity, which shifts the "hump" of the curve to the left resulting in a higher capacity estimate but a lower maximum spawner estimate (see Figure 5).

Table 9. Comparison of the number of spawners needed to achieve parr capacities in the Chiwawa River watershed and the Wenatchee River basin. For the Chiwawa River watershed, maximum spawners were estimated directly from the stock-recruitment functions. Maximum spawners for the entire Wenatchee River basin were estimated as the product of the extrapolated parr numbers times the ratio of maximum spawners to parr capacity for Chiwawa spring Chinook. Because of the nature of the Beverton-Holt model, no maximum spawners can be calculated from that model.

Capacity type	Model	Spawners need to achieve parr capacity	
		Chiwawa	Wenatchee
Population capacity	Smooth Hockey Stick	1,089	4,070
	Ricker	1,163	4,347
Habitat capacity	QR Ricker	973	3,636

Smolt Capacity

As with parr estimates, population capacity estimates for smolts varied depending on the population model used. For Chiwawa spring Chinook smolts, population capacities ranged from 45,161 to 55,702 smolts, with the smooth hockey stick providing the lowest estimate and the Beverton-Holt model providing the highest (Table 10). The population capacity estimates were about 55 to 86% of the habitat capacity estimates. Extrapolating Chiwawa capacity estimates to the entire Wenatchee River basin resulted in population capacities of 168,816 to 208,218 smolts and habitat capacity estimates of 241,164 to 334,276 smolts (Table 10). These were greater than those estimated using smolt and spawner data for the entire Wenatchee River basin. Fitting population models to smolt and spawner data for the entire basin resulted in population capacities of 93,560 to 108,696 smolts and habitat capacities of 186,567 to 235,131 smolts (Table 10).

Table 10. Comparison of spring Chinook smolt capacity estimates for the Chiwawa River watershed and the Wenatchee River basin. Population capacities were estimated directly from the stock-recruitment functions; habitat capacities were estimated by calculating 90% reference intervals (using quantile regression; QR) for the stock-recruitment models. Capacities for the Wenatchee River basin were estimated by extrapolating Chiwawa capacities using intrinsic potential and by fitting population models to the smolt and spawner data for the entire basin.

Capacity type	Model	Chiwawa smolt capacity	Wenatchee smolt capacity	
			Chiwawa extrapolation	Wenatchee data
Population capacity	Beverton-Holt	55,702	208,218	108,696
	Smooth Hockey Stick	45,161	168,816	93,560
	Ricker	49,532	185,152	99,944
Habitat capacity	QR Beverton-Holt	64,516	241,164	186,567
	QR Ricker	89,425	334,276	235,131

The number of spawners needed to achieve smolt capacity varied depending on the population model used (Table 11). For the Chiwawa River watershed, maximum spawners needed to achieve

population capacity for smolts ranged from 777 to 901 adults. Note that the maximum number of adults needed to achieve population capacity for smolts is less than those needed to achieve population capacity for parr. Extrapolating Chiwawa results to the entire Wenatchee River basin resulted in maximum spawner estimates of 2,904 to 3,368 adults. These estimates are considerably higher than those estimated from fitting population models to Wenatchee River basin data. The latter estimated maximum spawners ranging from 1,389 to 2,381 adults. We were able to estimate habitat capacity only with the Ricker model (Table 11). Using quantile regression to calculate the 90% RI for the Ricker model resulted in a maximum spawner abundance of 824 adults for the Chiwawa River watershed and 3,129 adults for the entire Wenatchee River basin. Extrapolating Chiwawa results to the entire Wenatchee River basin resulted in a maximum spawner estimate of 3,080, which is close to the estimate generated by fitting the model to Wenatchee River basin data.

Table 11. Comparison of the number of spawners needed to achieve smolt capacities in the Chiwawa River watershed and the Wenatchee River basin. Maximum spawners were estimated directly from the stock-recruitment functions. Maximum spawners for the entire Wenatchee River basin were also estimated as the product of the extrapolated smolt numbers times the ratio of maximum spawners to smolt capacity for Chiwawa spring Chinook. Because of the nature of the Beverton-Holt model, no maximum spawners can be calculated from that model.

Capacity type	Model	Spawners need to achieve smolt capacity		
		Chiwawa	Wenatchee	
			Chiwawa extrapolation	Wenatchee data
Population capacity	Smooth Hockey Stick	777	2,904	1,389
	Ricker	901	3,368	2,381
Habitat capacity	QR Ricker	824	3,080	3,129

As an additional exercise, we calculated smolt capacities and maximum spawners generated from fitting population models to smolt and spawner data in the Chiwawa River, Nason Creek, and White River watersheds, and compared the sum of those estimates to the Wenatchee River basin estimates. Only the Ricker model could be fit to the White River and Nason Creek data (see Hillman et al. 2017). Estimated population capacities from the Ricker model were 49,532 smolts in the Chiwawa, 4,412 smolts in Nason Creek, and 4,659 smolts in the White River, resulting in a cumulative population capacity of 58,603 smolts (1,550 spawners are needed to achieve this cumulative smolt capacity). The cumulative population capacity estimate is nearly 60% of the total population capacity calculated from fitting the Ricker model to the entire Wenatchee River basin data. If these estimates are correct, this means that about 40% of the current Wenatchee River basin smolt capacity is outside the Chiwawa River, Nason Creek, and White River watersheds. Hillman et al. (2017) report that over the period 1989 to 2016, on average, 76% of spring Chinook spawning occurs in the three watersheds. Thus, a large percentage of smolt capacity is generated outside the major spawning areas. We believe this highlights the importance of the mainstem Wenatchee River as a rearing area for juvenile spring Chinook.

Recommendations

Based on the simple analyses conducted in this report, we offer the following recommendations:

1. Where sufficient stock and recruitment data are available, and the data have sufficient contrast, then use population (stock-recruitment) modeling as the primary method to calculate population capacity and the number of spawners needed to produce the maximum number of recruits under current or average habitat conditions. Select the best fitting stock-recruitment model based upon AIC_c, unless other factors suggest otherwise, such as evidence for a biological mechanism. A biological mechanism supporting a Ricker function, for example, would be that there is a stock-dependent effect on the mortality of eggs and juveniles (i.e., mortality is proportional to the initial cohort size). When AIC_c values are not appreciably different, then select the model that is most useful (e.g., Ricker and smooth hockey stick models are easier to work with than the Beverton-Holt model).
2. Adult-to-adult data are the most relevant because they account for all life stages and delayed effects in freshwater (e.g., small size at migration), but they are also the most variable (i.e., low R^2). Therefore, adult-to-juvenile data (e.g., parr, yearling smolts, total migrants) are likely the most useful for determining freshwater population capacity. Where data are available, pre-spawn adult to spawning adult survival can also be assessed using population models to evaluate density dependence and pre-spawn adult capacity.
3. The population models used to estimate population capacity should also be used in reference streams so one can make comparisons of carrying capacities and density-corrected productivities. Unless there are good reasons for selecting a different juvenile life-stage, the default should be to use yearling smolts because they represent the capacity of the tributaries to produce yearlings and it is also a clear identification and quantification of a migrant life-stage.
4. In the absence of fish-habitat models, quantile regression can be used to estimate habitat capacity by calculating reference intervals for the population models. The percentage of the reference interval should be set using the error in the estimation of the recruits and the level of desire to exclude anomalous data. For example, if the 95% confidence interval is approximately 10% of the recruitment estimate, then the reference interval should be set at 90% (e.g., RI = 100% - C.I.%).
5. Where sufficiency conditions in (1) are not met, use habitat-based expansion of density at capacity for the most ecologically similar population. For example, use Twisp capacity estimates for habitat-based expansions in the Methow. The habitat expansion metric should be “total stream area weighted by intrinsic potential and temperature limited,” unless there are good reasons for a different expansion. The primary idea is to exclude areas that are known to not produce fish because of passage, temperature, or other limitations.
6. Capacity estimates should be described within the context of the information that was used to derive estimates. For example, spawner distribution of hatchery-origin fish could influence estimates of capacity if they are within poor habitat. However, the capacity estimates do reflect the historic and current hatchery practices. It is unknown how the capacity estimates would change if a different hatchery program that produced different spawning distributions was to be implemented. However, if those data do become available, then capacity estimates can be revised. Similarly, significant enhancements (e.g.,

improved passage) or degradations (e.g., fire) in habitat can also change capacity and can be incorporated into future estimates of capacity.

7. Regardless of the method used to estimate capacity, always describe the limitations of the data and assumptions of the models. Note where assumptions are violated and how these violations could affect the results of the analysis.

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APPENDIX 2: HATCHERY REPLACEMENT RATES

Based on ideas developed by the HETT, in February 2016, the HCP Hatchery Committees and PRCC Hatchery Subcommittee agreed to the following rules and HRR targets:

1. Use the estimated 40% HRR Target during 5-year statistical evaluation periods.
2. Use varying degrees of action depending on the numbers of years that annual HRR deviates from Target.
    a. Green Light (below Target for ≤ 2 years).
    b. Red Light (below Target for > 2 years).
3. Each program will have its own HRR target with the following exceptions.
    a. Nason Creek spring Chinook will use the Chiwawa Target (there are currently no data to calculate a target for Nason Creek spring Chinook).
    b. Methow and Chewuch spring Chinook will use the greater of their two Targets (they are MetComp stock and evaluated similarly).

Table 1. Release numbers and 5-year hatchery replacement rates (HRR) targets for Upper Columbia River Hatchery Programs.

Species	Owner	Program (Hatchery)	Basin (Purpose)	Smolts released[1]	5-Year HRR[2]
Steelhead	CPUD	Eastbank (Chiwawa)	Wenatchee (Conservation)	123,650	6.9
Steelhead	CPUD	Eastbank (Chiwawa)	Wenatchee (Safety Net)	123,650	6.9
Steelhead	DPUD	Wells (Wells)	Columbia (Safety Net)	160,000	26.5
Steelhead	DPUD	Wells (Wells)	Methow (Safety Net)	100,000	26.5
Steelhead	DPUD	Wells (Wells)	Twisp (Conservation)	48,000	26.5
Steelhead	GPUD	Wells (Omak)	Okanogan (Conservation)	100,000	7.3 [3]
SUM Chinook	CPUD	Eastbank (Chelan Falls)	Chelan (Conservation)	176,000	5.7
SUM Chinook	CPUD	Eastbank (Chelan Falls)	Chelan (Harvest)	400,000	5.7
SUM Chinook	CPUD, GPUD	Eastbank (Dryden)	Wenatchee (Conservation)	500,000	5.7
SUM Chinook	DPUD	Wells (Wells)	Columbia (Harvest)	320,000	3.0
SUM Chinook	GPUD	Eastbank (Carlton)	Methow (Conservation)	200,000	3.0
SUM Chinook	CCT	Chief Joseph	Okanogan (Harvest)	1,100,000	8.6
SPR Chinook	CPUD	Eastbank (Chiwawa)	Wenatchee (Conservation)	144,026	6.7

SPR Chinook	CPUD, DPUD, GPUD	Wells (Methow)	Methow (Conservation)	193,765	3.8
SPR Chinook	DPUD, GPUD	Wells (Twisp)	Methow (Conservation)	30,000	2.7
SPR Chinook	GPUD	Eastbank (Nason)	Wenatchee (Conservation)	223,670	6.7

[1] Release goal established by HCPs and adjusted by HC.
[2] Derived from Annual Reports.
[3] Harvest not included.

APPENDIX 3: PNI and pHOS Targets and Sliding Scales

Select CPUD, DPUD, and GPUD funded hatchery mitigation programs have PNI management targets, while others do not. Table 1 summarizes management strategies by species and population. Detailed information can be found in the sections that follow. Descriptions provided in the following sections are taken directly from HGMPs and/or issued and draft permits.

Table 1. Summary of management strategies by species and population.

Species	Population	Management Strategy	Comments
Spring Chinook	Wenatchee	Sliding Scale of PNI management	Details can be found in Section 2.0
	Methow	Two—population sliding scale PNI management	Details can be found in Section 3.0
	Okanogan	None Currently	Details can be found in Section 4.0
Steelhead	Wenatchee	Two-zone management.	Details can be found in 5.0
	Methow	In-development	Details forthcoming; Section 6.0
	Okanogan	None Currently	Details can be found in Section 7.0
Summer Chinook	Wenatchee	None Currently	Details can be found in Section 9.0
	Methow	None Currently	Details can be found in Section 10.0
	Okanogan	0.67; pHOS 0.30	Details can be found in Section 11.0
	Upper Columbia River	None Currently	Details can be found in Section 12.0
Fall Chinook	Hanford Reach	0.67	Details can be found in Section 13.0

2.0 Wenatchee Spring Chinook

Wenatchee spring Chinook will be managed according to the sliding scale identified in the Wenatchee Spring Chinook Management Plan (2010) and Permit Numbers 18118 and 18121. The sliding scale is based upon the estimated number of natural origin spring Chinook over Tumwater Dam. As more information becomes available the sliding scale may be adjusted as a result of gaining a better understanding of the pre-spawn mortality rate and carrying capacity.

Table 2. Sliding scale of PNI goals based on natural origin spring Chinook run size expected to the Wenatchee River basin. Percentiles are based on adult returns observed between 1999 and 2008.

Percentile	NOR Run Size				PNI
	Chiwawa	Nason Creek	White	Wenatchee River (above TWD)	
>75th	>372	>350	>87	>910	≥ 0.80
50% - 75%	278-372	259-349	68-86	631-909	≥ 0.67
25% - 50%	209-277	176-258	41-67	525-630	≥ 0.50
10%-25%	176-208	80-175	20-40	400-524	≥ 0.40
<10th	<175	<80	<20	<400	Any PNI

3.0 Methow/ Chewuch Spring Chinook

The following sliding scale (Table 3) is presented in the April 14, 2016 draft Methow Hatchery Spring Chinook Section 10-Draft. It is anticipated that no further changes will be made to the sliding scale prior to issuance of the final permits.

Table 3. PUD PNI sliding scale calculations for a range of natural run sizes.

Natural Origin Returns	PUD pHOS	WNFH pHOS	PUD pNOB	2-Pop PNI	PUD PNI (equation)
<300	Ensure minimum of 500 total spawners				
300	0.40	0.2	0.75	0.67	0.67
500	0.40	0.2	0.80	0.68	0.76
900	0.30	0.15	1.00	0.78	0.80
1500	0.25	0.1	1.00	0.8	0.80
2000	0.25	0.1	1.00	0.8	0.80
2500	0.25	0.1	1.00	0.8	0.80

4.0 Okanogan Spring Chinook

The Okanogan spring Chinook program is a re-introduction effort implemented as a non-essential experimental population under ESA Section 10j to re-introduce spring Chinook into the Okanogan River. As a non-essential experimental population targeting re-introduction and establishment of a local population of spring Chinook, the Okanogan spring Chinook program will not conduct adult management actions to reduce the proportion of 10j hatchery fish on the spawning grounds or conduct broodstocking efforts in the Okanogan for a 10-year period (2014 – 2023), as such, no PNI or pHOS objectives have been identified for this program in this 10-year period.

CJH Program segregated production released into the mainstem Columbia River are non-listed Leavenworth stock released reared/acclimated/released at CJH. Although no PNI or pHOS targets are identified for the Okanogan 10j population, minimizing strays from the CJH segregated spring Chinook program is a program objective, as such, returning segregated program fish will be subject to directed harvest and aggressive adult surplusing at CJH to minimize straying to the Okanogan River Basin as well as other extant upper Columbia River spring Chinook populations. Stray targets for the segregated program are 5% or less stray rate (i.e. spawning contribution to other upper Columbia River spring Chinook populations).

5.0 Wenatchee Steelhead

Interim escapement goal for Wenatchee River steelhead will be 1,500 spawners with an additional goal of attaining an average PNI of 0.67 for the Wenatchee River basin population as a whole. To achieve the stated goal, the Wenatchee steelhead program will use a two-zone management approach wherein the upper basin (above TWD) will be managed for recovery using an integrated recovery program, a separate spawning escapement goal, and a PNI standard to achieve the overall basin goal of an average PNI over time of 0.67 (Table 4). Areas below TWD will be managed to minimize hatchery supplementation with a pHOS goal of < 0.10.

Steelhead returning upstream of TWD will be managed as an integrated recovery program with a pNOB goal of 1.0. The above TWD escapement goal will be 1,094 spawners. Working within this framework, pNOB will be maximized above TWD while pHOS will be minimized.

Table 4. Wenatchee steelhead two-zone management and PNI targets.

Location	Run Escapement Goal	pNOB Conservation Program	pNOB Safety Net Program	pHOS	PNI
Above TWD	1,094	1.0	0.0	Varies	Varies
Below TWD	406	N/A	N/A	< 0.10	< 0.67
Basin Total	1,500	N/A	N/A	Minimal	Average = 0.67

6.0 Methow Steelhead

Methow steelhead PNI targets are currently in development.

7.0 Okanogan Steelhead

Current program has no PNI goal. CTCR submitted an Okanogan steelhead HGMP to NOAA Fisheries on February 4, 2014. Within the HGMP provisions were included to allow a greater collection of natural-origin broodstock and multiple adult management strategies to address over-escapement of hatchery-origin steelhead to the spawning grounds. The HGMP also identified a near-term (1-4 years) and a long-term PNI objectives of 0.50 and > 0.67, respectively. Once NOAA has completed the consultation and issued a new permit, providing the opportunity to increase the proportion of natural-origin fish in the broodstock and additional adult management strategies, the program will adopt the PNI objectives and this Appendix can be amended accordingly.

8.0 Wells Columbia Mainstem Safety-net Steelhead

The Safety-Net Mainstem Columbia component released below Wells Dam will be managed primarily at the Wells Hatchery volunteer channel. The objective of the adult management of the Safety-Net Mainstem Columbia component is to prevent runs of this component from moving into natural spawning areas. This will be accomplished through in-river harvest and removal of volunteers at the Wells Hatchery outfall. There are no PNI goals for this component.

9.0 Wenatchee Summer Chinook

No PNI goals are established.

10.0 Methow Summer Chinook

No PNI goals are established.

11.0 Okanogan Summer Chinook

Okanogan summer/fall Chinook will be managed to achieve a 5-year rolling average PNI of 0.67 and pHOS of 0.30. Strategies to achieve that PNI target include up to 100% pNOB, aggressive removal of hatchery-origin Chinook in selective fisheries, at the Okanogan weir, and during surplusing at CJH ladder. Reduction in the number of juveniles released in the Okanogan River Basin (integrated program) is also a management option, should adult management actions be unable to control the proportion of hatchery fish on the spawning grounds to achieve that PNI target.

CJH segregated summer/fall Chinook program rears/acclimates/releases smolts into the mainstem Columbia River at CJH. Broodstock are 100% hatchery-origin, as such no PNI target for this production component. Stray rate (i.e. contribution to upper Columbia summer/fall Chinook

populations) is 5% or less. Adult management on returning adults from the segregated program include fisheries, removal at the Okanogan weir, and removal at the CJH ladder.

12.0 Upper Columbia Summer Chinook (Chelan Falls and Wells)

No PNI goals are established. Chelan Falls and Wells FH summer Chinook programs are segregated harvest programs designed to provide opportunity for harvest. Adult returns are not intended to spawn naturally; therefore, there is no escapement goal for natural spawning areas. Adult returns will be managed to meet program objectives. Chelan Falls and Wells Hatchery summer Chinook are available for harvest in the ocean and Columbia River commercial, tribal, and recreational fisheries.

13.0 Priest Rapids Fall Chinook

The Hanford Reach fall Chinook population is intentionally supplemented by Grant PUD at the Priest Rapids Hatchery and the ACOE at the Priest Rapids and Ringold Springs hatcheries. Managers desire to achieve a population level PNI that includes all hatchery programs of $\geq$0.67. Grant PUD and the HSC do not have control over operation or expansion of the ACOE program and therefore will strive to operate the Priest Rapids Hatchery fall Chinook program in a way that does its fair share of achieving a population level PNI of 0.67.

APPENDIX 4: SPATIAL DISTRIBUTION OF SPAWNERS OR REDDS

Strategies for conservation programs typically intend that hatchery and naturally produced fish spawn together and in similar locations. However, in some cases, strategies may differ from this paradigm. In Table 1, conservation programs that have a spatial distribution management plan that deviates from similar to the natural spawning spatial distributions are presented. Otherwise, conservation programs are intended to have a spawning distribution similar to the natural origin spawning spatial distributions, as described by M&E Objective 5.3.

Table 1. Management targets for the spatial distribution of hatchery-origin redds for conservation programs that deviate from Objective 5.3.

Program	Target	Rational	Source
Carlton Summer Chinook	The observed spawning distribution of hatchery origin Methow summer Chinook from 2005-2010 represents the base-line spawner distribution for evaluating the performance of the hatchery program (i.e., M&E plan check-ins). It is acknowledged that this distribution is lower in the River than the spawning distribution of natural origin summer Chinook salmon.	Based upon an assessment of summer Chinook and ESA-listed spring Chinook abundance and spawner distribution, it was determined that an increase in summer Chinook spawning abundance in the upper most range of natural origin summer Chinook distribution or potentially above the current range may pose an unknown and potentially adverse impact to ESA listed spring Chinook. Due to the concern for spring Chinook, the HSC has endorsed an acclimation site in the Methow Basin that is lower in the basin than may be required to attain exact replication of natural and hatchery origin summer Chinook spawner distribution.	SOA 2011-02 Priest Rapids Coordinating Committee Hatchery Subcommittee Statement of Agreement on Monitoring & Evaluation (M&E) Objective for Spawning Distribution of Hatchery-Origin Summer Chinook
Dryden Summer Chinook	The observed spawning distribution of hatchery origin Wenatchee summer Chinook from 2008-2013 (previous 5 years to the current M&E check-in cycle) represents the base-line spawner distribution for evaluating the performance of the	The primary site endorsed by the HSC for Grant PUD overwinter acclimation of summer Chinook is the Dryden Pond, and is the current acclimation and release site for the existing summer Chinook supplementation program	Adapted from SOA 2011-02 Priest Rapids Coordinating Committee Hatchery Subcommittee Statement of Agreement on Monitoring & Evaluation (M&E) Objective for Spawning Distribution of Hatchery-Origin Summer Chinook

	hatchery program (i.e., M&E plan check-ins).	funded and owned by Chelan PUD. Because current data indicates that spawning distribution of hatchery summer Chinook from the existing program is lower in the Wenatchee River than natural origin spawners, expectations are that acclimation of Grant PUD's summer Chinook at Dryden Pond would continue to return hatchery origin summer Chinook that result in different spawning distributions for hatchery and natural summer Chinook.	

APPENDIX 5: WITHIN HATCHERY REARING TARGETS

Rearing Targets for Upper Columbia River Hatchery Programs. K-factor or fork length targets will be determined based on data from the pending "Five-Year Report."

Table 1. Numbers, fish per pound (fpp), coefficient of variation (CV), and condition factor (K) targets at release of Upper Columbia River Hatchery Programs.

Hatchery	Species	Life Stage	Basin	Release number	FPP	CV	K-factor
Methow	Spring Chinook	Yearling	Methow	193,765[1]	15	<10	TBD
Methow	Spring Chinook	Yearling	Twisp	30,000	15	<10	TBD
Chief Joseph	Spring Chinook	Yearling	Columbia	700,000	15	<10	TBD
Chief Joseph	Spring Chinook	Yearling	Okanogan	200,000	15	<10	TBD
Chiwawa	Spring Chinook	Yearling	Wenatchee	144,026	18	<10	TBD
Nason	Spring Chinook	Yearling	Wenatchee	223,670[3]	18-24	<10	TBD
Winthrop	Spring Chinook	Yearling	Methow	400,000	17	<10	TBD
Leavenworth	Spring Chinook	Yearling	Wenatchee	1.2 M	17	<10	TBD
Wells	Steelhead	Yearling	Columbia	160,000	6	<10	TBD
Wells	Steelhead	Yearling	Methow	100,000	6	<10	TBD
Wells	Steelhead	Yearling	Twisp	48,000	6	<10	TBD
Wells	Steelhead	Yearling	Omak	~100,000[4]	5-8	<10	TBD
Wells	Steelhead	Yearling	Okanogan	~100,000[4]	5-8	<10	TBD
Winthrop	Steelhead	Two year	Methow	200,000	4-6	<10	TBD
Chiwawa	Steelhead	Yearling	Wenatchee	247,300[5]	6	9.0	TBD
Wells	Summer Chinook	Subyearling	Columbia	480,000	50[6]	<7	TBD
Wells	Summer Chinook	Yearling	Columbia	320,000	10	<7	TBD
Chief Joseph	Summer Chinook	Subyearling	Columbia	400,000	50	<7	TBD
Chief Joseph	Summer Chinook	Subyearling	Okanogan	300,000	50	<7	TBD
Chelan Falls	Summer Chinook	Yearling	Chelan	576,000	13	9.0	TBD
Entiat	Summer Chinook	Yearling	Entiat	400,000	17	<10	TBD
Carlton	Summer Chinook	Yearling	Methow	200,000	13-17	<12	TBD
Chief Joseph	Summer Chinook	Yearling	Columbia	500,000	10	<7	TBD
Chief Joseph	Summer Chinook	Yearling	Okanogan	799,998[7]	10	<7	TBD
Dryden	Summer Chinook	Yearling	Wenatchee	500,001	18	9.0	TBD
Priest	Fall Chinook	Subyearling	Columbia	7.3 M[8]	50	<10	TBD
Ringold	Fall Chinook	Subyearling	Columbia	3.5 M	50	<10	TBD

[1] The total release includes the release of 108,249 into the Methow River at the Methow Fish Hatchery, 25,000 into the Methow River at the Goat Wall site, and 60,516 into the Chewuch River at the Chewuch Acclimation Facility.

[2] These fish come from Winthrop National Fish Hatchery (MetComp) eyed eggs.

[3] The total release includes 125,000 conservation fish and 98,670 safety net fish.

[4] The combined Okanogan and Omak steelhead release number is 100,000.

[5] The total release includes 66,771 fish into Nason Creek, 53,170 into the Chiwawa River, 102,359 into the Wenatchee River, and 25,000 into Blackbird Pond.

[6] The Wells subyearling Chinook are not reared to achieve a specific size target. The fish are released on a date to optimize survival and are grown to the largest size possible before release.

[7] The total release is divided equally among the Omak, Riverside, and Similkameen Acclimation Ponds.

[8] The total release consists of 5.6 m fall Chinook for the Grant PUD program and 1.7 M fall Chinook for the Army Corps of Engineers program.

APPENDIX 6: IDENTIFYING AND ANALYZING REFERENCE POPULATIONS

An important goal of supplementation is to increase spawning abundance and natural-origin recruitment of the supplemented population, and not reduce the productivity of the supplemented population. Indeed, a successful supplementation program must increase spawning abundance and natural-origin recruitment to levels above those that would have occurred without supplementation. There are several methods that can be used to test the effects of supplementation programs on these population metrics. One important method is to compare the performance of population metrics (e.g., spawning abundance, natural-origin recruitment, and productivity) in the supplemented population to those in un-supplemented (reference) populations. By comparing supplemented populations to reference populations, one can determine if the supplementation programs benefit, harm, or have no effect on the supplemented populations. These comparisons, however, are only valid if the performance of the reference populations is similar to the performance of the supplemented population prior to the period of supplementation. If the performance of the two populations differs significantly before any supplementation occurs, then any results from comparing the two populations after supplementation will be suspect. It is therefore important to select reference populations that are as similar as possible to the supplemented populations.

One of the goals of the Conceptual Approach to Monitoring and Evaluating the Chelan County PUD Hatchery Programs (Murdoch and Peven 2005) is to use reference populations to analyze the potential effects of hatchery supplementation programs on natural-origin salmon and steelhead spawner abundance and productivity[15]. Murdoch and Peven (2005) identified specific objectives to evaluate the performance of the program. For example, Objective 1 determines if the supplementation programs have increased the number of naturally spawning and naturally produced adults of the target population (supplemented population) relative to a reference population. Objective 7 determines if the proportion of hatchery fish on the spawning grounds affects the freshwater productivity (e.g., number of juveniles per redd) of supplemented streams when compared to reference streams. The relevant questions tested under each objective are as follows:

Objective 1:

- Is the annual change in the number of natural-origin recruits produced from the supplemented populations greater than or equal to the annual change in natural-origin recruits in an un-supplemented population?
- Is the change in natural replacement rates within the supplemented population greater than or equal to the change in natural replacement rates in an un-supplemented population?

Objective 7:

[15] Productivity is defined as adult recruits per spawner, where recruits are the number of adults produced from a given brood year (i.e., spawners plus adults harvested).

- Is the change in numbers of juveniles (smolts, parr, or emigrants) per redd in the supplemented population greater than or equal to that in an un-supplemented population?[16]

In this paper, we describe methods used to identify suitable reference streams and statistical techniques that can be used to compare reference populations with supplemented populations. Although we apply the methods described in this paper to Chiwawa spring Chinook salmon (hereafter referred to as Chinook), the methods should also apply to steelhead and other supplemented salmon stocks in the Upper Columbia Basin.

Identification of Reference Populations

Reference populations are an important component of an effectiveness monitoring design because they provide the standard by which treatment conditions are compared (ISRP and ISAB 2005; Murdoch and Peven 2005; Galbreath et al. 2008). Selecting appropriate reference areas and maintaining them over long periods of time is needed to establish the effectiveness of supplementation programs.

We developed a three-step process for identifying suitable reference populations (Figure 1). Each step serves as a filter. That is, potential reference populations are evaluated based on specific criteria under each step. Populations that pass through each step are considered suitable reference populations for a specific supplemented population.

[16] In this paper, we only address adult recruits, not juvenile recruits. This is because we were unable to find suitable reference populations for analysis of juveniles. However, the methods described in this paper would also apply to juveniles.

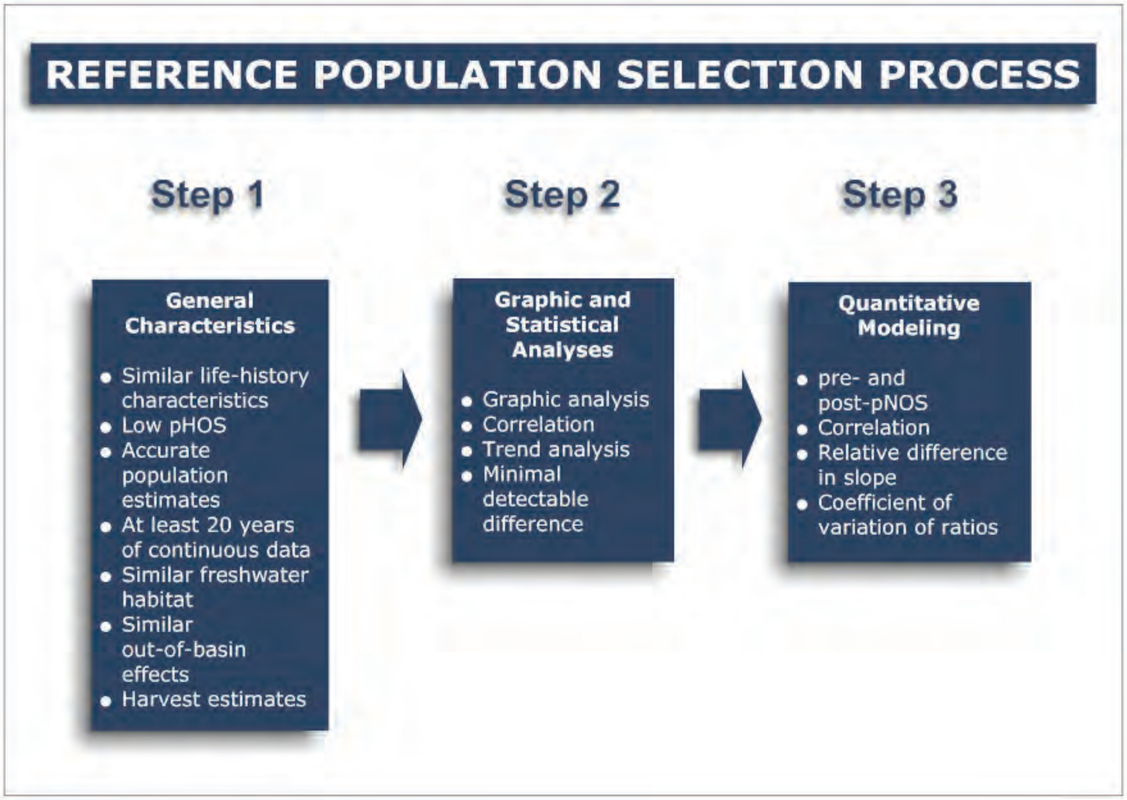

Figure 1. Criteria evaluated during each step in the process of identifying suitable reference populations.

Step 1: General Characteristics

Under step 1, potential reference populations are evaluated based on several general criteria. When compared to the supplemented population, potential reference populations should have:

- Similar life-history characteristics (e.g., run timing, migration characteristics, etc.).
- No or few hatchery fish in the reference area (pHOS < 10%).
- Accurate abundance estimates.
- Long time series of natural-origin abundance and productivity estimates (at least 20 years of continuous data).
- Similar trends in freshwater habitat.
- Similar out-of-basin effects (i.e., similar migration and ocean survivals).
- Harvest estimates for adjusting escapement estimates.

We used these criteria to begin the process of selecting suitable reference populations for the Chiwawa spring Chinook program. We began by identifying stream-type Chinook populations within the Columbia Basin. Galbreath et al. (2008; their Table 1) identified stream-type Chinook populations within the Columbia River Basin that may serve as suitable reference populations for hatchery programs. Supplementing their work with data from the NOAA Fisheries Salmon Population Summary Database, we identified 18 candidate stream-type Chinook populations that may serve as reference populations for the Chiwawa supplementation program (Table 1).

Table 1. Populations of stream-type Chinook salmon and their comparison to Chiwawa spring Chinook.

Population	Similar life-history	No or few hatchery fish	Accurate abundance estimates	Long time series (at least 20 years)	Similar freshwater habitat impairments	Similar out-of-basin effects	Comments
Deschutes River	Yes	Yes	Yes	Yes	No	No	
John Day mainstem	Yes	Yes	Yes	Yes	No	No	
Middle Fk John Day	Yes	Yes	Yes	Yes	No	No	
North Fk John Day	Yes	Yes	Yes	Yes	No	No	
Granite Creek	Yes	Yes	Yes	Yes	No	No	
Wenaha River	Yes	No	Yes	Yes	Yes	No	Hatchery strays (>10%)
Minam River	Yes	No	Yes	Yes	Yes	No	Hatchery strays (>10%)
Slate Creek	Yes	Yes	Yes	No	No	No	
Secesh River	Yes	Yes	Yes	Yes	Yes	No	
Middle Fk Salmon River	Yes	Yes	Yes	No	No	No	Fair productivity est.
Big Creek	Yes	Yes	Yes	Yes	No	No	
Camas Creek	Yes	Yes	Yes	Yes	No	No	Fair productivity est.
Loon Creek	Yes	Yes	Yes	Yes	No	No	Fair productivity est.
Sulphur Creek	Yes	Yes	Yes	Yes	No	No	
Bear Valley Creek	Yes	Yes	Yes	Yes	No	No	
Marsh Creek	Yes	Yes	Yes	Yes	Yes	No	
North Fk Salmon River	Yes	Yes	No	No	Yes	No	
Lemhi River	Yes	Yes	Yes	Yes	No	No	
East Fk Salmon River	Yes	No	Yes	Yes	No	No	Hatchery strays (>10%)
Valley Creek	Yes	No	Yes	Yes	No	No	Hatchery strays (>10%)
Chamberlain Creek	Yes	Yes	Yes	No	Yes	No	
Naches River	Yes	Yes	Yes	Yes	Yes	No	
Little Wenatchee River	Yes	No	Yes	Yes	Yes	Yes	Hatchery strays (>10%)
Entiat River	Yes	No	Yes	Yes	No	No	Hatchery release ending

We then assessed the accuracy and length of the series of abundance estimates. We assumed that abundance estimates generated from expanded redd counts or adjusted weir counts would compare well with estimates in the Chiwawa Basin, which were based on expanded redd counts. In addition, we looked for populations that had an abundance data series that extended from at least 1981 to present. Based on this analysis, we identified 18 populations with abundance estimates that could be compared to those from the Chiwawa Basin (Table 1).

Next, we determined if the potential reference populations came from watersheds with habitat conditions similar to those in the Chiwawa Basin. For this exercise, we searched recovery plans and draft recovery plans to identify tributary factors that limit Chinook abundance, productivity, and survival within the reference populations. We compared these factors with those limiting

Chinook salmon in the Chiwawa Basin. Based on this analysis, we identified eight populations with habitat impairments similar to those in the Chiwawa Basin (Table 1).

Finally, we examined the potential reference populations to see if they experienced out-of-basin effects similar to spring Chinook from the Chiwawa Basin. In this case, we compared the number of mainstem dams that each potential reference population passes during migration. Six of the potential reference populations pass less than six mainstem dams; the other populations pass eight mainstem dams (Table 1). Only the Little Wenatchee population passes seven dams, similar to the Chiwawa population.

In sum, there were no reference populations that matched the Chiwawa spring Chinook population on all the criteria identified above. Differential out-of-basin effects and freshwater habitat conditions prevented most reference populations from matching with Chiwawa spring Chinook. However, some of the potential reference populations were similar to the Chiwawa population on several criteria and warranted further investigation. We selected the following populations for further investigation: Sesech River, Marsh Creek, Naches River, Little Wenatchee, and Entiat River.

We included the Little Wenatchee because it is within the Wenatchee River basin and experiences similar out-of-basin effects and has the same climatic and environmental conditions as the Chiwawa. A confounding effect with the Little Wenatchee is that Chiwawa hatchery fish have strayed into the Little Wenatchee. However, straying of Chiwawa hatchery fish should decrease with the change in source water to the Chiwawa acclimation ponds in 2006. We also included the Entiat River because it is an adjacent basin to the Chiwawa and experiences similar climatic and environmental conditions. The spring Chinook hatchery program that has operated in the Entiat since 1975 has been discontinued. Therefore, this population offers a unique opportunity to compare the Chiwawa population to a population in which the hatchery program has been discontinued.

Step 2: Graphic and Statistical Analysis

Graphic Analysis

Although we were unable to find potential reference populations that matched with the Chiwawa population on all criteria considered under Step 1, spawner abundance, natural-origin recruits (NORs), and productivity of some of the potential reference populations may nevertheless track closely with the Chiwawa population. If the time series of abundance, NORs, and productivity of a potential reference population tracks closely with the abundance, NORs, and productivity of the Chiwawa population, the reference population may provide a reasonable reference condition for testing the effects of supplementation on the Chiwawa population.

Under Step 2, we used graphing techniques to examine the relationship of abundance, NORs, and productivity between the Chiwawa population and the five reference populations (Sesech River, Marsh Creek, Naches River, Little Wenatchee, and Entiat River). We compiled spawner abundance, NORs, and productivity data from local biologists and the NOAA Fisheries Salmon Population Summary Database. We then compared time series plots of spawner abundance, NORs, and productivity data of potential reference populations with the Chiwawa population (Figures 2, 3, and 4; plots on the left side of figures). The time series only included the period 1981 to 1992, which represented the period before supplementation of the Chiwawa population (pre-treatment period). We also plotted the relationship between the abundance, NORs, and productivity of each

potential reference population to the Chiwawa population (Figures 2, 3, and 4; plots on right side of figures). These plots show whether the reference populations closely tracked the Chiwawa population. As a point of reference, data points that fall along the dashed line would represent a perfect relationship between the two populations (i.e., both populations have identical abundance, NORs, and productivity estimates). While a perfect relationship between two independent populations is unrealistic, a strong linear relationship between the two populations indicates populations with similar trends.

Based on analysis of spawner abundance, the Naches River time series tracked more closely with the abundance of Chiwawa spring Chinook than did the other potential reference populations. The poor relationship with the other potential reference streams was largely because of the relatively high abundance of Chiwawa spring Chinook during the mid-1980s. As with spawner abundance, analyses of NORs indicated a close relationship between the Naches and Chiwawa populations. The other potential reference populations tracked poorly with the Chiwawa. The analyses of productivity indicated close relationships between potential reference populations and the Chiwawa population. The Naches, Sesech, and Little Wenatchee populations tracked the closest with the Chiwawa population.

When analyzing the potential effects of a supplementation program on fish performance, it is common to transform the data to meet various assumptions of statistical analysis. The most common transformation used to adjust abundance, NORs, and productivity data is the natural logarithm (LN or $\log_e$). We therefore transformed the spawner abundance, NORs, and productivity data using LN and re-plotted the relationships between the potential reference populations and the Chiwawa population (Figures 5, 6, and 7). We added 1 to each observation before taking its logarithm to avoid taking the logarithm of 0, which is undefined (note that the LN of 1 is 0).

By transforming spawner abundance, NORs, and productivity data, most of the potential reference populations tracked more closely with the Chiwawa population. The Naches, Entiat, and Little Wenatchee abundance data tracked the closest with the Chiwawa abundance data (Figure 5). For NORs, Marsh Creek and the Little Wenatchee populations tracked the closest with the Chiwawa (Figure 6). For productivity, the Naches, Sesech, and Little Wenatchee tracked the closest with the Chiwawa (Figure 7).

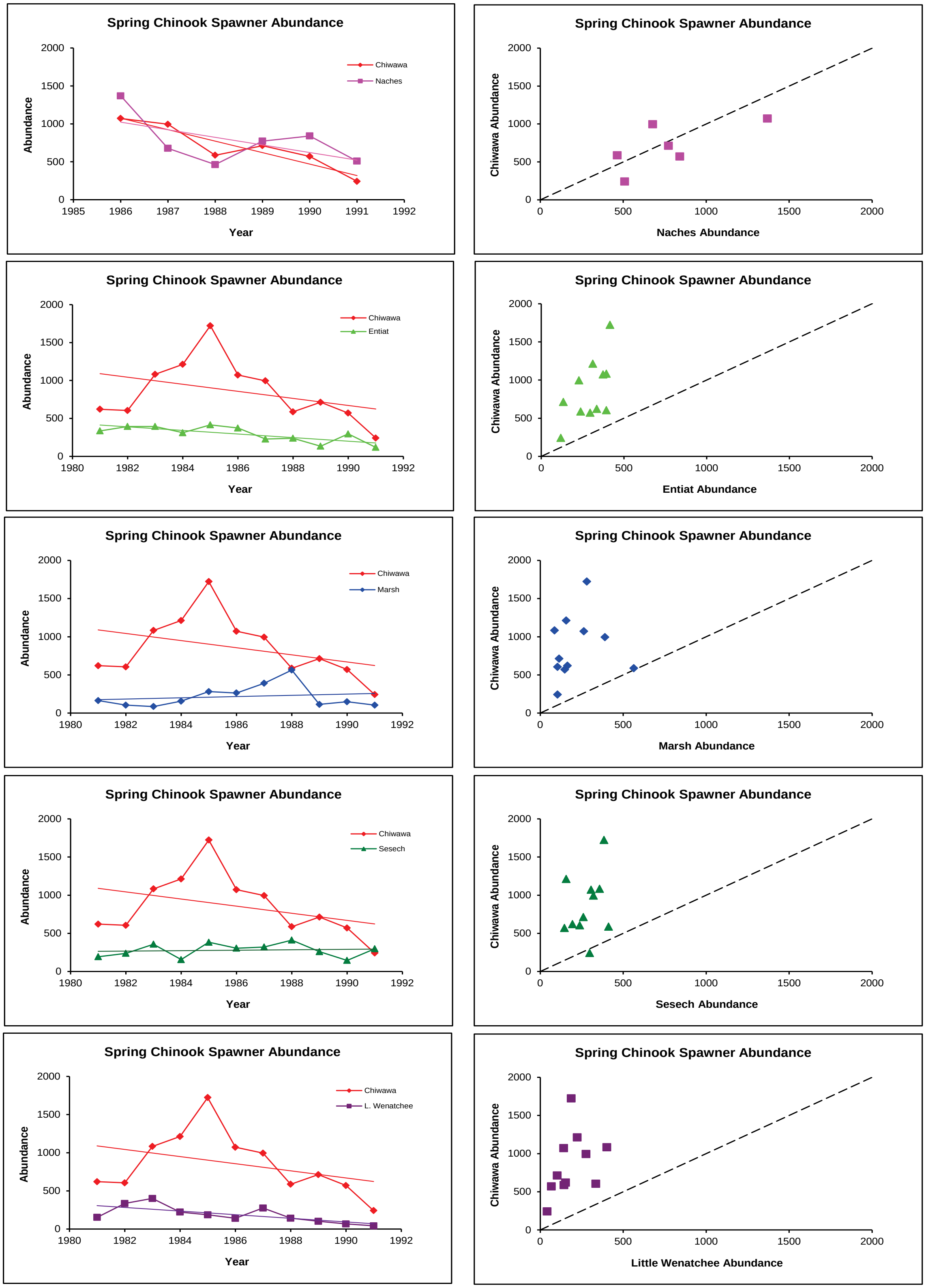

Figure 2. Time series of spawner abundance of potential reference populations and the Chiwawa spring Chinook population before the Chiwawa population was supplemented with hatchery fish.

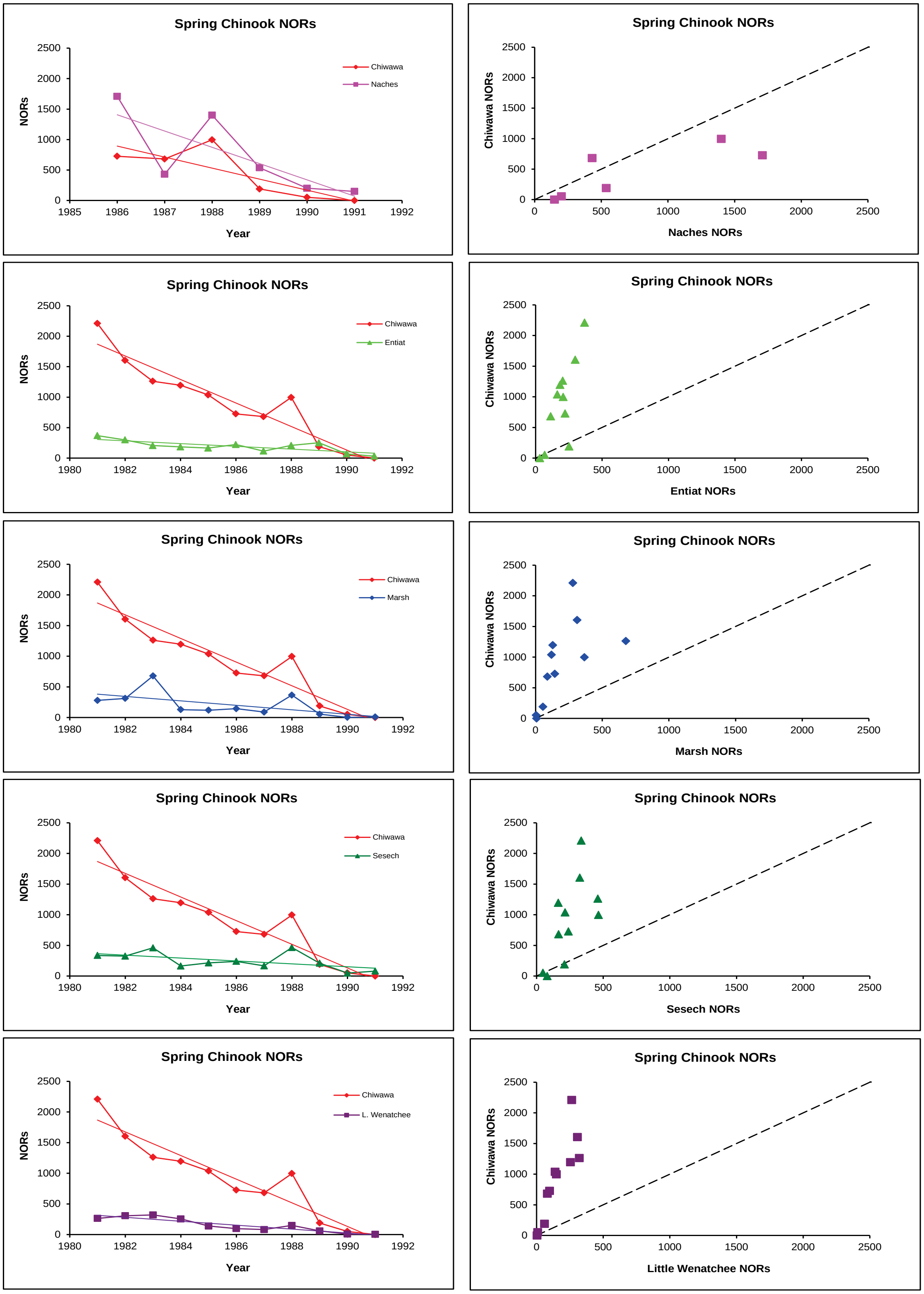

Figure 3. Time series of natural-origin recruits (NORs) of potential reference populations and the Chiwawa spring Chinook population before the Chiwawa population was supplemented with hatchery fish.

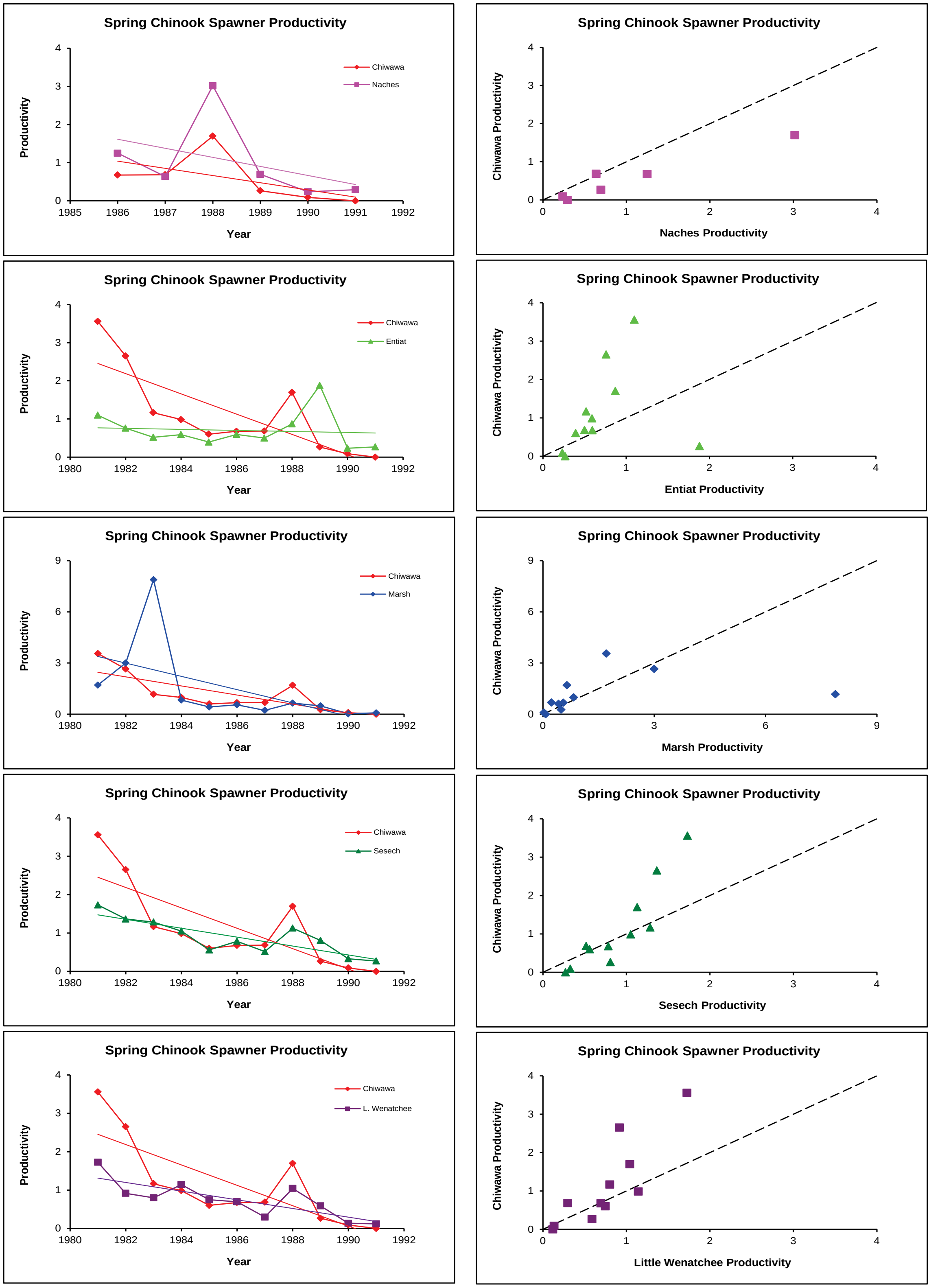

Figure 4. Time series of adult productivity of potential reference populations and the Chiwawa spring Chinook population before the Chiwawa population was supplemented with hatchery fish.

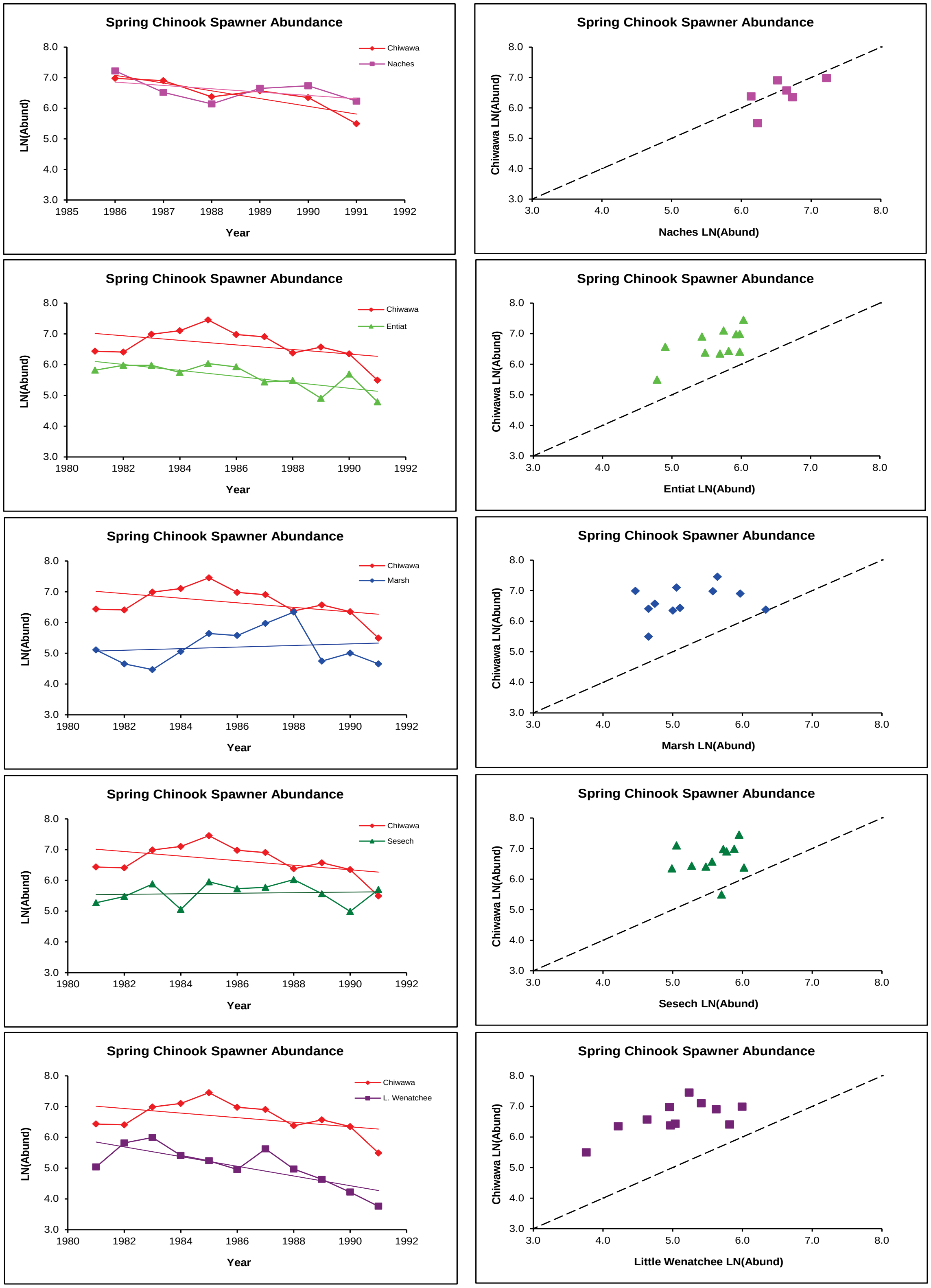

Figure 5. Time series of natural log spawner abundance of potential reference populations and the Chiwawa spring Chinook population before the Chiwawa population was supplemented with hatchery fish.

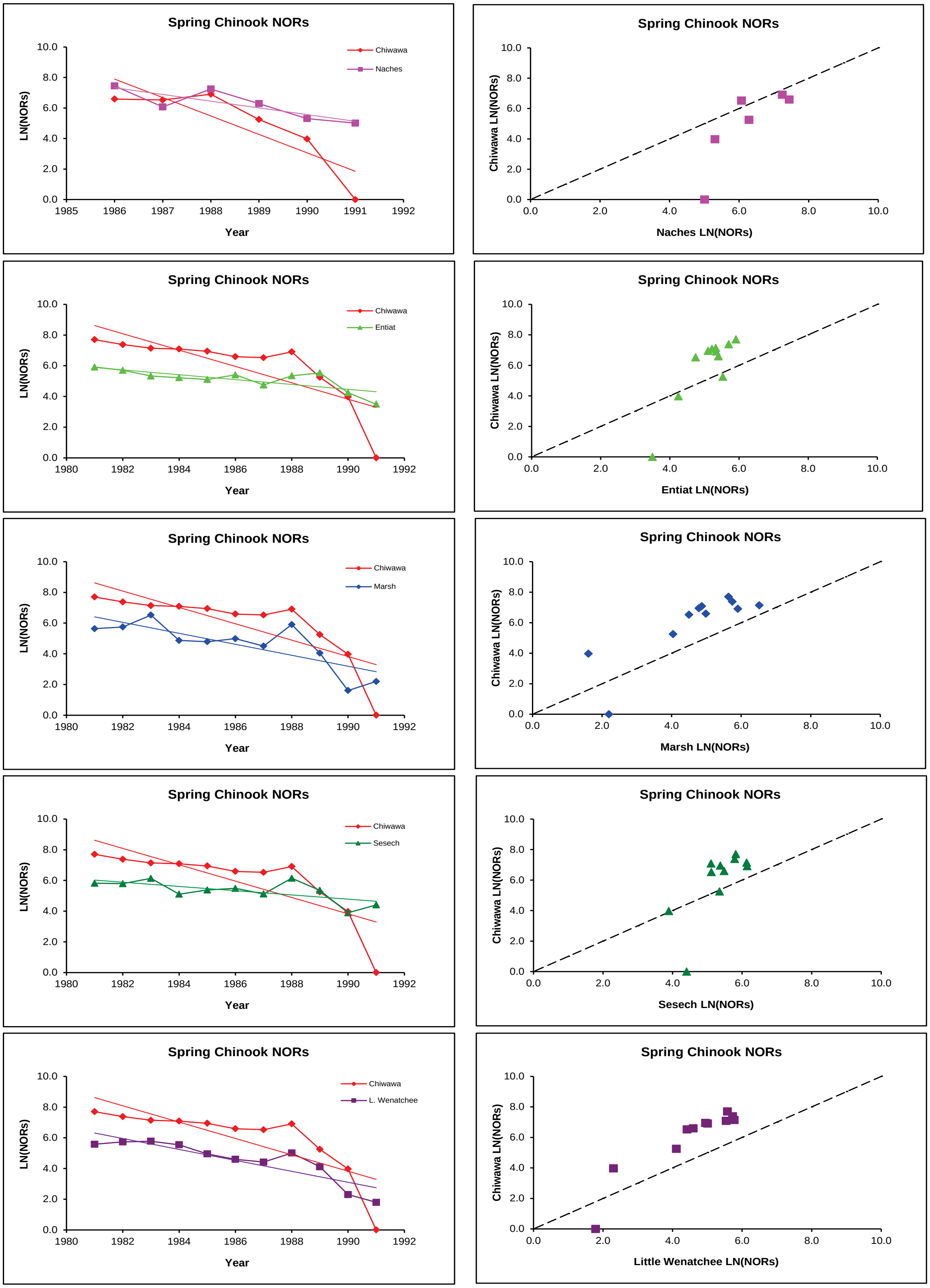

Figure 6. Time series of natural log natural-origin recruits (NORs) of potential reference populations and the Chiwawa spring Chinook population before the Chiwawa population was supplemented with hatchery fish.

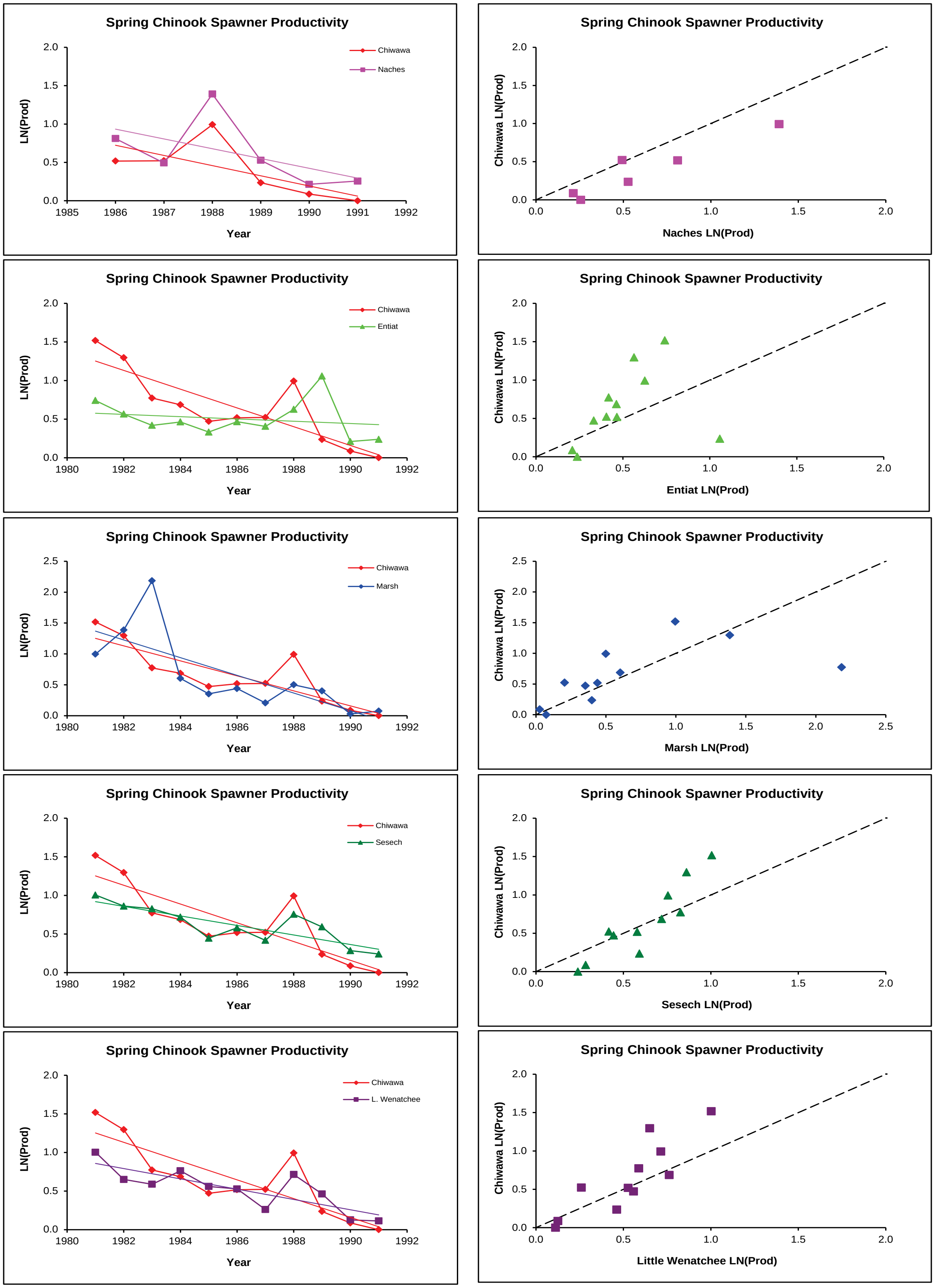

Figure 7. Time series of natural log adult productivity of potential reference populations and the Chiwawa spring Chinook population before the Chiwawa population was supplemented with hatchery fish.

Correlations and Trends

Other methods for evaluating the suitability of potential reference populations under Step 2 include correlation and trend analyses. For correlation analysis, we simply calculated the Pearson correlation coefficient, which is an index of the strength of the association between the potential reference populations and the Chiwawa population. The coefficient ranges from -1 to 1, where a value near 1 or -1 represents that strongest association between the populations. A value of 0 means no association. We used only spawner abundance, NORs, and productivity data during the pre-treatment period (1981-1992). We assumed that populations with coefficients greater than 0.6 represented reasonable reference conditions.

For trend analyses, we used least squares techniques to compute a straight-line trend through the spawner abundance and productivity data for the potential reference populations and the Chiwawa population. Trends were fit to the pre-treatment time series data (1981-1992). We then used t-tests to determine if the slopes of the trends between potential reference populations and the Chiwawa population differed significantly.

It is important to note that time-series trend analyses are susceptible to temporal correlations in the data. Autoregressive integrated moving average (ARIMA) models can be used to describe the correlation structure in temporal data (Gotelli and Ellison 2004). However, these models require a long time series (N > 40) and therefore we could not use them to model the spring Chinook data. As such, we were unable to correct for any temporal correlation that may exist within the time series.

Tests of correlation with spawner abundance data indicated that the Naches River closely correlated with the Chiwawa population (Table 2). There was no difference in abundance trends between the potential reference populations and the Chiwawa population (Table 2; Figure 2). For NORs, all potential reference populations correlated with the Chiwawa population (Table 2). However, trends in NORs of all reference populations, except Naches, differed significantly from the Chiwawa population (Table 2; Figure 3). For productivity, the Naches, Sesech, and Little Wenatchee correlated with the Chiwawa population (Table 2). Only the Entiat productivity trend differed significantly from the Chiwawa population trend (Table 2; Figure 4).

Table 2. Pearson correlation coefficients and t-test results comparing slopes of trends between potential reference populations and the Chiwawa spring Chinook population; d.f. = degrees of freedom and for correlation coefficients, an asterisk (*) indicates significance at $P < 0.05$.

Reference populations	Pearson correlation coefficient	t-test on slopes		
		t-value	d.f.	P-value
Spawner Abundance Data				
Naches	0.684*	-0.659	8	0.528
Entiat	0.598*	-0.596	18	0.559
Marsh	0.147	-1.341	18	0.197
Sesech	0.274	-1.265	18	0.222
Little Wenatchee	0.399	-0.591	18	0.562
Natural-Origin Recruits				
Naches	0.803*	0.666	8	0.524
Entiat	0.795*	-7.495	18	0.000

Reference populations	Pearson correlation coefficient	t-test on slopes		
		t-value	d.f.	P-value
Marsh	0.605*	-5.786	18	0.000
Sesech	0.648*	-6.874	18	0.000
Little Wenatchee	0.880*	-7.206	18	0.000
Productivity Data				
Naches	0.960*	0.169	8	0.870
Entiat	0.272	-3.057	18	0.007
Marsh	0.320	0.605	18	0.553
Sesech	0.903*	-2.059	18	0.054
Little Wenatchee	0.848*	-2.065	18	0.054

We also ran correlation and trend analyses on natural-log transformed spawner abundance, NORs, and productivity data. These analyses indicated that the Naches, Entiat, and Little Wenatchee abundance data correlated with the Chiwawa population data (Table 3). None of the abundance trends of the potential reference populations differed significantly from the Chiwawa population trend (Table 3; Figure 5). For NORs, all potential reference populations correlated with the Chiwawa population (Table 3). Only trends in NORs of the Entiat and Sesech differed significantly from the Chiwawa population (Table 2; Figure 6). For productivity, the Naches, Marsh, Sesech, and Little Wenatchee correlated with the Chiwawa population data (Table 3). Only the Entiat productivity trend differed significantly from the Chiwawa population trend (Table 3; Figure 7).

Table 3. Pearson correlation coefficients and t-test results comparing slopes of trends between potential reference populations and the Chiwawa spring Chinook population; d.f. = degrees of freedom and for correlation coefficients, an asterisk (*) indicates significance at $P < 0.05$. Analyses were conducted on natural-log transformed abundance and productivity data.

Reference populations	Pearson correlation coefficient	t-test on slopes		
		t-value	d.f.	P-value
LN Spawner Abundance Data				
Naches	0.642*	-1.323	8	0.222
Entiat	0.652*	0.412	18	0.685
Marsh	0.294	-1.324	18	0.202
Sesech	0.149	-1.431	18	0.170
Little Wenatchee	0.670*	1.325	18	0.202
LN Natural-Origin Recruits				
Naches	0.824*	-1.985	8	0.082
Entiat	0.886*	-2.563	18	0.019
Marsh	0.830*	-1.038	18	0.313
Sesech	0.730*	-2.664	18	0.016
Little Wenatchee	0.927*	-1.150	18	0.265
LN Productivity Data				

Reference populations	Pearson correlation coefficient	t-test on slopes		
		t-value	d.f.	P-value
Naches	0.944*	-0.042	8	0.968
Entiat	0.373	-3.043	18	0.007
Marsh	0.610*	0.428	18	0.674
Sesech	0.913*	-2.050	18	0.055
Little Wenatchee	0.862*	-1.811	18	0.087

In summary, based on correlation, trend, and graphic analyses, the Naches, Entiat, and Little Wenatchee populations appear to be reasonable reference populations for comparing spawner abundance data with Chiwawa data. For NORs, the Naches, Marsh, and Little Wenatchee appear to be reasonable reference populations. For productivity, the Naches, Marsh, Sesech, and Little Wenatchee populations appear to be reasonable reference populations for the Chiwawa population.

Minimal Detectable Differences (MDD)

Given a suite of potential reference populations, it is important to conduct power analyses to determine the minimum differences that can be detected when comparing the reference populations to the supplemented population. As a final exercise under Step 2, we examined potential reference populations for the smallest minimal detectable differences. Before conducting power analyses, several decisions needed to be made, including what statistical procedures will be used to analyze the data, the desired level of statistical power (probability of rejecting a false null hypothesis), the size of the type-I error (the probability of rejecting a true null hypothesis of no difference), and the number of samples (i.e., years) included in the analysis. In this case, the number of samples represents the number of treatment (supplementation) years. The number of pre-treatment years (1981-1992) was based on the number of years of quality data available for Chiwawa spring Chinook and potential reference populations.

We designed the study as a modified BACI (Before-After, Control-Impact) design, which includes replication before and after supplementation in both the treated (T) population and the reference (R) populations. A common approach used to analyze data from BACI designs includes analysis of difference scores (Stewart-Oaten et al. 1992; Smith et al. 1993). Differences are calculated between paired treatment and reference population scores (i.e., T-R). Another approach is to calculate ratios (treatment/reference; T/R) for paired treatment and reference population scores (Skalski and Robson 1992). Finally, differences in annual changes in paired treatment and reference population scores can be calculated (i.e., ΔT-ΔR) (Murdoch and Peven 2005; Hays et al. 2006).[17] These derived difference and ratio scores are then analyzed for a before-after treatment effect with a two-sample t-test, Aspin-Welch modification of the t-test, or a randomization test. For power analyses, we calculated minimal detectable differences assuming the use of an independent two-sample t-test with a type-I error rate of 0.05, power of 0.80 (beta or type-II error rate of 0.20), and sample sizes (treatment years) of 5, 10, 15, 20, 25, and 50 years.

[17] The difference of annual difference scores was estimated by first subtracting the population parameter (e.g., spawner abundance) in year 2 from year 1. This continues for all years in the data series for both treatment ($T_{t+1} - T_t$) and reference populations ($R_{t+1} - R_t$). We then calculated differences between paired treatment and reference annual difference scores [$(T_{t+1} - T_t) - (R_{t+1} - R_t) = \Delta T - \Delta R$].

The power analysis calculated the minimal detectable difference between mean difference or ratio scores before and during supplementation. We used existing data to calculate variances for the pre-supplementation and supplementation periods. Thus, variances were known and unequal. For both spawner abundance and NORs, the null hypothesis tested was that the mean difference or ratio before supplementation equaled the mean difference or ratio during supplementation. The alternative hypothesis was that the mean difference or ratio before supplementation was less than the mean difference during supplementation (one-tail test; Difference < 0). For productivity, the null hypothesis tested was that the mean difference or ratio before supplementation equaled the mean difference or ratio during supplementation. The alternative hypothesis was that the mean difference or ratio before supplementation was greater than the mean difference during supplementation (one-tail test; Difference > 0).

Based on spawner abundance data, power analysis indicated that the Sesech-Chiwawa pairing consistently produced the smallest detectable differences (Table 4). However, when the abundance data were transformed using natural logs, the Entiat-Chiwawa pairing produced the smallest detectable difference (Table 5). Minimal detectable differences, based on mean difference scores on untransformed data and a treatment period of 20 years, ranged from 334 to 394 adult spawners; transformed data ranged from 0.479 to 1.010. These analyses indicate that the Naches, Entiat, Sesech, and Little Wenatchee populations appear to be reasonable reference populations for comparing spawner abundance data with Chiwawa data. The Marsh Creek population produced some of the largest detectable differences and based on these analyses may not be a reasonable reference population.

Table 4. Minimal detectable differences between mean difference and ratio scores before and during supplementation. Analyses were conducted on spawner abundance data.

Response variable	Treatment years	Minimal detectable differences by reference population				
		Naches	Entiat	Marsh	Sesech	Little Wenatchee
T-R	5	638	604	560	396	652
	10	464	448	444	354	481
	15	405	395	406	341	424
	20	376	368	387	334	394
	25	358	352	376	331	376
	50	322	319	354	323	340
T/R	5	0.600	2.084	39.251	1.569	5.498
	10	0.506	1.548	24.729	1.508	3.828
	15	0.478	1.367	19.646	1.490	3.256
	20	0.465	1.275	16.828	1.481	2.954
	25	0.458	1.219	14.974	1.475	2.765
	50	0.447	1.105	10.573	1.465	2.366
ΔT-ΔR	5	1,049	761	717	518	766
	10	750	542	539	411	547
	15	650	467	480	376	473
	20	598	429	450	359	434

Response variable	Treatment years	Minimal detectable differences by reference population				
		Naches	Entiat	Marsh	Sesech	Little Wenatchee
	25	567	405	431	348	410
	50	506	355	395	329	361

Table 5. Minimal detectable differences between mean difference and ratio scores before and during supplementation. Analyses were conducted on natural-log transformed spawner abundance data.

Response variable	Treatment years	Minimal detectable differences by reference population				
		Naches	Entiat	Marsh	Sesech	Little Wenatchee
T-R	5	0.975	0.871	2.061	0.828	1.013
	10	0.721	0.613	1.375	0.648	0.722
	15	0.637	0.525	1.138	0.588	0.623
	20	0.595	0.479	1.010	0.559	0.571
	25	0.569	0.450	0.928	0.541	0.539
	50	0.521	0.390	0.749	0.505	0.473
T/R	5	0.157	0.162	2.343	0.160	0.368
	10	0.116	0.115	1.474	0.125	0.247
	15	0.102	0.099	1.170	0.114	0.206
	20	0.095	0.090	1.001	0.108	0.183
	25	0.091	0.085	0.890	0.104	0.169
	50	0.082	0.075	0.625	0.098	0.138
ΔT-ΔR	5	1.261	1.288	3.076	1.160	1.467
	10	0.898	0.900	2.020	0.887	1.001
	15	0.776	0.768	1.653	0.797	0.840
	20	0.713	0.698	1.463	0.751	0.755
	25	0.675	0.655	1.325	0.724	0.701
	50	0.600	0.564	1.038	0.670	0.585

Based on NORs, power analysis indicated that the Entiat-Chiwawa, Marsh-Chiwawa, and Little Wenatchee-Chiwawa pairings produced the smallest detectable differences (Table 6). When NORs were transformed using natural logs, the Little Wenatchee-Chiwawa pairing produced the smallest detectable difference (Table 7). Minimal detectable differences, based on mean difference scores on untransformed data and a treatment period of 20 years, ranged from 483 to 640 NORs; transformed data ranged from 0.958 to 2.262. These analyses indicate that the Entiat, Marsh, and Little Wenatchee populations appear to be reasonable reference populations for comparing NORs with Chiwawa data.

Table 6. Minimal detectable differences between mean difference and ratio scores before and during supplementation. Analyses were conducted on natural-origin recruits.

Response variable	Treatment years	Minimal detectable differences by reference population				
		Naches	Entiat	Marsh	Sesech	Little Wenatchee
T-R	5	1,139	541	573	630	546
	10	809	511	515	550	503
	15	698	502	498	526	489
	20	640	497	489	514	483
	25	604	494	484	507	479
	50	534	489	474	493	472
T/R	5	0.469	2.538	5.196	1.976	6.973
	10	0.451	2.183	4.183	1.894	5.118
	15	0.446	2.072	3.854	1.869	4.492
	20	0.445	2.017	3.691	1.857	4.170
	25	0.444	1.986	3.594	1.850	3.973
	50	0.443	1.924	3.405	1.836	3.572
ΔT-ΔR	5	1,639	500	519	609	531
	10	1,239	386	409	433	396
	15	1,109	348	374	372	351
	20	1,046	329	356	341	328
	25	1,009	318	346	321	314
	50	943	295	325	281	285

Table 7. Minimal detectable differences between mean difference and ratio scores before and during supplementation. Analyses were conducted on natural-log transformed natural-origin recruits.

Response variable	Treatment years	Minimal detectable differences by reference population				
		Naches	Entiat	Marsh	Sesech	Little Wenatchee
T-R	5	2.380	1.646	1.967	2.247	1.174
	10	2.291	1.479	1.505	1.835	1.026
	15	2.270	1.428	1.351	1.702	0.980
	20	2.262	1.403	1.273	1.636	0.958
	25	2.258	1.389	1.227	1.597	0.945
	50	2.253	1.361	1.133	1.522	0.920
T/R	5	0.322	0.332	0.739	0.398	0.356
	10	0.301	0.289	0.581	0.334	0.322
	15	0.296	0.275	0.530	0.314	0.312
	20	0.294	0.269	0.504	0.305	0.307
	25	0.293	0.265	0.488	0.299	0.304

Response variable	Treatment years	Minimal detectable differences by reference population				
		Naches	Entiat	Marsh	Sesech	Little Wenatchee
	50	0.291	0.258	0.458	0.288	0.298
ΔT-ΔR	5	2.858	2.400	2.355	3.283	2.109
	10	2.560	1.714	1.881	2.311	1.552
	15	2.485	1.481	1.728	1.979	1.365
	20	2.456	1.360	1.652	1.805	1.269
	25	2.443	1.285	1.607	1.697	1.210
	50	2.430	1.130	1.519	1.471	1.092

Using untransformed productivity data, power analysis indicated that the Little Wenatchee-Chiwawa pairing consistently produced the smallest detectable differences (Table 8). The Marsh-Chiwawa pairings produced the largest detectable differences. When we analyzed natural-log transformed productivity data, the Naches-Chiwawa and Little Wenatchee-Chiwawa pairings produced the smallest detectable differences (Table 9). Minimal detectable differences, based on mean difference scores on untransformed data and a treatment period of 20 years, ranged from 0.754 to 1.839; transformed data ranged from 0.277 to 0.477. These analyses indicate that the Naches, Entiat, Sesech, and Little Wenatchee populations appear to be reasonable reference populations for comparing productivity data with Chiwawa data. The Marsh Creek population produced some of the largest detectable differences and based on these analyses may not be a reasonable reference population.

Table 8. Minimal detectable differences between mean difference and ratio scores before and during supplementation. Analyses were conducted on productivity data.

Response variable	Treatment years	Minimal detectable differences by reference population				
		Naches	Entiat	Marsh	Sesech	Little Wenatchee
T-R	5	2.181	1.382	2.033	3.517	1.192
	10	1.442	1.119	1.900	2.265	0.901
	15	1.186	1.033	1.859	1.828	0.804
	20	1.047	0.991	1.839	1.588	0.754
	25	0.959	0.966	1.828	1.432	0.724
	50	0.764	0.917	1.806	1.074	0.664
T/R	5	1.364	1.773	0.863	0.876	2.167
	10	1.095	1.359	0.831	0.687	1.587
	15	1.011	1.221	0.822	0.625	1.391
	20	0.971	1.152	0.817	0.594	1.290
	25	0.949	1.110	0.814	0.575	1.228
	50	0.910	1.027	0.908	0.538	1.102
ΔT-ΔR	5	3.298	1.864	3.211	4.420	1.942
	10	2.263	1.382	2.968	2.811	1.291

Response variable	Treatment years	Minimal detectable differences by reference population				
		Naches	Entiat	Marsh	Sesech	Little Wenatchee
	15	1.909	1.220	2.894	2.248	1.066
	20	1.723	1.137	2.859	1.938	0.944
	25	1.606	1.087	2.839	1.735	0.866
	50	1.365	0.986	2.800	1.259	0.695

Table 9. Minimal detectable differences between mean difference and ratio scores before and during supplementation. Analyses were conducted on natural-log transformed productivity data.

Response variable	Treatment years	Minimal detectable differences by reference population				
		Naches	Entiat	Marsh	Sesech	Little Wenatchee
T-R	5	0.540	0.551	0.674	0.890	0.585
	10	0.367	0.452	0.542	0.590	0.413
	15	0.308	0.421	0.499	0.486	0.355
	20	0.277	0.405	0.477	0.430	0.324
	25	0.257	0.396	0.465	0.393	0.305
	50	0.215	0.378	0.440	0.314	0.265
T/R	5	0.915	1.286	0.743	0.697	1.685
	10	0.744	0.973	0.704	0.541	1.227
	15	0.691	0.868	0.692	0.489	1.072
	20	0.666	0.815	0.687	0.463	0.993
	25	0.652	0.783	0.683	0.447	0.943
	50	0.628	0.719	0.677	0.416	0.843
ΔT-ΔR	5	0.885	0.810	1.028	1.252	0.971
	10	0.631	0.609	0.822	0.809	0.640
	15	0.546	0.542	0.755	0.655	0.525
	20	0.502	0.508	0.722	0.570	0.463
	25	0.475	0.487	0.702	0.516	0.423
	50	0.423	0.446	0.664	0.391	0.333

Step 3: Quantitative Method for Ranking Selection Criteria

Not surprisingly, different selection criteria produced different results (Table 10). Determining whether a given population is or is not a suitable reference population based on selection criteria such as graphic analysis can be subjective. In addition, treating each selection criterion as equally important may not be appropriate. For example, using the information in Table 10, is it appropriate to select a reference population that has two or three “Yes” entries, or should only populations with four “Yes” entries be selected as suitable reference populations? This approach does not allow certain selection criteria to carry more weight in the overall selection process. That is, correlation may be more important than graphic analysis in the overall selection process. In order to reduce

subjectivity, we developed a method of scoring and weighting each selection criterion. This method allows a more quantitative process for selecting suitable reference populations.

Table 10. Summary of results from graphic analysis, correlations, trend analysis, and power analysis (minimal detectable differences). "Yes" indicates that the population is a suitable reference population for the Chiwawa population; "No" indicates that it may not be a suitable reference population.

Potential reference populations	Graphic analysis	Correlation	Trends	Minimal detectable differences
Spawner Abundance				
Naches	Yes	Yes	Yes	Yes
Entiat	Yes	Yes	Yes	Yes
Marsh	No	No	Yes	No
Sesech	No	No	Yes	Yes
Little Wenatchee	Yes	Yes	Yes	Yes
Natural-Origin Recruits				
Naches	Yes	Yes	Yes	No
Entiat	No	Yes	No	Yes
Marsh	Yes	Yes	Yes	Yes
Sesech	No	Yes	No	No
Little Wenatchee	Yes	Yes	Yes	Yes
Productivity				
Naches	Yes	Yes	Yes	Yes
Entiat	No	No	No	Yes
Marsh	No	Yes	Yes	No
Sesech	Yes	Yes	Yes	Yes
Little Wenatchee	Yes	Yes	Yes	Yes

We developed scoring methods for each of the following five selection criteria:

(1) The proportion of natural-origin spawners (pNOS) in the reference population for the period before supplementation (pre-pNOS);

(2) pNOS in the reference population for the period following supplementation (post-pNOS);

(3) The correlation between the reference and supplemented populations before supplementation;

(4) The relative difference in slopes between the reference and supplemented populations before supplementation; and

(5) The coefficient of variation (CV) of the ratio of supplemented to reference populations before the period of supplementation.

Each selection criteria was scored from 0 to 1, with 0 being the worst possible score and 1 being the best.

The pre- and post-pNOS values were calculated as the average pNOS values before and after supplementation, respectively. Because pNOS values range from 0-1, we did not need to rescale

these values. When using reference populations to evaluate the effects of supplementation programs, it is important that the reference populations maintain high values of pNOS throughout the life of the monitoring program. Therefore, we heavily weighted the mean pNOS scores. We assigned weights of 30 and 40 to the mean pre- and post-pNOS scores, respectively. The relatively larger weight for the post-supplementation period is to reduce the likelihood of retaining a reference population that becomes influenced by hatchery fish during the supplementation period.

We assessed the association between the reference and supplemented populations during the pre-supplementation period by calculating the Pearson correlation coefficient, which ranges from -1 to 1. To scale the coefficient between 0 and 1, we took the absolute value of the coefficient. Thus, a coefficient of -0.92 would be reported as 0.92. For our analyses, we were not concerned with the direction of the relationship, only the strength of the relationship. The correlation coefficient was given a weight of 12.5.

As noted earlier, we used least squares to fit a linear trend to each of the reference populations and the supplemented population during the pre-supplementation period. Using the slope estimates for each trend line, we calculated the relative difference in slopes as the slope of the supplemented population minus the slope of the reference population, divided by the slope of the reference population. To scale this value between 0 and 1, we used absolute values, and depending on the direction of the slopes, we subtracted the relative difference from 1. The latter was needed to make sure a larger relative difference value indicated a small difference in slopes between the supplemented and reference populations. The relative difference score was given a weight of 7.5.

Finally, as a means to score effect size, we calculated the CV of the ratio of supplemented to reference population parameters (i.e., T/R). The CV was calculated as the standard deviation of the ratios divided by the absolute value of the mean ratios. The CV was subtracted from 1. This scaled the value from 0 to 1 with larger values representing the best condition. The CV was given a weight of 10, which is greater than the weight for trend, but less than the weight for correlation.

The total score for a reference population was calculated by multiplying the estimated value, which ranged from 0 to 1, by its weight. The sum of the five weighted values provided a total score, which ranged from 0 to 100. Based on several simulations, we set the cut-off score at 81. That is, if the total score for a given reference population equaled or exceeded 81, the population was included as a suitable reference population. If the total score fell below 81, the population was not considered a suitable reference. Based on the distribution of all scores possible, a score of 81 or greater represented only 3% of the total distribution. Thus, a cut-off of 81 is quite conservative.

Under Step 3, we used this method to select the final suite of suitable reference populations. Table 11 shows results from scoring each of the reference populations using the quantitative method. Using the cut-off criterion of 81, only the Naches, Marsh, and Sesech populations would be considered suitable reference populations for the Chiwawa supplementation program. Both the Entiat and Little Wenatchee populations failed to meet the minimum score, largely because of the influence of hatchery fish within those populations (i.e., relatively low pNOS values).

Table 11. Results from scoring potential reference populations using the selection criteria (pNOS, correlation, trend, and effect size). Populations with scores less than 81 were considered unsuitable as reference populations. Populations with scores equal to or greater than 81 were considered suitable references. These results were based on natural-log transformed data.

Potential reference populations	Population metric		
	Abundance	NORs	Productivity
Naches	85	88	91
Entiat	23	21	16
Marsh	79	91	87
Sesech	84	85	88
Little Wenatchee	51	53	49

An important benefit from scoring the different selection criteria is that the total scores can be used to weight the outcome of differing statistical results. For example, analyses may show that when three suitable reference populations are compared to the supplemented population, two of the reference populations may indicate a significant treatment effect, while the third indicates no effect. Under this scenario it is not clear if the supplementation program has or has not affected the abundance or productivity of the supplemented population. If, however, the two reference populations that produced a significant result had higher total scores than the reference population that did not indicate a significant result, one can place more weight on the results from populations with higher total scores.

Conclusions

The purpose of this exercise was to develop a method for selecting suitable reference populations that could be used to assess the effects of supplementation programs on spawner abundance, NORs, and productivity. The selection process included a three-step process (Figure 8). Step 1 identified populations with similar life-history characteristics, few or no hatchery spawners, a long time series of accurate abundance and productivity estimates, and similar freshwater habitat impairments and out-of-basin effects. Populations that met these criteria were then examined for their graphical and statistical relationship with the supplemented population (Step 2). The statistical analysis under Step 2 were converted to a quantitative model (Step 3) that was used to generate a weighted score for pNOS, correlation, trends, and effect sizes for each potential reference population. Reference populations with total scores of 81 or greater were selected as suitable reference populations.

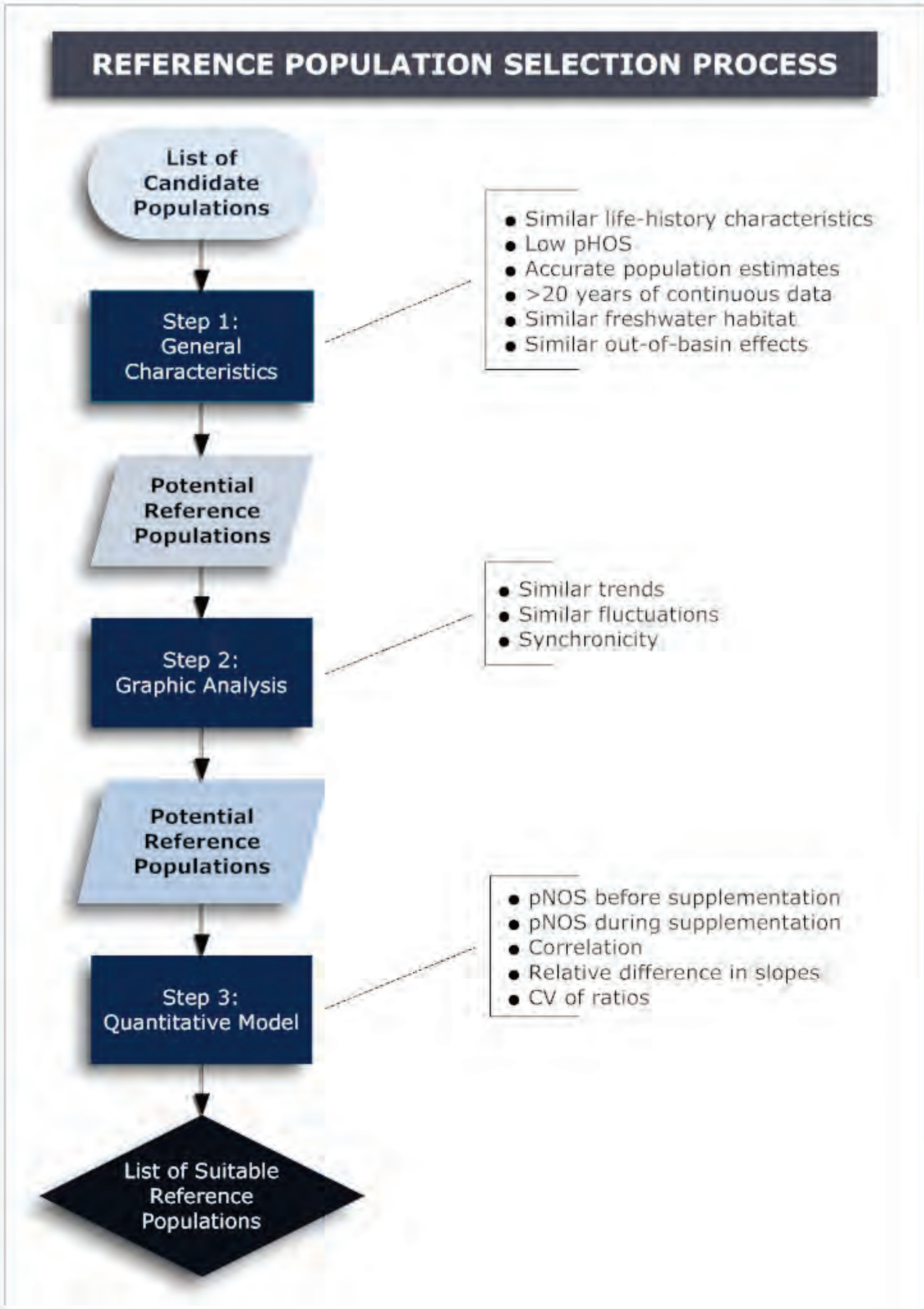

Figure 8. Three-step process for selecting suitable reference populations for supplemented populations.

We used this approach to select suitable reference populations for analyzing the effects of the Chiwawa spring Chinook supplementation program on fish abundance and productivity. The method indicated that the Naches, Marsh, and Sesech populations would serve as suitable reference populations for the Chiwawa spring Chinook supplementation program. Both the Entiat and Little Wenatchee populations failed to meet the minimum score, largely because of the influence of hatchery fish within those populations (i.e., relatively low pNOS values). However, because the presence of hatchery spring Chinook within those populations should decrease, they may serve as unique reference populations in which the comparisons change from all populations receiving

hatchery fish to only the Chiwawa population receiving hatchery fish. Therefore, we will continue to include both the Little Wenatchee and Entiat populations in future analyses.

An important assumption in the use of reference populations is that the supplemented and reference populations that tracked each other before supplementation would continue to track each other in the absence of supplementation. Given that the reference populations did not match the Chiwawa population on all criteria examined (Table 1) and some reference populations tracked the Chiwawa population more poorly than others (Figures 2-7; Tables 2-4), there may be some uncertainty as to whether differences observed between the Chiwawa and reference populations during the supplementation period are associated with the hatchery program, "nuisance" factors[18], or a combination of both. In addition, we have no ability to regulate or control activities in reference areas. Any large-scale change (man-made or natural) in reference areas could affect our ability to assess the effectiveness of the supplementation program.

Because we have no ability to maintain reference areas for long periods of time and may not be able to control all activities even within the supplemented populations, we propose the use of a "causal-comparative" approach to strengthen the certainty of our inferences (Pearsons and Temple 2010). The causal-comparative approach relies on correlative data to try and make a case for causal inference.[19] Correlation is used to rule out alternative hypotheses (note that we make our case as much if not more by disproving plausible alternatives as we do by showing that the data are consistent with a hypothesis). For example, large scale land-use activities or natural events can affect stream flows, fine sediment recruitment, and water temperatures. Changes in these factors can affect the freshwater survival and productivity of fish independently of supplementation programs. If changes in habitat, migratory, and ocean conditions do not affect reference and treatment populations similarly, inferences associated with supplementation programs may be confounded. By measuring and tracking these extraneous factors within reference and treatment areas, we can assess the effects of these state variables on population conditions independent of the supplementation programs. This allows us to more effectively assess the influence of supplementation programs on populations.

To that end, we recommend that the following state variables be measured and tracked within the Chiwawa Basin and each of the reference areas: mean annual precipitation, total and riparian forest cover, road density, impervious surface, and alluvium. These variables can be used to describe differences in water temperatures at different life stages (pre-spawning, egg incubation, and summer rearing) and substrate characteristics, including fine sediments and embeddedness (Jorgensen et al. 2009). They can be used to assess possible changes in spawner abundance, NORs, and productivity that are independent of supplementation.

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[18] A "nuisance" factor is any factor that is outside the control of the experimenter and can affect the response variable (spawner abundance or productivity). In this case, nuisance factors may include differences in freshwater habitat trends and conditions, out-of-basin effects (e.g., migration and ocean survival), and hatchery strays that affect the Chiwawa and reference populations differently.

[19] It is important to point out that correlation does not demonstrate cause-and-effect. It only suggests a relationship between variables. Thus, inferences based on correlation lack the certainty that is associated with a design-based approach.

Analyses with Reference Populations

Once suitable reference populations are selected, methods for analyzing the supplemented and reference populations need to be identified. What follows is a description of different analyses that can be used to assess the effects of supplementation programs on spawner abundance, NORs, and productivity using reference populations. Later in this report we describe methods for assessing supplementation effects when reference populations are not available.

We used some of the reference populations selected for the Chiwawa program to illustrate the different methods for evaluating the effects of the supplementation program on spawner abundance, NORs, and productivity. For abundance, we selected the Naches, Entiat, Little Wenatchee, and Sesech populations as suitable references for the Chiwawa population. For NORs, we selected the Naches, Entiat, Marsh, and Little Wenatchee populations as suitable references. For productivity, we selected the Naches, Sesech, Little Wenatchee, and Marsh Creek as suitable references for the Chiwawa. As noted earlier, we included the Little Wenatchee and Entiat populations, even though they did not meet all the criteria for suitable reference populations.

Analysis of Trends

As a first step, we used trend analyses to assess the effects of the Chiwawa supplementation program on spring Chinook spawner abundance, NORs, and productivity. Here, we compared the slopes of the trends between each treatment/reference pair before and during supplementation using t-tests. If the hatchery program is successfully supplementing the natural spring Chinook population, trends in spawner abundance and NORs should deviate significantly (i.e., the slope of the supplemented population should be greater than the slopes of the reference populations during the supplementation period). For productivity, the slope of the supplemented population, relative to the reference population, should increase or remain the same.

Trend analysis indicated that the relationship of slopes of spawner abundance between the Chiwawa and reference populations did not change significantly after the initiation of supplementation (Figure 9; Table 12). This was true for both transformed and untransformed abundance data. Before supplementation, spawner abundances trended down in both the Chiwawa and reference populations (Figure 9). During the period of supplementation, abundances in both the Chiwawa and reference populations trended upward. Interestingly, in nearly all treatment/reference comparisons, the Pearson correlation coefficient was greater in the supplementation period than in the pre-supplementation period (Table 12). This was most evident in the transformed abundance data (Figure 9).

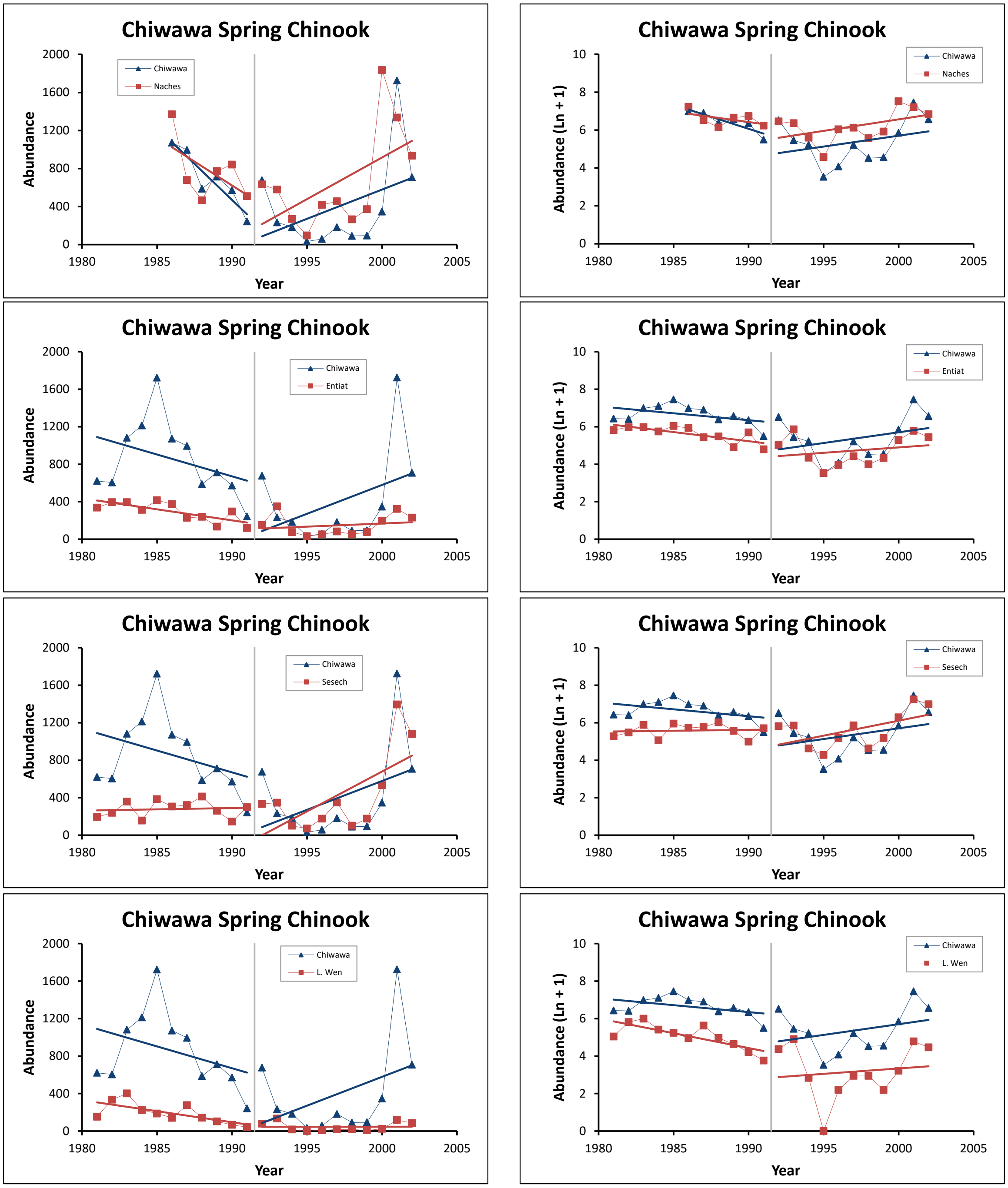

Figure 9. Trends in spring Chinook spawner abundance in the Chiwawa and reference populations. The vertical lines in the figures separate the pre- and post-supplementation periods. Figures on the left include untransformed spawner abundance data; those on the right include natural-log transformed data.

Table 12. Pearson correlation coefficients and t-test results comparing slopes of spawner abundance trends between reference populations and the Chiwawa spring Chinook population before and during the supplementation periods; for correlation coefficients, an asterisk (*) indicates significance at $P < 0.05$. Analyses include both untransformed and natural-log transformed spawner abundance data.

Reference population	Pearson correlation coefficient		Test on slopes			
			t-value		P-value	
	Before	During	Before	During	Before	During
Spawner Abundance						
Naches	0.684*	0.595	-0.659	-0.414	0.528	0.684
Entiat	0.598*	0.672*	-0.596	1.162	0.559	0.260
Sesech	0.274	0.904*	-1.265	-0.418	0.222	0.681
Little Wenatchee	0.399	0.685*	-0.591	1.330	0.562	0.200
LN Spawner Abundance						
Naches	0.642*	0.813*	-1.323	-0.047	0.222	0.963
Entiat	0.652*	0.860*	0.412	0.422	0.685	0.678
Sesech	0.149	0.878*	-1.431	-0.333	0.170	0.743
Little Wenatchee	0.670*	0.861*	1.325	0.316	0.202	0.756

Trend analysis indicated that the relationship of slopes of NORs between the Chiwawa and reference populations did not change significantly after the initiation of supplementation (Figure 10; Table 13). Before supplementation, Chiwawa NORs trended downward more strongly than the reference populations (Figure 10). However, during the supplementation period, both the Chiwawa and reference population NORs trended upward in parallel. In nearly all treatment/reference comparisons, the Pearson correlation coefficient was greater in the pre-supplementation period than in the supplementation period (Table 13).

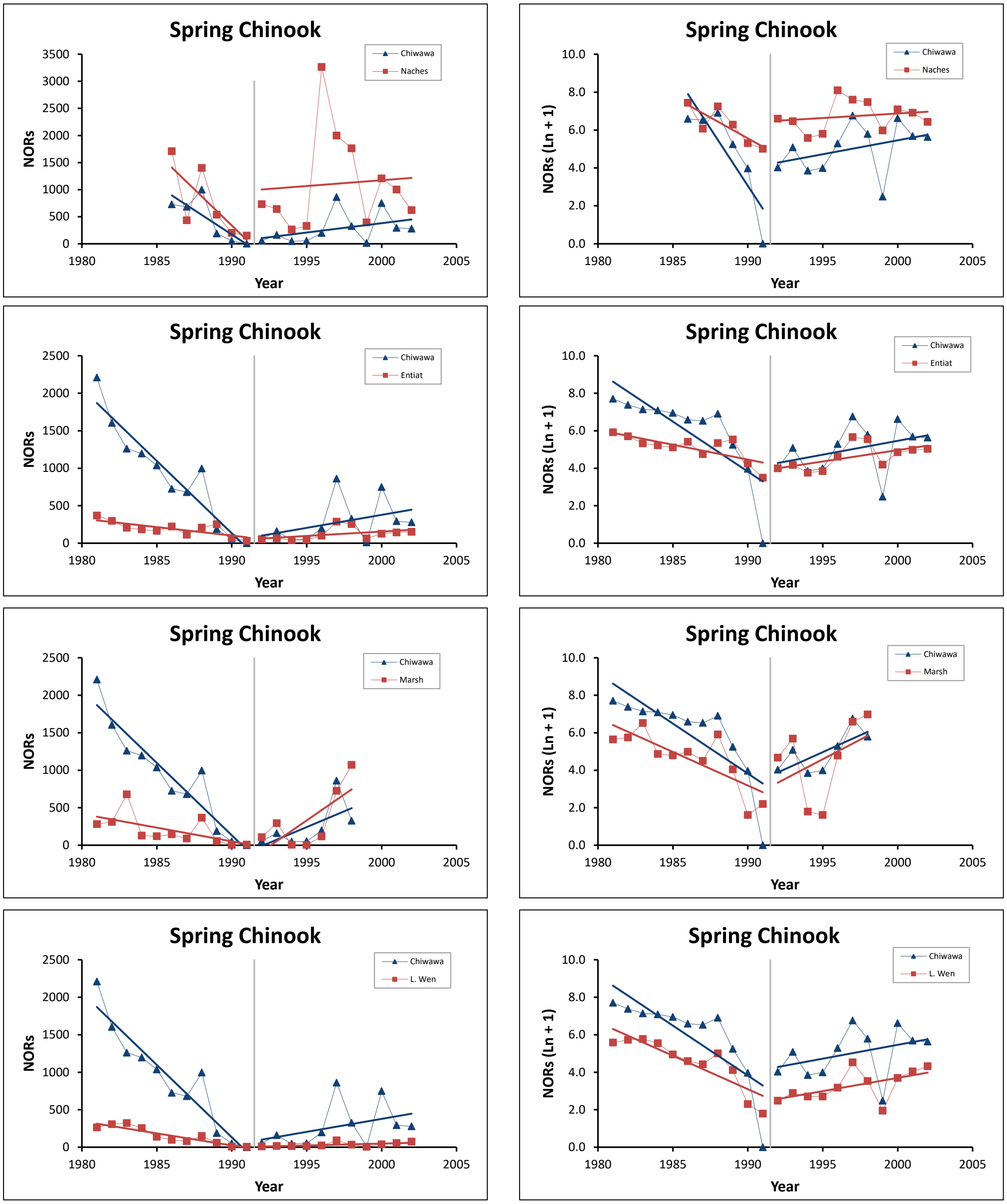

Figure 10. Trends in spring Chinook natural-origin recruits (NORs) in the Chiwawa and reference populations. The vertical lines in the figures separate the pre- and post-supplementation periods. Figures on the left include untransformed NORs; those on the right include natural-log transformed data.

Table 13. Pearson correlation coefficients and t-test results comparing slopes of natural-origin recruits trends between reference populations and the Chiwawa spring Chinook population before and during the supplementation periods; for correlation coefficients, an asterisk (*) indicates significance at P < 0.05. Analyses include both untransformed and natural-log transformed natural-origin recruits.

Reference population	Pearson correlation coefficient		Test on slopes			
			t-value		P-value	
	Before	During	Before	During	Before	During
Natural-Origin Recruits						
Naches	0.803*	0.432	0.666	0.140	0.524	0.890
Entiat	0.795*	0.754*	-7.495	0.847	0.000	0.408
Marsh	0.605*	0.677*	-5.786	-0.718	0.000	0.489
Little Wenatchee	0.880*	0.758*	-7.206	1.128	0.000	0.274
LN Natural-Origin Recruits						
Naches	0.824*	0.710*	-1.985	0.693	0.082	0.497
Entiat	0.886*	0.796*	-2.563	0.202	0.019	0.842
Marsh	0.830*	0.835*	-1.038	-0.134	0.313	0.896
Little Wenatchee	0.927*	0.898*	-1.150	0.046	0.265	0.964

As with NORs and spawner abundance data, trend analysis indicated that the relationship of slopes of productivity (recruits/spawner) between the Chiwawa and reference populations did not change significantly after the initiation of supplementation (Figure 11; Table 14). This was true for both transformed and untransformed productivity data. Before supplementation, productivities trended down in both the Chiwawa and reference populations (Figure 11). During the period of supplementation, productivities fluctuated widely in both the Chiwawa and reference populations. Nevertheless, during the supplementation period, productivities generally increased in both the reference and Chiwawa populations. Unlike with spawner abundance, the Pearson correlation coefficients resulting from analysis of productivity data were generally higher in the pre-supplementation period than during the supplementation period (Table 14).

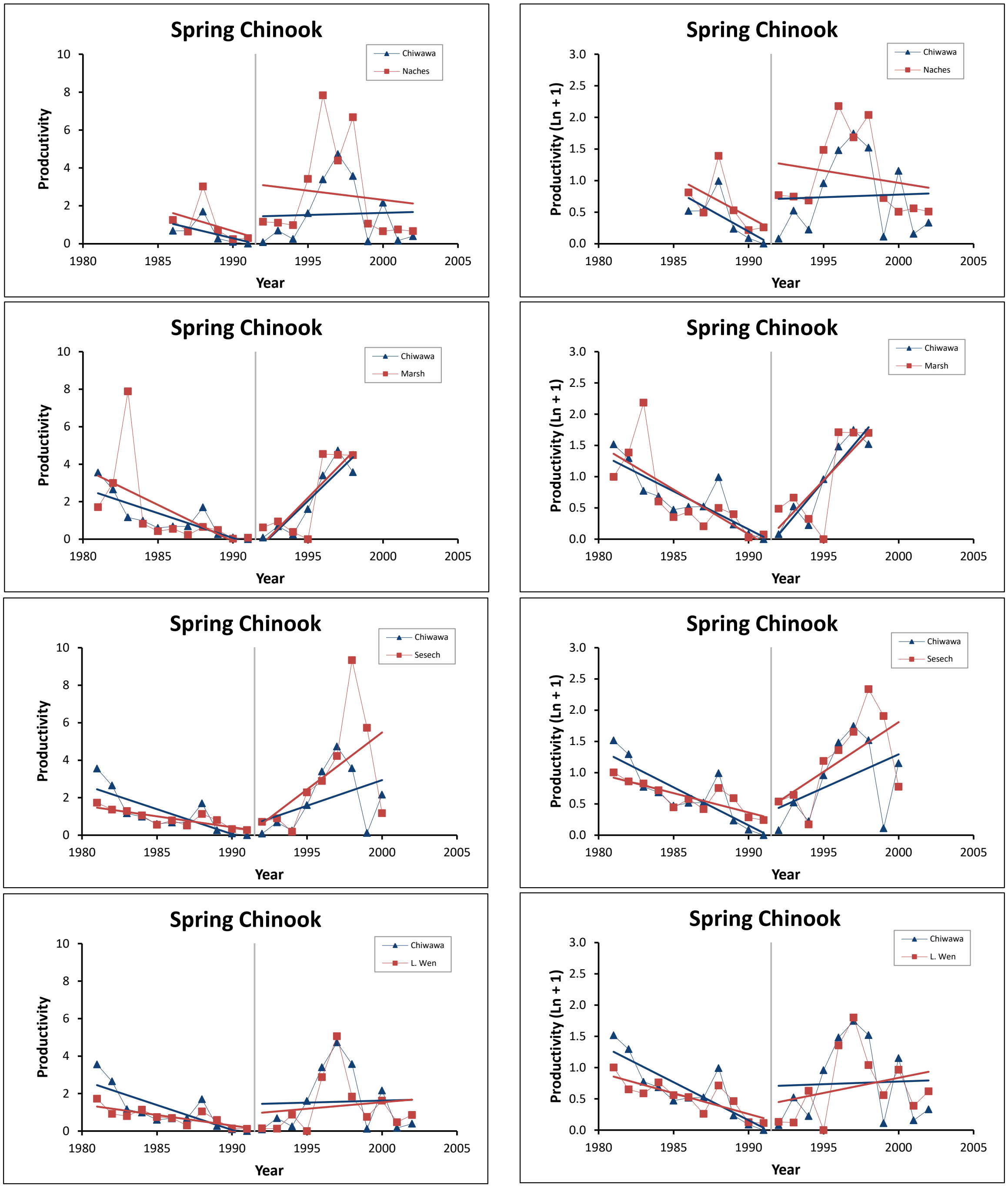

Figure 11. Trends in spring Chinook productivity (recruits/spawner) in the Chiwawa (supplemented) and reference populations. The vertical lines in the figures separate the pre- and post-supplementation periods. Figures on the left include untransformed productivity data; those on the right include natural-log transformed data.

Table 14. Pearson correlation coefficients and t-test results comparing slopes of productivity (recruits/spawner) trends between reference populations and the Chiwawa spring Chinook population before and during the supplementation periods; for correlation coefficients, an asterisk (*) indicates significance at P < 0.05. Analyses include both untransformed and natural-log transformed productivity data.

Reference population	Pearson correlation coefficient		Test on slopes			
			t-value		P-value	
	Before	During	Before	During	Before	During
Productivity						
Naches	0.960*	0.802*	0.169	0.387	0.870	0.703
Marsh	0.320	0.910*	0.605	-0.132	0.553	0.898
Sesech	0.903*	0.491	-2.059	-0.837	0.054	0.417
Little Wenatchee	0.848*	0.864*	-2.065	-0.213	0.054	0.834
LN Productivity						
Naches	0.944*	0.805*	-0.042	0.526	0.968	0.605
Marsh	0.610*	0.804*	0.428	0.281	0.674	0.784
Sesech	0.913*	0.531	-2.050	-0.463	0.055	0.651
Little Wenatchee	0.862*	0.751*	-1.811	-0.480	0.087	0.637

Using trend analysis, we found no evidence that the supplementation program has significantly increased the spawner abundance and NORs of spring Chinook in the Chiwawa Basin. Even though we documented an increasing trend in spawner abundance and NORs during the supplementation period, a similar increase in spawner abundance and NORs was observed in the reference populations. In addition, we found no evidence that the supplementation program has increased the productivity of spring Chinook in the Chiwawa Basin. Importantly, the productivity of spring Chinook in the Chiwawa Basin did not trend downward during the supplementation period. Thus, based on trend analysis, it appears that the supplementation program has not increased or decreased the abundance and productivity of spring Chinook in the Chiwawa Basin.

We note that this exercise only tests the slopes of the trend lines. It does not test for differences in elevations of the trend lines. A supplementation program could increase spawner abundance, NORs, and productivity of the target population without changing the slopes of the trend lines. That is, supplementation could cause the elevation of the trend line to be greater during the supplementation period than during the pre-supplementation period. In the next section we evaluate elevation differences by testing mean differences before and after supplementation.

Analysis of Mean Differences, Ratios, and Rates

For assessing mean differences between supplemented and reference populations, we derived three different response variables using transformed and untransformed spawner abundance, NORs, and productivity data. The first included difference scores, which were calculated as the difference between paired treatment and reference data (T-R). The second included ratios, which were calculated as the ratio of paired treatment and reference data (T/R). Finally, we calculated the differences in annual changes in paired treatment and reference population data (ΔT-ΔR; see footnote #2).

If the hatchery program is successfully supplementing the natural spring Chinook population, the mean difference or ratio score of paired spawner abundance data and NORs during the supplementation period should be greater than the pre-supplementation period. For productivity, the mean difference or ratio score during the supplementation period should be equal to or higher than the pre-supplementation period. We tested the following statistical hypotheses.

Spawner Abundance and NORs:

Ho: Mean Difference (or Ratio) before supplementation ≥ Mean Difference (or Ratio) during supplementation.

Ha: Mean Difference (or Ratio) before supplementation < Mean Difference (or Ratio) during supplementation (i.e., μ_{pre} - $\mu_{post} < 0$).

Productivity (Recruits/Spawner):

Ho: Mean Difference (or Ratio) before supplementation ≤ Mean Difference (or Ratio) during supplementation.

Ha: Mean Difference (or Ratio) before supplementation > Mean Difference (or Ratio) during supplementation (i.e., μ_{pre} - $\mu_{post} > 0$).[20]

For each set of response variables, we tested before/after supplementation effects using a one-tailed Aspin-Welch unequal-variance test. We used the Aspin-Welch unequal-variance test instead of Student's t-test, because in nearly every case, the variances of response variables in the pre-treatment and supplementation periods were unequal.[21] This was true even for natural-log transformed variables. We used the modified Levene equal-variance test to assess the equality of variance. In some cases, the distributions of response variables were not normal (based on the Omnibus Normality test and examination of histograms, normal probability plots, and box plots). Therefore, we also used a randomization test, based on 10,000 Monte Carlo simulations, to assess differences in response variables before and during supplementation. The randomization procedure only allowed the testing of two-tailed hypotheses. Therefore, we generated 95% confidence intervals on the mean difference (μ_{pre} - μ_{post}) using bootstrapping methods to determine the direction of the difference. We generated 5,000 bootstrap samples to calculate confidence intervals.

All these statistical methods assume that the samples of derived difference or ratio scores from the pre-supplementation and supplementation periods were independent. However, BACI designs, like time-series trend analysis, are repeated-measures designs and therefore are susceptible to temporal correlations in the data. This means that the two samples of difference or ratio scores may not be independent. Under this scenario, ARIMA models can be used to describe the correlation structure in temporal data (Gotelli and Ellison 2004). ARIMA models can be fit individually to the reference and supplemented time series data, or to a derived data series created by taking the ratio or difference of the supplemented/reference data at each time step. ARIMA models, however, require a long time series (N > 40) and therefore we could not use them to model

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20 Because of the logic of null hypothesis testing, the rejection of the null hypothesis of no difference in productivity would mean that the supplementation program has reduced the productivity of the target population (here rejection of the null indicates "harm"). Notice that the rejection of the null hypothesis of no difference in spawner abundance means that the supplementation program has improved the spawner abundance in the target population (here rejection of the null indicates "benefit").

21 In cases in which the variances were equal, both the Aspin-Welch test and Student's t-test gave the same result.

the spring Chinook data. Thus, we acknowledge that our analyses may be confounded if the samples are not independent.

Difference Scores (T-R)

Analysis of supplementation effects on spawner abundance using difference scores indicated that supplementation did not significantly increase spawning abundance in the Chiwawa Basin (Table 15; Figure 12). Only the Little Wenatchee-Chiwawa pairing using transformed abundance data indicated a significant increase in spawning abundance following supplementation. The randomization test indicated significant differences in several of the treatment-reference pairs; however, the bootstrap CIs indicated that those differences were in the wrong direction (i.e., CIs > 0). That is, compared to the reference populations, spawner abundance decreased in the Chiwawa Basin during the supplementation period (Figure 12).

Table 15. Results of the Aspin-Welch unequal-variance test, randomization test (based on 10,000 Monte Carlo samples), and 95% CI (based on 5,000 bootstrap samples) on transformed and untransformed spawner abundance data. Tests determined if the mean difference scores during the supplementation period were greater than mean difference scores during the pre-supplementation period.

Reference population	Aspin-Welch unequal-variance test			Randomization test P-value	Bootstrap 95% CI
	t-value	P-value	Effect size		
Spawner Abundance					
Naches	1.066	0.848	184	0.322	-162 – 472
Entiat	1.872	0.962	316	0.078	17 – 633
Sesech	4.502	0.999	607	0.000	349 – 851
Little Wenatchee	1.773	0.954	321	0.093	0 – 690
LN Spawner Abundance					
Naches	2.603	0.990	0.701	0.026	0.210 – 1.214
Entiat	1.701	0.946	0.388	0.108	-0.033 – 0.811
Sesech	5.394	0.999	1.327	0.000	0.891 – 1.805
Little Wenatchee	-2.259	0.018	0.609	0.034	-1.125 – -0.097

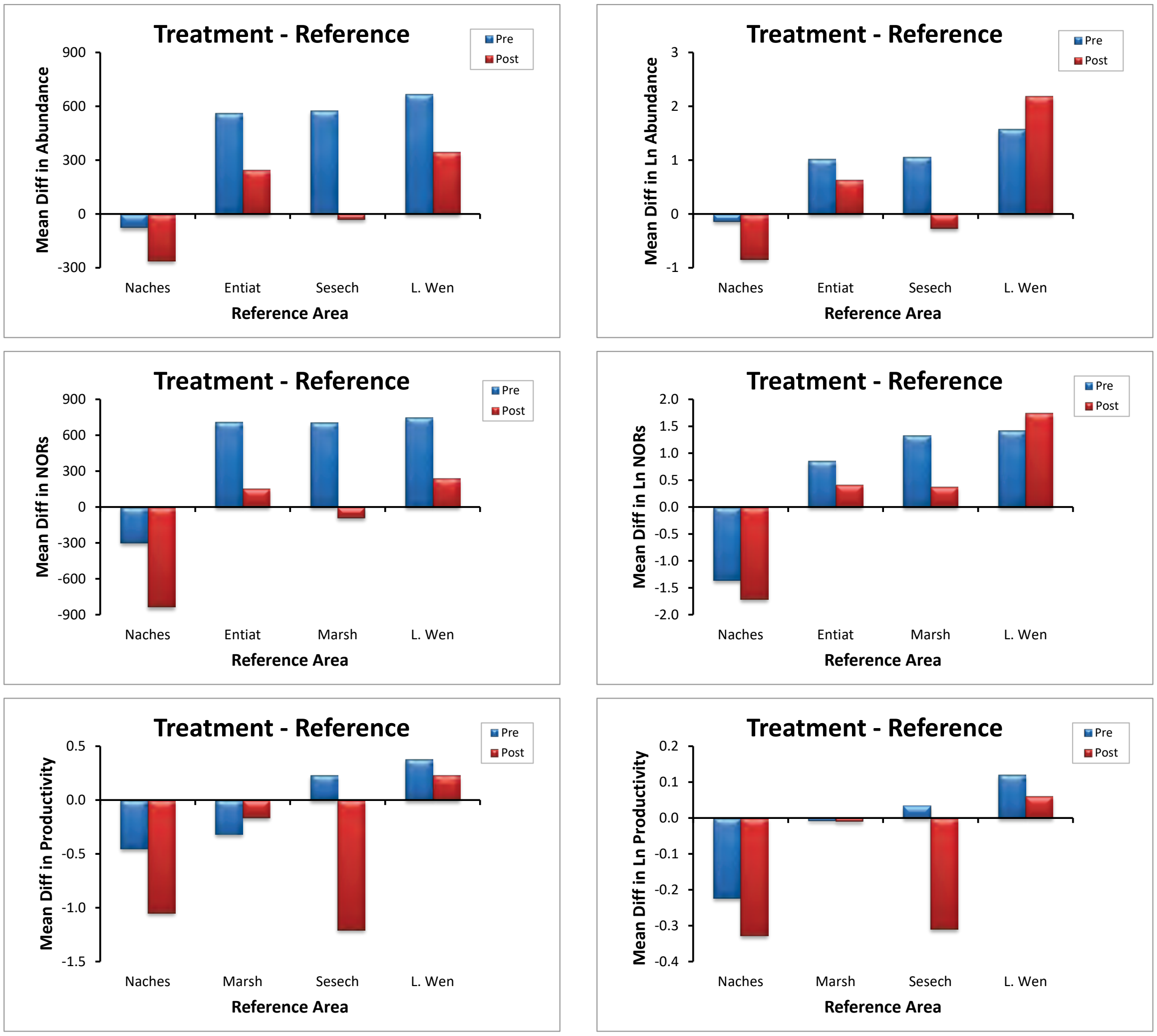

Figure 12. Mean difference (Treatment – Reference) scores of untransformed (figures on the left) and transformed (figures on the right) spawner abundance, natural-origin recruits (NORs), and productivity data before (pre) and after (post) spring Chinook supplementation in the Chiwawa Basin. Positive effects of supplementation on spawner abundance and NORs are indicated when the post-supplementation (red) bars are greater than their corresponding pre-supplementation (blue) bars. Negative effects of supplementation on productivity are indicated when the pre-supplementation (blue) bars are greater than their corresponding post-supplementation (red) bars.

Analysis of supplementation effects on NORs using difference scores indicated that supplementation did not significantly increase NORs in the Chiwawa Basin (Table 16; Figure 12). The randomization test indicated significant differences in several of the treatment-reference pairs; however, the bootstrap CIs indicated that those differences were in the wrong direction. That is, compared to the reference populations, NORs decreased in the Chiwawa Basin during the supplementation period (Figure 12).

Table 16. Results of the Aspin-Welch unequal-variance test, randomization test (based on 10,000 Monte Carlo samples), and 95% CI (based on 5,000 bootstrap samples) on transformed and untransformed natural-origin recruits. Tests determined if the mean difference scores during the supplementation period were greater than mean difference scores during the pre-supplementation period.

Reference population	Aspin-Welch unequal-variance test			Randomization test P-value	Bootstrap 95% CI
	t-value	P-value	Effect size		
Natural-Origin Recruits					
Naches	1.787	0.953	537	0.081	-60 – 1039
Entiat	2.879	0.993	558	0.007	201 – 916
Marsh	3.817	0.999	795	0.001	381 – 1153
Little Wenatchee	2.668	0.991	510	0.013	145 – 863
LN Natural-Origin Recruits					
Naches	0.430	0.659	0.354	0.686	-0.948 – 1.975
Entiat	0.788	0.779	0.445	0.465	-0.504 – 1.583
Marsh	1.45	0.916	0.953	0.168	-0.169 – 2.243
Little Wenatchee	-0.813	0.214	-0.319	0.506	-0.948 – 0.484

Analysis of supplementation effects on productivity (adult recruits/spawner) using difference scores indicated that supplementation did not significantly decrease productivity in the Chiwawa Basin (Table 17; Figure 12). All tests, regardless of treatment-reference pairs, indicated that productivity did not change significantly during the supplementation period. These tests indicate that supplementation has not negatively affected the productivity of spring Chinook salmon in the Chiwawa Basin.

Table 17. Results of the Aspin-Welch unequal-variance test, randomization test (based on 10,000 Monte Carlo samples), and 95% CI (based on 5,000 bootstrap samples) on transformed and untransformed productivity data. Tests determined if the mean difference scores during the supplementation period were less than mean difference scores during the pre-supplementation period.

Reference population	Aspin-Welch unequal-variance test			Randomization test P-value	Bootstrap 95% CI
	t-value	P-value	Effect size		
Productivity					
Naches	1.134	0.139	0.594	0.296	-0.427 – 1.540
Marsh	-0.203	0.579	0.152	0.932	-0.304 – 1.381
Sesech	1.607	0.071	1.435	0.151	-0.403 – 2.917
Little Wenatchee	0.431	0.335	0.147	0.665	-0.498 – 0.762
LN Productivity					
Naches	0.770	0.227	0.104	0.480	-0.125 – 0.378
Marsh	0.012	0.495	0.003	0.992	-0.375 – 0.493
Sesech	1.463	0.087	0.343	0.161	-0.135 – 0.732
Little Wenatchee	0.390	0.351	0.060	0.701	-0.229 – 0.347

Ratio Scores (T/R)

As with difference scores, analysis of supplementation effects on spawner abundance using ratios indicated that supplementation did not significantly increase spawning abundance in the Chiwawa Basin (Table 18; Figure 13). Only the Little Wenatchee-Chiwawa pairing indicated a significant increase in spawning abundance following supplementation. Analysis with both transformed and untransformed Little Wenatchee-Chiwawa data indicated a significant effect. In contrast, only difference scores derived from transformed data indicated a significant effect. The randomization test indicated significant differences in several of the treatment-reference pairs; however, the bootstrap CIs indicated that those differences were in the wrong direction. That is, compared to the reference populations, spawner abundance decreased in the Chiwawa Basin during the supplementation period (Figure 13).

Table 18. Results of the Aspin-Welch unequal-variance test, randomization test (based on 10,000 Monte Carlo samples), and 95% CI (based on 5,000 bootstrap samples) on transformed and untransformed spawner abundance data. Tests determined if the mean ratios during the supplementation period were greater than mean ratios during the pre-supplementation period.

Reference population	Aspin-Welch unequal-variance test			Randomization test P-value	Bootstrap 95% CI
	t-value	P-value	Effect size		
Spawner Abundance					
Naches	2.110	0.970	0.398	0.065	0.056 – 0.737
Entiat	1.254	0.888	0.731	0.223	-0.365 – 1.834
Sesech	4.251	0.999	2.428	0.000	1.278 – 3.435
Little Wenatchee	-2.649	0.009	3.897	0.018	-6.579 – -1.202
LN Spawner Abundance					
Naches	2.783	0.993	0.120	0.021	0.045 – 0.199
Entiat	1.273	0.890	0.055	0.220	-0.026 – 0.135
Sesech	5.143	0.999	0.244	0.000	0.160 – 0.335
Little Wenatchee	-3.462	0.002	0.327	0.003	-0.516 – -0.154

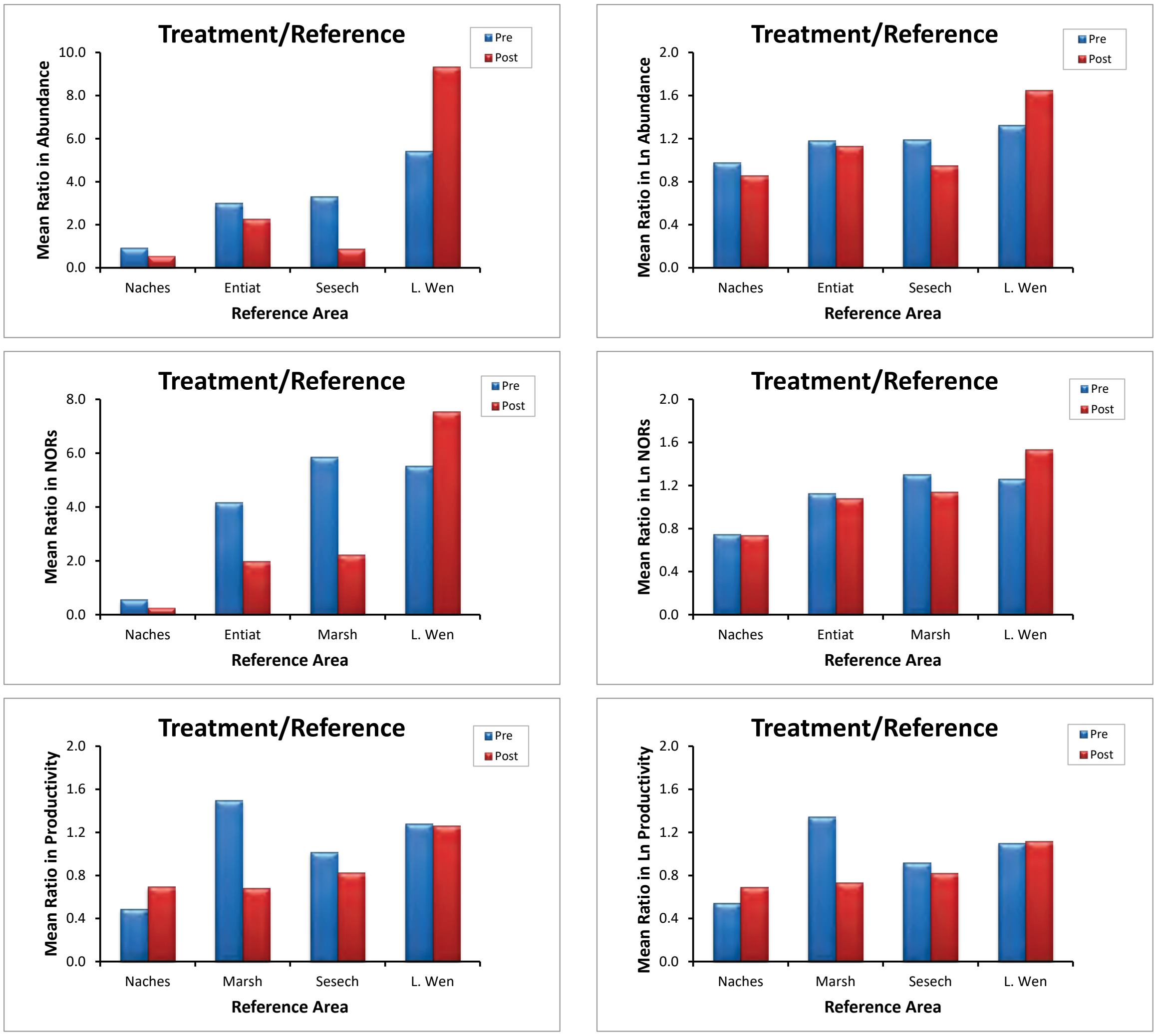

Figure 13. Mean ratios (Treatment/Reference) scores of untransformed (figures on the left) and transformed (figures on the right) spawner abundance, natural-origin recruits (NORs), and productivity data before (pre) and after (post) spring Chinook supplementation in the Chiwawa Basin. Positive effects of supplementation on spawner abundance and NORs are indicated when the post-supplementation (red) bars are greater than their corresponding pre-supplementation (blue) bars. Negative effects of supplementation on productivity are indicated when the pre-supplementation (blue) bars are greater than their corresponding post-supplementation (red) bars.

Analysis of supplementation effects on NORs using ratios indicated that supplementation did not significantly increase NORs in the Chiwawa Basin (Table 19; Figure 13). Only the Little Wenatchee-Chiwawa pairing indicated a significant increase in transformed NORs following supplementation. The randomization test indicated significant differences in several of the treatment-reference pairs; however, the bootstrap CIs indicated that those differences were in the wrong direction. That is, compared to the reference populations, NORs decreased in the Chiwawa Basin during the supplementation period (Figure 13).

Table 19. Results of the Aspin-Welch unequal-variance test, randomization test (based on 10,000 Monte Carlo samples), and 95% CI (based on 5,000 bootstrap samples) on transformed and untransformed natural-origin recruits. Tests determined if the mean ratios during the supplementation period were greater than mean ratios during the pre-supplementation period.

Reference population	Aspin-Welch unequal-variance test			Randomization test P-value	Bootstrap 95% CI
	t-value	P-value	Effect size		
Natural-Origin Recruits					
Naches	1.318	0.881	0.306	0.219	-0.157 – 0.670
Entiat	2.447	0.987	2.172	0.028	0.593 – 3.871
Marsh	2.001	0.965	3.638	0.075	0.532 – 7.201
Little Wenatchee	-1.148	0.136	2.020	0.284	-5.055 – 1.516
LN Natural-Origin Recruits					
Naches	0.057	0.522	0.009	0.967	-0.230 – 0.351
Entiat	0.359	0.638	0.049	0.759	-0.173 – 0.336
Marsh	0.603	0.721	0.161	0.579	-0.272 – 0.681
Little Wenatchee	-1.914	0.038	0.277	0.027	-0.504 – 0.031

Analysis of supplementation effects on productivity (adult recruits/spawner) using ratios indicated that supplementation did not significantly decrease productivity in the Chiwawa Basin (Table 20; Figure 13). Although the Aspin-Welch test indicated a significant effect when comparing the Chiwawa to the Marsh Creek population, both the randomization test and the bootstrap CI did not indicate a significant effect. These tests indicate that supplementation has probably not negatively affected the productivity of spring Chinook salmon in the Chiwawa Basin.

Table 20. Results of the Aspin-Welch unequal-variance test, randomization test (based on 10,000 Monte Carlo samples), and 95% CI (based on 5,000 bootstrap samples) on transformed and untransformed productivity data. Tests determined if the mean ratios during the supplementation period were less than mean ratios during the pre-supplementation period.

Reference population	Aspin-Welch unequal-variance test			Randomization test P-value	Bootstrap 95% CI
	t-value	P-value	Effect size		
Productivity					
Naches	-0.677	0.745	0.209	0.688	-0.700 – 0.425
Marsh	2.236	0.022	0.814	0.054	0.112 – 1.459
Sesech	0.677	0.253	0.191	0.515	-0.356 – 0.718
Little Wenatchee	0.033	0.487	0.018	0.979	-0.879 – 1.162
LN Productivity					
Naches	-0.639	0.734	0.148	0.616	-0.548 – 0.316
Marsh	1.952	0.036	0.613	0.081	-0.003 – 1.170
Sesech	0.447	0.330	0.098	0.663	-0.301 – 0.515
Little Wenatchee	-0.034	0.513	0.015	0.982	-0.692 – 0.861

Difference of Annual Difference Scores (ΔT-ΔR)

Analysis of supplementation effects on spawner abundance using difference scores of annual changes indicated that supplementation did not significantly increase spawning abundance in the Chiwawa Basin (Table 21; Figure 14). None of the statistical analyses detected a significant increase in annual change in the Chiwawa Basin relative to the reference populations.

Table 21. Results of the Aspin-Welch unequal-variance test, randomization test (based on 10,000 Monte Carlo samples), and 95% CI (based on 5,000 bootstrap samples) on transformed and untransformed spawner abundance data. Tests determined if mean difference scores of annual change during the supplementation period were greater than mean difference scores of annual change during the pre-supplementation period.

Reference population	Aspin-Welch unequal-variance test			Randomization test P-value	Bootstrap 95% CI
	t-value	P-value	Effect size		
Spawner Abundance					
Naches	0.009	0.503	2	0.995	-502 – 539
Entiat	-0.239	0.407	48	0.826	-414 – 327
Sesech	-0.126	0.451	20	0.902	-311 – 266
Little Wenatchee	-0.318	0.377	65	0.761	-452 – 311
LN Spawner Abundance					
Naches	-0.425	0.339	0.142	0.698	-0.744 – 0.466
Entiat	-0.084	0.467	0.028	0.933	-0.681 – 0.593
Sesech	-0.349	0.366	0.117	0.740	-0.741 – 0.515
Little Wenatchee	0.001	0.500	0.000	0.999	-0.663 – 0.687

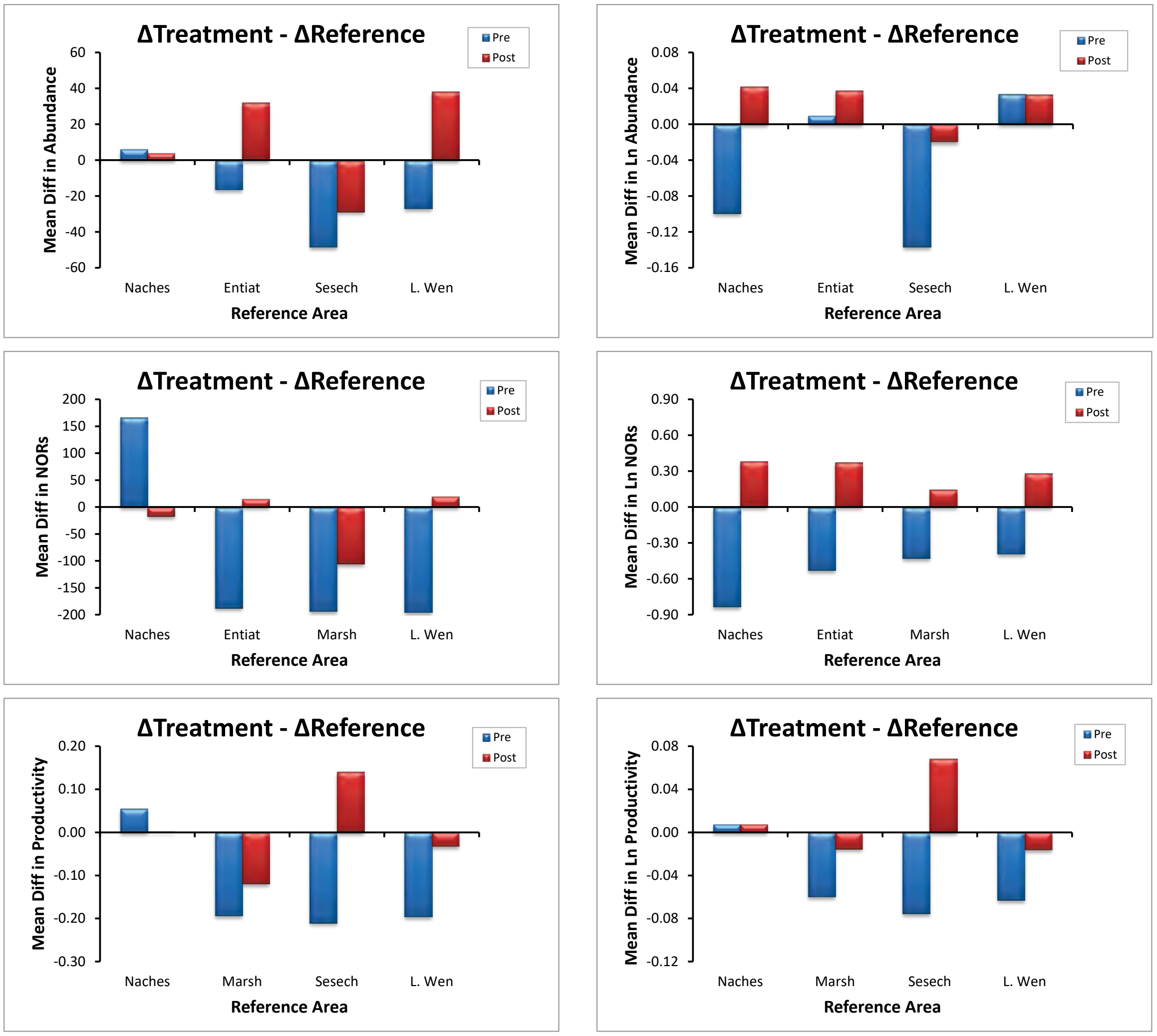

Figure 14. Mean difference scores of annual changes (ΔTreatment – ΔReference) of untransformed (figures on the left) and transformed (figures on the right) spawner abundance and productivity data before (pre) and after (post) spring Chinook supplementation in the Chiwawa Basin.

Analysis of supplementation effects on NORs using difference scores of annual changes indicated that supplementation did not significantly increase NORs in the Chiwawa Basin (Table 22; Figure 14). None of the statistical analyses detected a significant increase in annual change in the Chiwawa Basin relative to the reference populations.

Table 22. Results of the Aspin-Welch unequal-variance test, randomization test (based on 10,000 Monte Carlo samples), and 95% CI (based on 5,000 bootstrap samples) on transformed and untransformed natural-origin recruits. Tests determined if mean difference scores of annual change during the supplementation period were greater than mean difference scores of annual change during the pre-supplementation period.

Reference population	Aspin-Welch unequal-variance test			Randomization test P-value	Bootstrap 95% CI
	t-value	P-value	Effect size		
Natural-Origin Recruits					
Naches	0.399	0.652	184	0.741	-699 – 989
Entiat	-1.381	0.092	202	0.194	-471 – 86
Marsh	-0.505	0.311	88	0.624	-425 – 206
Little Wenatchee	-1.437	0.084	214	0.179	-481 – 64
LN Natural-Origin Recruits					
Naches	-1.301	0.118	1.214	0.224	-2.783 – 0.531
Entiat	-1.408	0.088	0.901	0.188	-1.977 – 0.387
Marsh	-0.712	0.244	0.570	0.517	-1.952 – 0.975
Little Wenatchee	-1.154	0.132	0.674	0.274	-1.706 – 0.497

Analysis of supplementation effects on productivity (adult recruits/spawner) using difference scores of annual changes indicated that supplementation did not significantly decrease productivity in the Chiwawa Basin (Table 23; Figure 14). All tests, regardless of treatment-reference pairs, indicated that productivity did not change significantly during the supplementation period.

Table 23. Results of the Aspin-Welch unequal-variance test, randomization test (based on 10,000 Monte Carlo samples), and 95% CI (based on 5,000 bootstrap samples) on transformed and untransformed productivity data. Tests determined if the mean difference scores of annual change during the supplementation period were less than mean difference scores of annual change during the pre-supplementation period.

Reference population	Aspin-Welch unequal-variance test			Randomization test P-value	Bootstrap 95% CI
	t-value	P-value	Effect size		
Productivity					
Naches	0.002	0.475	0.054	0.952	-1.464 – 1.583
Marsh	-0.063	0.525	0.074	0.948	-2.395 – 2.031
Sesech	-0.317	0.621	0.350	0.628	-2.387 – 1.695
Little Wenatchee	-0.347	0.633	0.163	0.728	-1.023 – 0.725
LN Productivity					
Naches	0.000	0.500	0.000	0.999	-0.408 – 0.445
Marsh	-0.126	0.549	0.044	0.904	-0.715 – 0.595
Sesech	-0.449	0.668	0.144	0.727	-0.685 – 0.509
Little Wenatchee	-0.200	0.578	0.047	0.842	-0.466 – 0.391

We believe results from analysis of mean differences of annual change (ΔT-ΔR) in spawning abundance, NORs, and productivity are difficult to interpret and may be insensitive to treatment effects. A simpler analysis, which is also easier to interpret, is the use of trend analysis. Therefore, we recommend that analyses using differences of annual change be replaced with trend analysis.

Corrections for Density Dependence and Carrying Capacity

The analyses described above assume that the density of spawners or recruits does not affect the survival and productivity of fish. However, it is well known that the density of fish can affect the number of recruits as well as the productivity of the population. This occurs through the relationship between density and mortality. Mortality of fish can be generally classified as density independent and density dependent. In general, when densities are low, the mortality is density independent, but as densities increase, the amount of density-dependent mortality increases. Monitoring programs can make use of this information to derive density-corrected estimates of productivity. In this section, we describe two different methods for deriving density-corrected estimates of productivity.

The first method controlled the effects of density on productivity (adult recruits/spawner; R/S) by partitioning observed productivities into density-independent and density-dependent productivity. When abundance is below the minimum number of spawners (S) needed to produce the maximum number of recruits (K_{sp}), the observed productivity is used in statistical tests. However, when the abundance is equal to or above K_{sp}, the modeled value of productivity (R/K_{sp}) is used in statistical tests.

$$\boldsymbol{Adj\ R/S = \begin{cases} R/S, & if\ S < K_{sp} \\ R/K_{sp}, & if\ S \geq K_{sp} \end{cases}}$$

The density-independent and density-dependent productivities were then combined in a single test.

The second method was based on one of the goals of supplementation, which is to fill the capacity of the environment with fish. This method corrects for differences in carrying capacities between the supplemented and reference populations. We did this by calculating the percent saturation of NORs. That is, we calculated the fraction of the habitat (τ) that was filled with NORs by dividing the observed NOR by the modeled maximum number of NORs (K_R) that the habitat could support.

$$\boldsymbol{\tau = \frac{NOR_{obs}}{K_R}}$$

Note that 1-τ represents the unused portion of the carrying capacity and is the term that is multiplied by the exponential growth equation to derive the logistic growth equation. We included τ in the statistical analyses.

These two methods require the estimation of carrying capacity (K_R) and the spawning abundance that produces the maximum number of recruits (K_{sp}). We estimated these parameters for both reference populations and the supplemented population using Ricker, Beverton-Holt, and smooth hockey stick stock-recruitment models. We used only spawner abundance as a predictor of subsequent brood recruitment. We made the following assumptions in proceeding with the analysis:

- Density-dependent mortality—For some time period before recruitment, the brood instantaneous mortality rate is proportional to the number of parent spawners (Ricker 1954).
- Lognormal variation—At any particular spawning stock size, the variation in recruitment is log-normally distributed about its average, and acts multiplicatively (Quinn and Deriso 1999).
- Measurement error—Error in spawning stock size estimates (measurement error) is small relative to the range of spawning stock sizes observed (Hilborn and Walters 1992). Variation in realized recruitment at any particular spawning stock size (process error) dominates recruitment measurement error.
- Stationarity—The average stock-recruitment relationship is constant over time (Hilborn and Walters 1992). That is, environmental conditions randomly affect survival independent of stock size or time.

In general, the methods we used to fit the models to the data followed those outlined in Hilborn and Walters (1992) and Froese (2008). The Ricker model, which assumes that the number of recruits increases to a maximum and then declines as the number of spawners increases, takes the form:

$$\boldsymbol{E(R) = \alpha S e^{-\beta S}}$$

where E(R) is the expected recruitment, S is spawner abundance, α is the number of recruits per spawner at low spawning levels, and β describes how quickly the recruits per spawner drop as the number of spawners increases. We estimated K_R as:

$$\boldsymbol{K_R = \left(\frac{\alpha}{\beta}\right) e^{-1}}$$

and K_{sp} as:

$$\boldsymbol{K_{sp} = \frac{1}{\beta}}$$

The Beverton-Holt model assumes that the number of recruits increases constantly toward an asymptote as the number of spawners increases. After the asymptote is reached, the number of recruits neither increases nor decreases. The asymptote represents the maximum number of recruits the system can support (i.e., carrying capacity for the system; K_R). The Beverton-Holt curve takes the form:

$$\boldsymbol{E(R) = \frac{(\alpha S)}{(\beta + S)}}$$

where E(R) and S are as above, α is the maximum number of recruits produced (K_R), and β is the number of spawners needed to produce (on average) recruits equal to one-half the maximum number of recruits. Because $K_{sp} = \infty$ in the Beverton-Holt model, we estimated K_{sp} as the number of spawners needed to produce 0.99(K_R).

Like the Beverton-Holt model, the smooth hockey stick model assumes that the number of recruits increases toward an asymptote (carrying capacity; K_R) as the number of spawners increases. After the carrying capacity is reached, the number of recruits neither increases nor decreases. The carrying capacity represents the maximum number of recruits the system can support. This curve

takes the form (Froese 2008):

$$\boldsymbol{E(R) = R_\infty\left(1 - e^{-\left(\frac{\alpha}{R\infty}\right)S}\right)}$$

where E(R) and S are as above, α is the slope at the origin of the spawner-recruitment curve, and R_∞ is the carrying capacity of recruits (note that $R_\infty = K_R$). As with the Beverton-Holt model, we estimated K_{sp} as the number of spawners needed to produce $0.99(K_R)$.

We used non-linear regression to fit the three models to spawner-recruitment data. Before fitting the models, we transformed recruitment data using natural logs. We estimated bias and uncertainty measures (95% CI) for the model parameters using bootstrap procedures, which assumed that the {R, S} sample represented or approximated the population. The number of bootstrap samples was 3,000. We computed and stored the non-linear regression results for each bootstrap sample. We then calculated the bootstrap 95% CI by arranging the 3,000 bootstrap parameter values in sorted order and selected the 2.5 and 97.5 percentiles from the list.

We used Akaike's Information Criterion for small sample size (AIC_c) to determine which model(s) best explained the relationship between spawners and recruitment in the supplemented and reference populations. AIC_c was estimated as:

$$\boldsymbol{AIC_c = -2log\big(£(\theta|data)\big) + 2K + \left(\frac{2K(K+1)}{n-K-1}\right)}$$

where *log(£(θ|data))* is the maximum likelihood estimate, *K* is the number of estimable parameters (structural parameters plus the residual variance parameter), and *n* is the sample size (Burnham and Anderson 2002). We used least-squares methods to estimate *log(£(θ|data))*, which was calculated as $log(\sigma^2)$, where σ^2 = residual sum of squares divided by the sample size ($\sigma^2 = RSS/n$). AIC_c assessed model fit in relation to model complexity (number of parameters). The model with the smallest AIC_c value represented the "best approximating" model within the model set. Remaining models were ranked relative to the best model using AIC_c difference scores (ΔAIC_c), Akaike weights (w_i), and evidence ratios. Models with ΔAIC_c values less than 2 indicated that there is substantial support for these models as being the best-fitting models within the set (Burnham and Anderson 2002). Models with values greater than 2 had less support. Akaike weights are probabilities estimating the strength of the evidence supporting a particular model as being the best model within the model set. Models with small w_i values are less plausible as competing models (Burnham and Anderson 2002). If no single model could be specified as the best model, a "best subset" of competing models was identified using (1) AIC_c differences to indicate the level of empirical support each model had as being the best model, (2) evidence ratios based on Akaike weights to indicate the relative probability that any model is the best model, and (3) coefficients of determination (R^2) assessing the explanatory power of each model.

Stock-Recruitment Analysis

We successfully fit stock-recruitment models to the Chiwawa and reference population data. The span of spawner data for the Chiwawa and reference populations was greater than 14 times the minimum observed spawners, which should provide sufficient contrast for estimation of model parameters. In addition, the span of recruitment data was greater than 12 times the minimum observed recruitment, again providing sufficient contrast for estimation of parameters. The relationship between natural log R/S and spawners indicated that some of the highest productivities occurred at the lower spawner levels and the lowest productivities generally occurred at the highest spawner levels (Figure 15). This is consistent with the assumption of density-dependent mortality.

Although model fits were generally poor, explaining less than 40% of the residual variation in natural-log recruitment data, we were able to estimate average maximum recruitment levels (K_R) and the spawning levels needed to produce maximum recruitment (K_{sp}) (Table 24; Figure 15). For all populations examined, Akaike information criterion was unable to identify a best approximating model (i.e., ΔAIC_c values were less than 2, indicating support for all three models). However, evaluation of 95% CIs and the asymptotic correlation coefficients indicated that the smooth hockey stick model may be the best approximating model for each population. Therefore, we used estimates of K_R and K_{sp} derived from the smooth hockey stick model to correct for density dependence and different carrying capacities in treatment-reference comparisons.

As part of the regression diagnostics, we examined the dependence of the model residuals on time and found a significant ($P < 0.05$), positive, one-year-lag autocorrelation for the Entiat (0.562), Marsh (0.551), Sesech (0.564), and Little Wenatchee (0.629) populations. For the purposes of our work here, we did not attempt to correct for this one-year-lag correlation in the residuals. Future analyses will explore the use of autoregressive models (e.g., AR1; Noakes et al. 1987) to correct for autocorrelation.

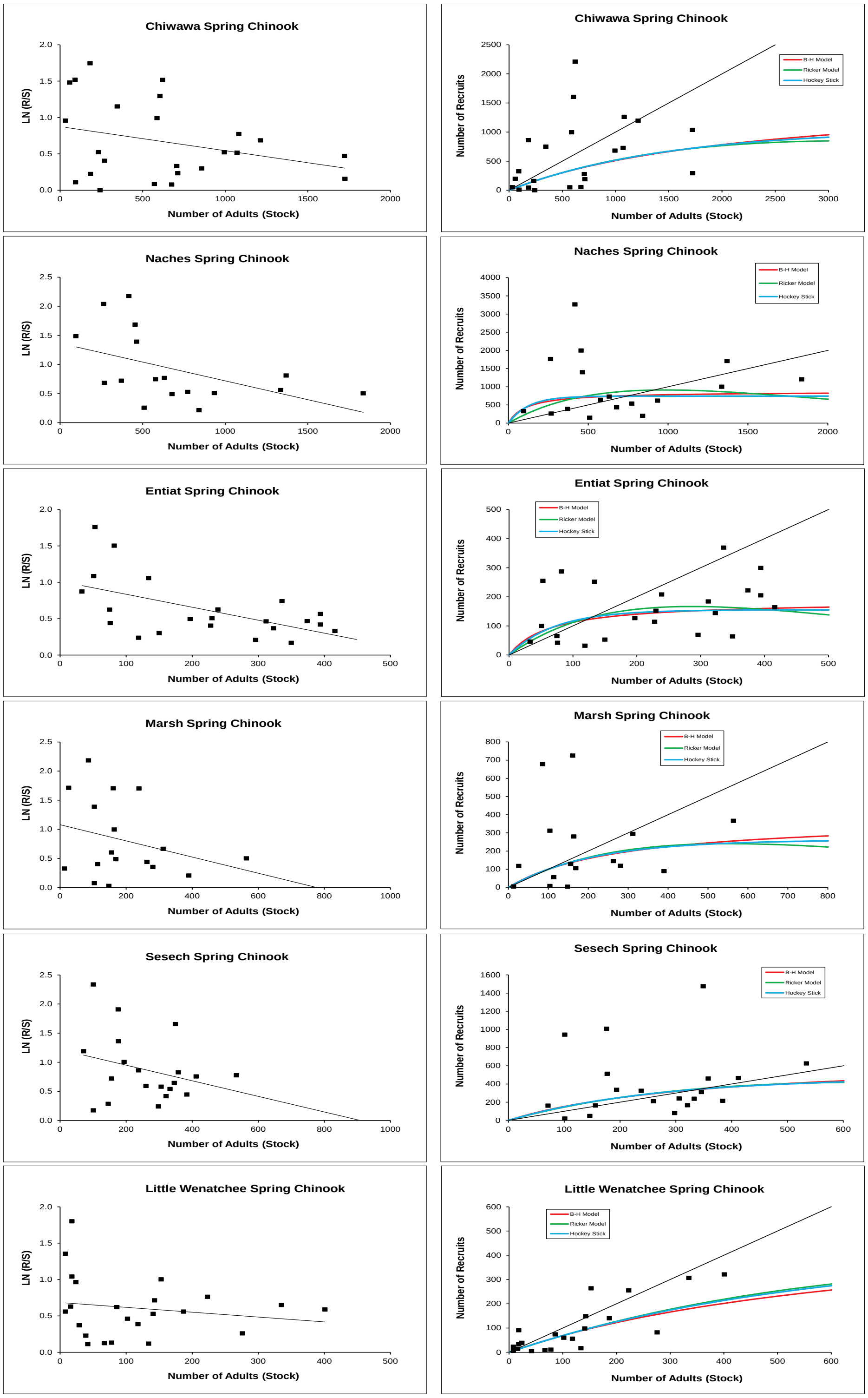

Figure 15. Relationships between natural log recruits/spawner (LN R/S) and spawners (Stock) in the Chiwawa and reference populations (figures on the left) and relationships between numbers of untransformed recruits and spawners in the Chiwawa and reference populations (figures on the right). Figures on the right also show the fit of the Ricker, Beverton-Holt, and the smooth hockey stick models to the data (black straight line represents R=S).

Table 24. Results from fitting Ricker, Beverton-Holt, and smooth hockey stick models to stock-recruitment data from the Chiwawa and reference populations. 95% CI on parameter estimates are based on 3,000 bootstrap trials; Corr coef = asymptotic correlation of the parameter estimates; K_R = maximum natural origin recruits (recruits at carrying capacity); K_{sp} = number of spawners needed to produce K_R; AICc = Akaike's Information Criterion for small sample size; Adj R^2 = coefficient of determination that is adjusted for the number of parameters in the model.

Model	Parameter	Parameter value	Bootstrap 95% CI	Corr coef	K_R	K_{sp}	AICc	Adj R^2
Chiwawa Population								
Ricker	α	0.7048	-0.6197 1.1055	0.791	852	3,285	-47.949	0.125
	β	0.000304	-0.000668 0.000609					
Beverton-Holt	α	1687.4	-65654539 3062.1	0.989	1,687	43,760	-47.962	0.125
	β	2308.5	-99999538 4526.1					
Smooth hockey stick	α	6.956	-41.313 8.2270	-0.708	1,049	6,847	-47.949	0.125
	β	0.7118	-2.397 1.122					
Naches Population								
Ricker	α	2.5223	-2.0003 3.9672	0.844	912	983	-45.063	-0.143
	β	0.001018	-0.000752 0.001717					
Beverton-Holt	α	869.4	97.4 1641.4	0.858	869	11,455	-46.801	-0.097
	β	111.8	-346.2 569.8					
Smooth hockey stick	α	6.612	5.9223 7.006	-0.399	744	565	-46.831	-0.095
	β	6.013	-89.071 12.026					
Entiat Population								
Ricker	α	1.5843	0.1609 2.4178	0.867	167	286	-68.365	-0.049
	β	0.003496	0.001141 0.005906					
Beverton-Holt	α	186.1	67.9 304.3	0.880	186	1,277	-69.895	0.029
	β	65.0	-59.1 189.2					
Smooth hockey stick	α	5.045	4.381 5.378	-0.450	155	344	-69.379	0.003
	β	2.180	-89.369 3.704					
Marsh Creek Population								
Ricker	α	1.1852	-1.8268 1.9269	0.823	241	552	-32.237	0.218

Model	Parameter	Parameter value	Bootstrap 95% CI	Corr coef	K_R	K_{sp}	AICc	Adj R^2
	β	0.001810	-0.003063 0.003625					
Beverton-Holt	α	383.3	-85109314 665.4	0.970	383	5,310	-32.291	0.234
	β	282.4	-99999944 564.9					
Smooth hockey stick	α	5.565	-22.631 6.584	-0.694	261	984	-32.264	0.227
	β	1.265	-108.574 2.531					
Sesech Population								
Ricker	α	1.6835	-2.9253 2.5951	0.912	421	680	-54.589	-0.005
	β	0.001470	-0.002951 0.002941					
Beverton-Holt	α	689.9	-986.8 2366.7	0.981	690	6,591	-54.678	0.000
	β	351.7	-1059.0 1762.5					
Smooth hockey stick	α	6.1528	-22.851 6.815	-0.821	470	1,185	-54.633	-0.002
	β	0.8000	-119.370 2.909					
Little Wenatchee Population								
Ricker	α	0.7447	0.0828 1.0280	0.735	356	1,298	-66.978	0.357
	β	0.000770	-0.003052 0.001541					
Beverton-Holt	α	564.7	-74423355 1067.6	0.994	565	13,400	-67.055	0.358
	β	719.7	-99999856 1413.4					
Smooth hockey stick	α	6.0181	-49.5620 8.1122	-0.683	411	2,544	-67.000	0.357
	β	0.7550	-0.9539 1.0452					

Method 1: Productivity Data Adjusted for Density Dependence

Analysis of supplementation effects on productivity (adult recruits/spawner adjusted for density-dependent effects based on the smooth hockey stick model) using difference scores indicated that supplementation did not significantly decrease productivity in the Chiwawa Basin (Table 25; Figure 16). All tests, regardless of treatment-reference pairs, indicated that productivity did not change significantly during the supplementation period, even though productivity did decrease during the supplementation period (Figure 16). These results are consistent with those based on unadjusted productivity data (Table 17). This is because most abundance estimates were below the level of assumed density dependence.

Table 25. Results of the Aspin-Welch unequal-variance test, randomization test (based on 10,000 Monte Carlo samples), and 95% CI (based on 5,000 bootstrap samples) on transformed and untransformed productivity data corrected for density dependence. Tests determined if the mean difference scores during the supplementation period were greater than mean difference scores during the pre-supplementation period.

Reference population	Aspin-Welch unequal-variance test			Randomization test P-value	Bootstrap 95% CI
	t-value	P-value	Effect size		
Productivity					
Naches	0.904	0.190	0.496	0.412	-0.511 – 1.497
Marsh	-0.203	0.579	0.152	0.927	-1.298 – 1.372
Sesech	1.607	0.071	1.435	0.146	-0.359 – 2.911
Little Wenatchee	0.431	0.335	0.147	0.668	-0.487 – 0.781
LN Productivity					
Naches	0.570	0.290	0.083	0.568	-0.168 – 0.362
Marsh	0.012	0.495	0.003	0.991	-0.373 – 0.480
Sesech	1.463	0.087	0.343	0.171	-0.125 – 0.732
Little Wenatchee	0.390	0.351	0.060	0.709	-0.218 – 0.365

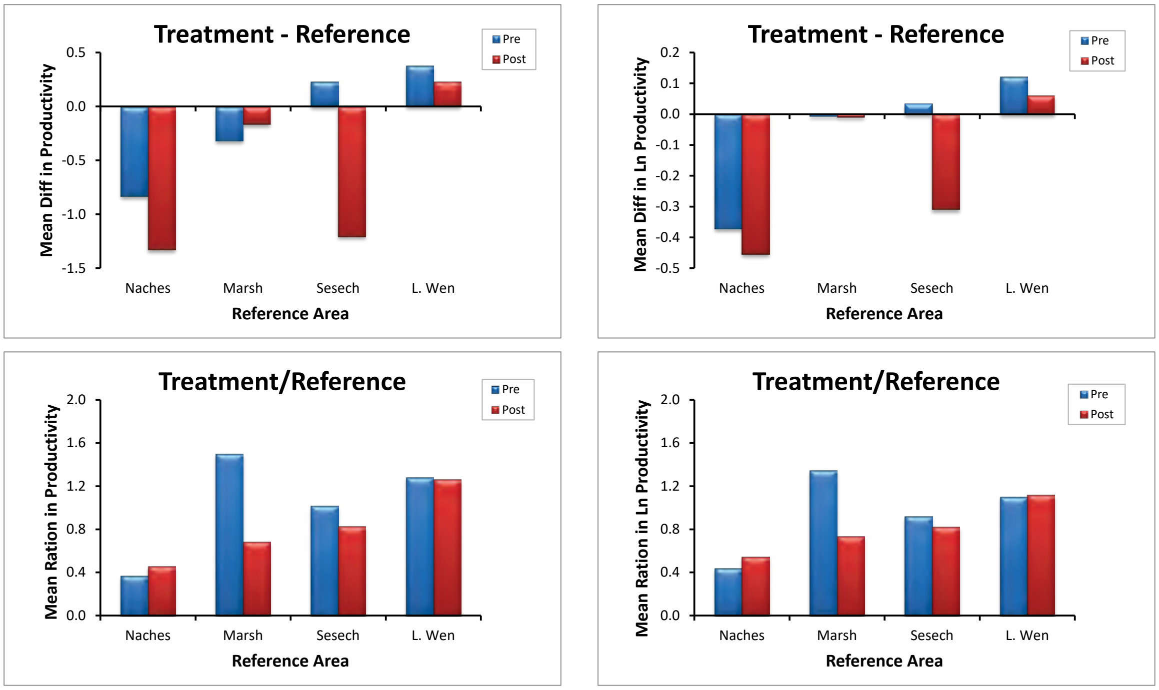

Figure 16. Mean differences (Treatment – Reference; figures on the top) and mean ratios (Treatment/Reference; figures on the bottom) of transformed and untransformed productivity data (adjusted for density dependence) before (pre) and after (post) spring Chinook supplementation in the Chiwawa Basin. Negative effects of supplementation on productivity are indicated when the pre-supplementation (blue) bars are greater than their corresponding post-supplementation (red) bars.

Analysis of supplementation effects on productivity (adult recruits/spawner adjusted for density-dependent effects) using ratios indicated that supplementation did not significantly decrease productivity in the Chiwawa Basin (Table 26; Figure 16). The Aspin-Welch test and the 95% CIs did indicate a significant effect when comparing the Chiwawa to the Marsh Creek population. These results are consistent with those using unadjusted productivity data (Table 20). Again, this is because most abundance estimates were below the level of assumed density dependence.

Table 26. Results of the Aspin-Welch unequal-variance test, randomization test (based on 10,000 Monte Carlo samples), and 95% CI (based on 5,000 bootstrap samples) on transformed and untransformed productivity data corrected for density dependence. Tests determined if the mean ratios during the supplementation period were less than mean ratios during the pre-supplementation period.

Reference population	Aspin-Welch unequal-variance test			Randomization test P-value	Bootstrap 95% CI
	t-value	P-value	Effect size		
Productivity					
Naches	-0.529	0.696	0.087	0.597	-0.394 – 0.214
Marsh	2.236	0.022	0.814	0.056	0.140 – 1.470
Sesech	0.677	0.253	0.191	0.496	-0.343 – 0.727
Little Wenatchee	0.033	0.487	0.018	0.978	-0.902 – 1.181
LN Productivity					
Naches	-0.621	0.726	0.104	0.536	-0.406 – 0.191

Reference population	Aspin-Welch unequal-variance test			Randomization test P-value	Bootstrap 95% CI
	t-value	P-value	Effect size		
Marsh	1.952	0.036	0.613	0.076	0.005 – 1.163
Sesech	0.447	0.330	0.098	0.649	-0.312 – 0.498
Little Wenatchee	-0.034	0.513	0.015	0.980	-0.697 – 0.852

Our analyses assume that there is a spawner abundance (K_{sp}) at which density-independent effects end and density-dependent effects begin. In reality, density-dependent effects occur at low spawning abundance and intensify as spawning abundance increases (evident in the changing slope of the three stock-recruitment curves used in our analyses). We did not account for these increasing density-dependent effects at spawner abundances less than K_{sp}. If we accounted for the increasing effects of density dependence at spawning abundances less than K_{sp}, the analysis with and without productivity adjustments may give different results.

Method 2: Fraction of Carrying Capacity Filled with NORs

We analyzed the effects of supplementation on filling the capacity of the habitat with natural-origin recruits. The smooth hockey stick model derived the carrying capacity (K_R) estimates for the Chiwawa and reference populations. The fraction of the carrying capacity filled with Chinook recruits before and during supplementation for the Chiwawa and reference populations is provided in Table 27. These data indicate that for the Chiwawa population, the mean fraction of the K_R filled with fish decreased significantly from the pre-supplementation period through the supplementation period (Table 27). Likewise, the Entiat and Little Wenatchee populations showed a significant decline in the mean fraction of K_R filled with adult recruits. In contrast, the mean fraction of K_R in the Naches and Marsh Creek populations increased during the same period (Table 27).[22] Interestingly, the fraction of K_R filled with adult recruits for all populations trended downward during the pre-supplementation period (Figure 17). During the supplementation period, however, the fraction of K_R filled with adult recruits trended upward for all populations. These results suggest that agents of mortality outside the Chiwawa and reference populations were reducing recruitment to the populations.

22 Although we do not show the results here, statistical analysis of the mean fraction of carrying capacity filled by adult recruits using natural-log transformed data produced the same result as using untransformed data. This was true for all populations.

Table 27. Fraction of the carrying capacity that was filled with Chinook salmon adult recruits in the Chiwawa and reference populations before (pre) and during (post) supplementation in Chiwawa Basin. The smooth hockey stick model estimated carrying capacity for each population. Statistical results from comparing the pre and post mean scores using the Aspin-Welch unequal-variance test are provided at the bottom of the table.

Supplementation period	Chiwawa	Reference populations			
		Naches	Entiat	Marsh	L. Wenatchee
Pre-supplementation period (1981-1992)	2.11		2.38	1.07	0.64
	1.53		1.93	1.20	0.75
	1.20		1.32	2.60	0.78
	1.14		1.19	0.49	0.62
	0.99		1.06	0.46	0.34
	0.70	2.30	1.43	0.56	0.24
	0.65	0.58	0.74	0.34	0.20
	0.95	1.88	1.34	1.40	0.36
	0.18	0.72	1.63	0.22	0.15
	0.05	0.27	0.45	0.02	0.02
	0.00	0.20	0.21	0.03	0.01
Pre-Mean:	0.86	0.99	1.24	0.76	0.37
Pre-Range:	0.00 – 2.11	0.20 – 2.30	0.21 – 2.38	0.02 – 2.60	0.01 – 0.78
Post-supplementation period (1992-2002)	0.05	0.98	0.34	0.41	0.03
	0.15	0.86	0.41	1.13	0.04
	0.04	0.35	0.27	0.02	0.03
	0.05	0.44	0.30	0.02	0.03
	0.19	4.39	0.65	0.45	0.06
	0.82	2.68	1.85	2.78	0.22
	0.31	2.37	1.65	4.10	0.08
	0.01	0.53	0.42		0.02
	0.71	1.62	0.82		0.10
	0.28	1.35	0.93		0.14
	0.27	0.83	0.98		0.18
Post-Mean:	0.26	1.49	0.78	1.27	0.08
Post-Range:	0.04 – 0.82	0.35 – 4.39	0.30 – 1.85	0.02 – 4.10	0.02 – 0.22
One-sided Aspin-Welch t-test of pre and post means	t = 2.846; P = 0.007	t = -0.967; P = 0.825	t = 1.833; P = 0.041	t = -0.799; P = 0.776	t = 3.321; P = 0.003

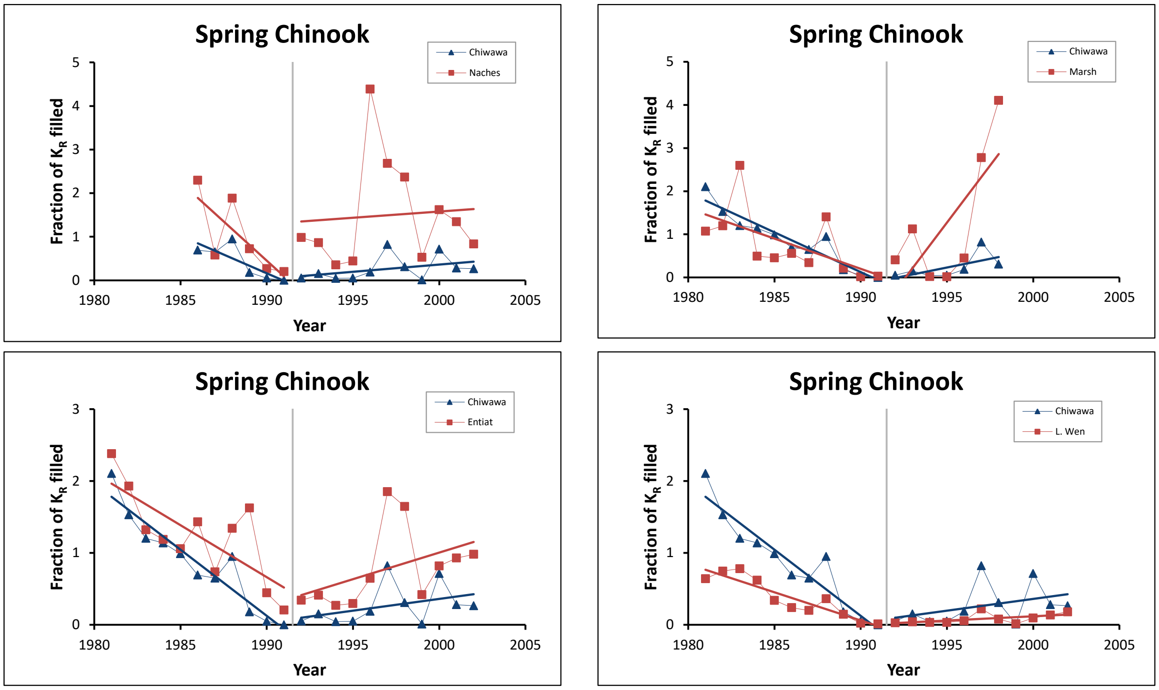

Figure 17. Trends in the fraction of the carrying capacity that was filled with Chinook salmon adult recruits in the Chiwawa and reference populations before (pre) and during (post) supplementation in Chiwawa Basin. The vertical lines in the figures separate the pre- and post-supplementation periods. The smooth hockey stick model estimated carrying capacity for each population.

We then compared the mean difference scores and ratios between the Chiwawa and reference populations before and during supplementation using data representing the fraction of K_R filled with adult recruits. In most of the Chiwawa-reference population comparisons, the absolute value of the mean difference between the fraction of K_R filled with recruits was greater in the supplementation period than during the pre-supplementation period; two of the four pairings were significant (Table 28; Figure 18). Analysis of difference scores using natural-log transformed data indicated that three of the four pairings were significant (Table 28).

Results from analyses using ratios were similar to results using difference scores. Mean ratio scores were generally smaller during the supplementation period than during the pre-supplementation period (Figure 18). This indicated that the mean fraction of K_R filled by adult recruits in most reference populations was greater during the supplementation period than during the pre-supplementation period (i.e., the denominator in the ratio increased between the pre- and post-supplementation periods). In contrast, the fraction of K_R filled by adult recruits in the Chiwawa decreased from the pre- to post-supplementation period (i.e., the numerator in the ratio decreased between the pre- and post-supplementation periods). Thus, unlike the Chiwawa population, the capacity of most reference populations was becoming more saturated during the period when the Chiwawa was being supplemented. Statistical analysis with mean ratios indicated that two of the four pairings were significant (Table 29).

Analyses comparing the Little Wenatchee with the Chiwawa indicate that adult recruits to the Little Wenatchee have been well below its carrying capacity. During the pre-supplementation period, the capacity of the Little Wenatchee was on average 37% saturated with adult recruits. During the supplementation period, the capacity of the Little Wenatchee declined to 8% saturation

with adult recruits (a 22% decline). The Chiwawa, during the pre-supplementation period, was on average 86% saturated. During the supplementation period, percent saturation in the Chiwawa decreased to 26% (a 30% decrease). During the same time periods, the capacity of the Entiat population, which until recently has been supplemented, declined from 124% to 78% saturation (a 63% decline).

Table 28. Results of the Aspin-Welch unequal-variance test, randomization test (based on 10,000 Monte Carlo samples), and 95% CI (based on 5,000 bootstrap samples) on the fraction of the habitat capacity (K_R) that is filled with natural origin recruits. Analyses include both transformed and untransformed data. Tests determined if the mean difference scores during the supplementation period were greater than mean difference scores during the pre-supplementation period.

Reference population	Aspin-Welch unequal-variance test			Randomization test P-value	Bootstrap 95% CI
	t-value	P-value	Effect size		
Fraction of Capacity Filled					
Naches	1.550	0.071	0.657	0.145	-0.173 – 1.378
Entiat	0.835	0.207	0.141	0.422	-0.167 – 0.475
Marsh	2.026	0.040	1.141	0.055	0.064 – 2.054
Little Wenatchee	2.166	0.023	0.310	0.031	0.035 – 0.569
LN Fraction of Capacity Filled					
Naches	2.123	0.026	0.311	0.039	0.031 – 0.575
Entiat	1.405	0.087	0.122	0.176	-0.034 – 0.289
Marsh	2.547	0.017	0.519	0.017	0.125 – 0.864
Little Wenatchee	1.744	0.049	0.130	0.100	-0.004 – 0.273

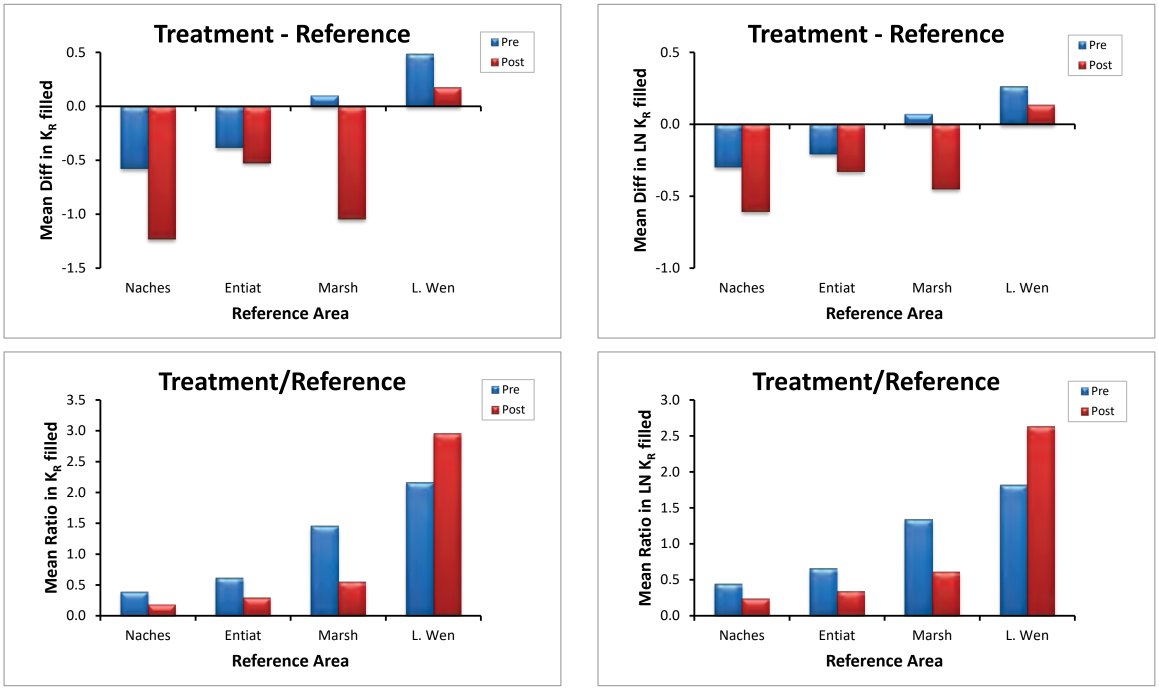

Figure 18. Mean differences (Treatment – Reference; figures on the top) and mean ratios (Treatment/Reference; figures on the bottom) of transformed and untransformed fractions of carrying capacity filled with adult recruits before (pre) and after (post) spring Chinook supplementation in the Chiwawa Basin.

Table 29. Results of the Aspin-Welch unequal-variance test, randomization test (based on 10,000 Monte Carlo samples), and 95% CI (based on 5,000 bootstrap samples) on the fraction of the habitat capacity (K_R) that is filled with natural origin recruits. Analyses include both transformed and untransformed data. Tests determined if the mean ratios during the supplementation period were less than mean ratios during the pre-supplementation period.

Reference population	Aspin-Welch unequal-variance test			Randomization test P-value	Bootstrap 95% CI
	t-value	P-value	Effect size		
Fraction of Capacity Filled					
Naches	1.317	0.119	0.217	0.219	-0.103 – 0.482
Entiat	2.449	0.013	0.321	0.028	0.085 – 0.577
Marsh	2.001	0.035	0.905	0.070	0.138 – 1.788
Little Wenatchee	-1.148	0.864	0.791	0.278	-1.979 – 0.578
LN Fraction of Capacity Filled					
Naches	1.257	0.127	0.207	0.249	-0.099 – 0.484
Entiat	2.346	0.016	0.313	0.031	0.072 – 0.583
Marsh	1.737	0.056	0.729	0.111	0.028 – 1.531
Little Wenatchee	-1.525	0.924	0.815	0.142	-1.751 – 0.195

Comparing Stock-Recruitment Curves

As a final set of treatment and reference population comparisons, we compared the stock-recruitment curves of the Chiwawa population (using {R, S} data only from the supplementation period) to the reference populations (using all available {R, S} data). Specifically, we tested whether the regression parameters were equal between the Chiwawa population and the reference populations, and whether the fitted curves coincided between populations. Earlier in this report we described the data, methods, and results of fitting the Ricker, Beverton-Holt, and smooth hockey stick curves to the data. Because AIC_c was unable to identify a best approximating model, here we included all three models in our analyses. We tested the following hypotheses.

Parameter equivalence:

Ho: Stock-recruitment parameters (α and β) of the Chiwawa population = Stock-recruitment parameters of the reference populations.

Ha: Stock-recruitment parameters (α and β) of the Chiwawa population ≠ Stock-recruitment parameters of the reference populations.

Curve equivalence:

Ho: Modeled stock-recruitment curves of the Chiwawa population = Modeled stock-recruitment curves of the reference populations.

Ha: Modeled stock-recruitment curves of the Chiwawa population ≠ Modeled stock-recruitment curves of the reference populations.

We used two-sided randomization tests to test the null hypotheses of equal model parameters and that fitted curves coincided. Because the total number of permutations was in the millions, we used a Monte Carlo approach to randomly select 10,000 permutations. The test statistic for comparing the model parameters was formed by summing the difference between the population parameter estimates for each pair of populations. The test statistic for comparing the whole curve was formed by summing the difference between the estimated predicted values for each pair of populations at 500 equally spaced points along the curve.

Ricker Relationships

Ricker curves differed significantly between the Chiwawa and reference populations (Figure 19; Table 30). Interestingly, however, the parameters in the Ricker model did not differ significantly among most populations (Table 30). Only the β parameter differed significantly between the Chiwawa and Entiat populations.

In the Ricker model, the α parameter represents intrinsic productivity (i.e., recruits per spawner at low spawner densities). In this analysis, there was not enough evidence in the stock-recruitment data to reject the hypothesis of inequality in intrinsic productivity. Thus, this test was unable to demonstrate that supplementation, based on the Ricker curve, affected productivity in the Chiwawa population.

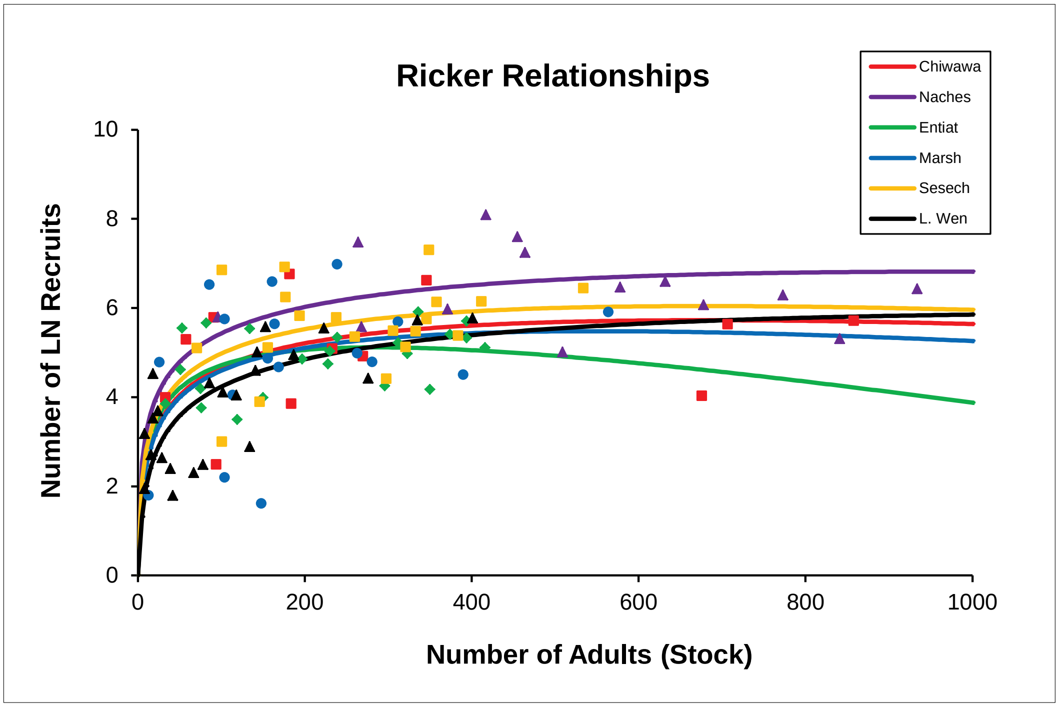

Figure 19. Scatter plot of the number of spawners and natural log adult recruits and fitted Ricker curves to the Chiwawa (supplemented population) and reference (un-supplemented) populations.

Table 30. Randomization test results comparing the equality of Ricker curves and equality of parameter values (α and β). Randomization tests were based on 10,000 Monte Carlo samples. Equality or curves was based on 500 points along the x-axis (spawner abundance axis).

Curves tested	Curve inequality randomization P-value	Parameter inequality		
		Model Parameter		Randomization P-value
		Chiwawa	Reference	
Chiwawa v. Naches	0.008	α = 1.2247	α = 2.5267	0.236
		β = 0.0015	β = 0.0010	0.600
Chiwawa v. Entiat	0.004	α = 1.2247	α = 1.5836	0.978
		β = 0.0015	β = 0.0035	0.025
Chiwawa v. Marsh	0.034	α = 1.2247	α = 1.1855	0.997
		β = 0.0015	β = 0.0018	0.688
Chiwawa v. Sesech	0.036	α = 1.2247	α = 1.6818	0.972
		β = 0.0015	β = 0.0015	0.997
Chiwawa v. L. Wenatchee	0.034	α = 1.2247	α = 0.7439	0.969
		β = 0.0015	β = 0.0008	0.203

Beverton-Holt Relationships

Beverton-Holt curves differed significantly only between the Chiwawa and Naches populations (Figure 20; Table 31). There was no significant difference in curves between the Chiwawa and the other reference populations. The parameters in the Beverton-Holt model did not differ significantly among any of the populations (Table 31). This was true even for the Chiwawa and Naches populations.

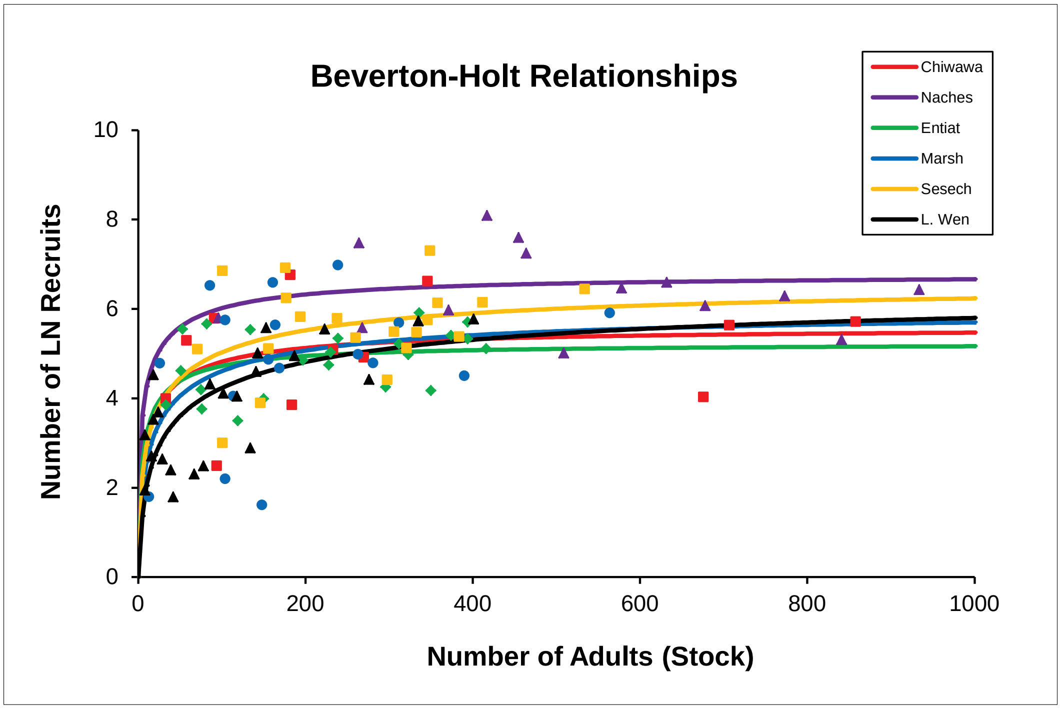

Figure 20. Scatter plot of the number of spawners and natural log adult recruits and fitted Beverton-Holt curves to the Chiwawa (supplemented population) and reference (un-supplemented) populations.

Table 31. Randomization test results comparing the equality of Beverton-Holt curves and equality of parameter values (α and β). Randomization tests were based on 10,000 Monte Carlo samples. Equality or curves was based on 500 points along the x-axis (spawner abundance axis).

Curves tested	Curve inequality randomization P-value	Parameter inequality		
		Model Parameter		Randomization P-value
		Chiwawa	Reference	
Chiwawa v. Naches	0.036	α = 264.25	α = 870.62	0.777
		β = 113.79	β = 112.24	0.963
Chiwawa v. Entiat	0.746	α = 264.25	α = 186.34	0.960
		β = 113.79	β = 65.33	0.954
Chiwawa v. Marsh	0.850	α = 264.25	α = 381.79	0.944
		β = 113.79	β = 281.04	0.891

Curves tested	Curve inequality randomization P-value	Parameter inequality		
		Model Parameter		Randomization P-value
		Chiwawa	Reference	
Chiwawa v. Sesech	0.272	α = 264.25	α = 689.31	0.821
		β = 113.79	β = 351.59	0.869
Chiwawa v. L. Wenatchee	0.654	α = 264.25	α = 568.69	0.864
		β = 113.79	β = 725.87	0.751

Smooth Hockey Stick Relationships

Smooth hockey stick curves differed significantly between the Chiwawa and Naches populations and the Chiwawa and Sesech populations (Figure 21; Table 32). There was no significant difference in curves between the Chiwawa and the other reference populations. Most of the parameters in the smooth hockey stick model did not differ significantly among the populations (Table 32). However, the productivity parameter β did differ significantly between the Chiwawa and the Naches and the Chiwawa and Little Wenatchee populations. The β parameter for the Naches was significantly greater than the Chiwawa, while the β parameter for the Little Wenatchee was significantly less than the Chiwawa.

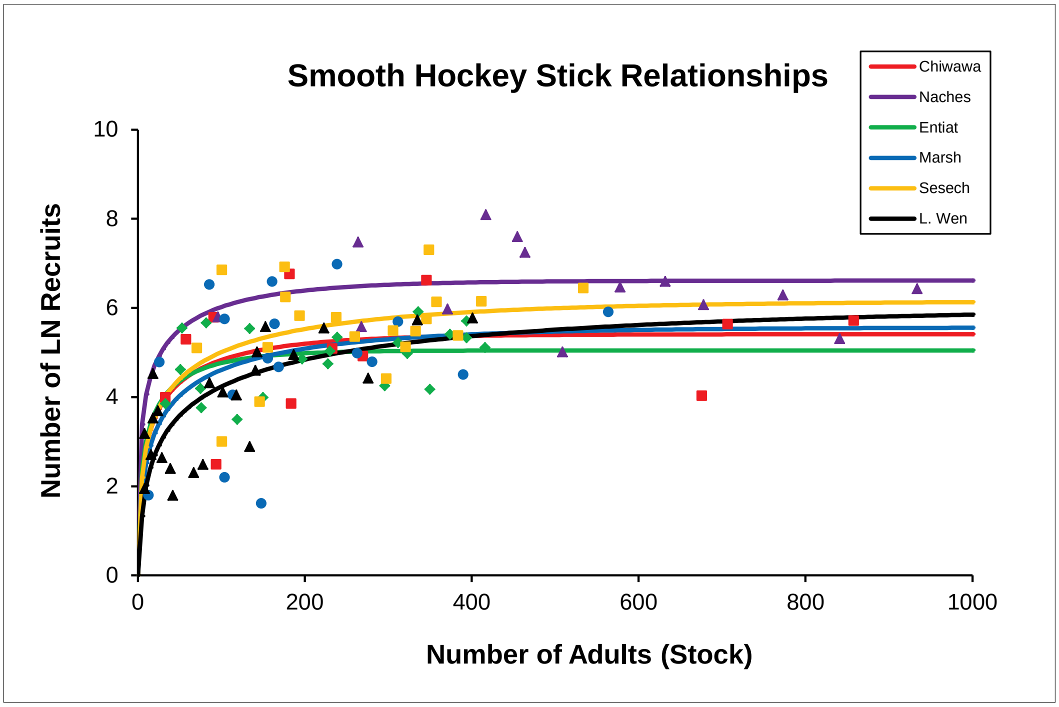

Figure 21. Scatter plot of the number of spawners and natural log adult recruits and fitted smooth hockey stick curves to the Chiwawa (supplemented population) and reference (un-supplemented) populations.

Table 32. Randomization test results comparing the equality of smooth hockey stick curves and equality of parameter values (α and β). Randomization tests were based on 10,000 Monte Carlo samples. Equality or curves was based on 500 points along the x-axis (spawner abundance axis).

Curves tested	Curve inequality randomization P-value	Parameter inequality		
		Model Parameter		Randomization P-value
		Chiwawa	Reference	
Chiwawa v. Naches	0.000	α = 5.41	α = 6.61	0.000
		β = 1.84	β = 5.99	0.000
Chiwawa v. Entiat	0.999	α = 5.41	α = 5.05	0.999
		β = 1.84	β = 2.17	0.999
Chiwawa v. Marsh	0.999	α = 5.41	α = 5.56	0.999
		β = 1.84	β = 1.27	0.999
Chiwawa v. Sesech	0.000	α = 5.41	α = 6.15	0.000
		β = 1.84	β = 1.80	0.999
Chiwawa v. L. Wenatchee	0.990	α = 5.41	α = 6.02	0.999
		β = 1.84	β = 0.75	0.000

Comparing different stock-recruitment curves and their parameters did not provide strong evidence that the supplementation program has negatively affected the productivity of the Chiwawa population.

Analysis without Reference Populations

In some cases, suitable reference populations may not exist to compare with supplemented populations. It is therefore important to have alternative analyses to assess supplementation effects. In this section, we describe methods that can be used to assess supplementation effects when suitable reference populations are not available. We discuss before-after comparisons, correlation analysis, and comparisons to standards as alternatives when reference populations are unavailable.

Before-After Comparisons

Before-after analyses compare population metrics (spawner abundance, NORs, and productivity) before supplementation to those during supplementation. In this case, data collected before supplementation represent the reference condition. The assumption is that population trajectories measured during the pre-supplementation period would continue in the absence of supplementation. We compared trends in abundance and productivity, mean abundance and productivity, and stock-recruitment relationships before and after supplementation.

Trend Analysis

Comparing trends before and after supplementation can be used to assess the effects of supplementation. Here, we compared the slopes of trends of spawner abundance, NORs, and productivity before and during supplementation using t-tests. If the hatchery program is successfully supplementing the natural spring Chinook population, the trend for spawner abundance and NORs during supplementation should be greater than the slope during the pre-supplementation period. For productivity, the slope during the supplementation period should increase or remain the same as that during the pre-supplementation period.

Visual examination of trends of Chiwawa data indicates that spawner abundance, NORs, and productivity decreased during the pre-supplementation period, but increased during the supplementation period (Figure 22). Only the changes in NOR trends were significant (Figure 22). This was true for both transformed and untransformed data.

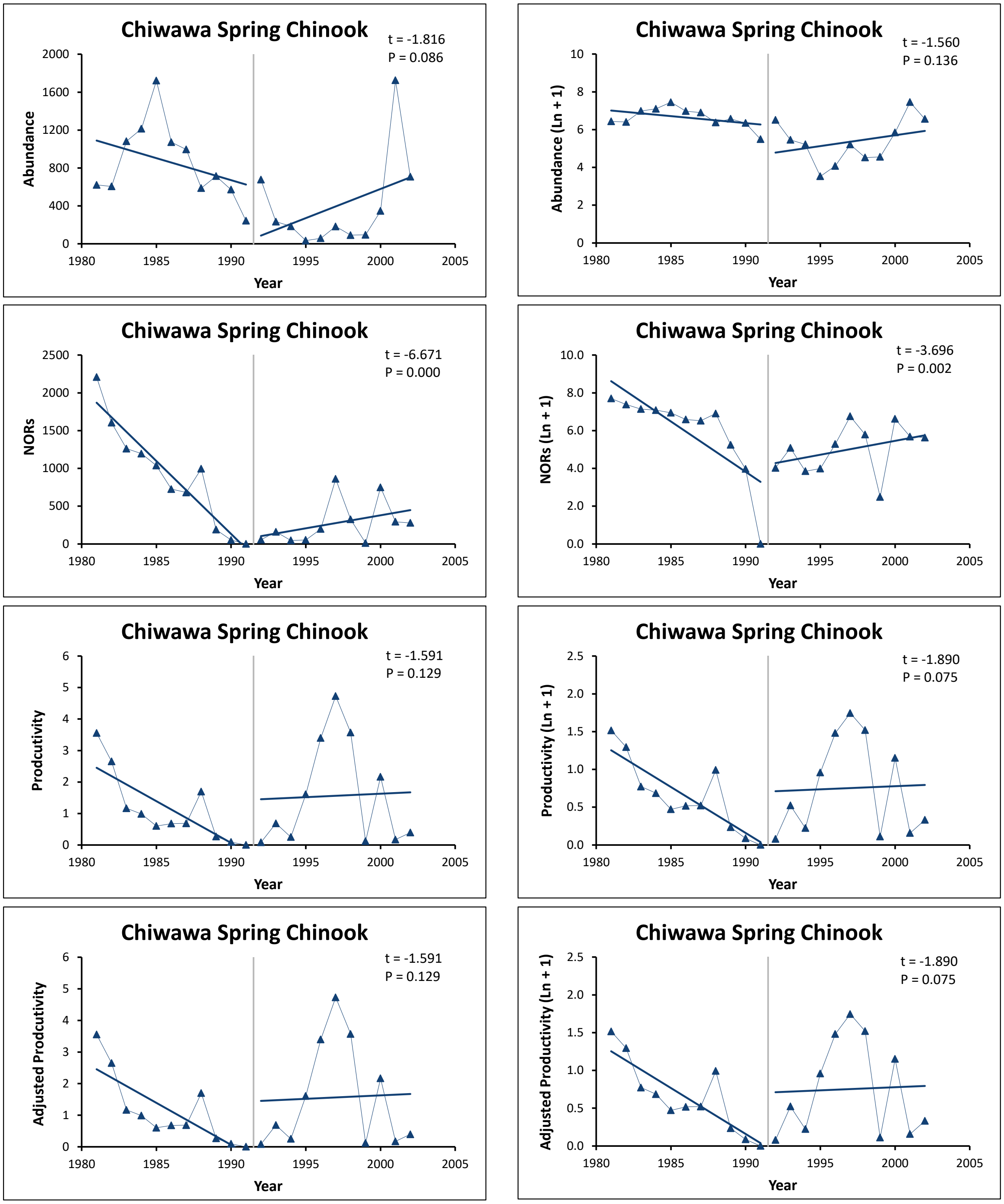

Figure 22. Trends in Chiwawa spring Chinook spawner abundance, natural-origin recruits (NORs), productivity (adults recruits per spawner), and adjusted productivity (adjusted for density dependence) before and during supplementation. The vertical lines in the figures separate the pre- and post-supplementation periods. Figures on the left show untransformed data; figures on the right include natural-log transformed data. Figures include results of t-tests comparing slope of trends before and during supplementation.

Analysis of Mean Scores

We also compared mean spawner abundance, NORs, and productivity data before and after supplementation. If the hatchery program is successfully supplementing the natural spring Chinook population, mean spawner abundance and NORs during the supplementation period should be greater than the pre-supplementation period. For productivity, the mean productivity during the supplementation period should be equal to or higher than the pre-supplementation period. We tested the following statistical hypotheses.

Spawner Abundance and NORs:

Ho: Mean spawner abundance and NORs before supplementation ≥ Mean spawner abundance and NORs during supplementation.

Ha: Mean spawner abundance and NORs before supplementation < Mean spawner abundance and NORs during supplementation.

Productivity (Recruits/Spawner):

Ho: Mean productivity before supplementation ≤ Mean productivity during supplementation.

Ha: Mean productivity before supplementation > Mean productivity during supplementation.

We tested before-after supplementation effects using a one-tailed Aspin-Welch unequal-variance test. We also used a randomization test, based on 10,000 Monte Carlo simulations, to assess differences in spawner abundance and productivity before and during supplementation. The randomization procedure only allowed the testing of two-tailed hypotheses. Therefore, we generated 95% confidence intervals on the mean difference (μ_{pre} - μ_{post}) using bootstrapping methods to determine if the significant result from the randomization test was in the right direction. We generated 5,000 bootstrap samples to calculate confidence intervals.

Mean spawner abundance during the supplementation period was significantly less than the pre-supplementation spawner abundance (Table 33). Mean spawner abundance decreased 46% between the pre- and post-supplementation periods. Likewise, mean NORs decreased significantly between the two periods (Table 33). On the other hand, productivity increased slightly, but not significantly, between the pre- and post-supplementation periods (Table 33). This was true for both adjusted and transformed productivity data.

Table 33. Statistical results comparing mean scores of spawner abundance, natural-origin recruits (NORs), and productivity (using both untransformed and natural-log transformed) before and during supplementation of Chiwawa spring Chinook. Randomization tests were based on 10,000 Monte Carlo samples and 95% CI were based on 5,000 bootstrap samples.

Population metric	Mean scores		Test on means			
			Aspin-Welch test		Random test P-value	Bootstrap 95% CI
	Before	During	t-value	P-value		
Abundance	856	393	2.383	0.986	0.028	112 - 843
LN Abundance	6.6	5.4	3.304	0.997	0.004	0.56 – 1.99
NORs	905	275	2.846	0.993	0.009	214 – 1034
LN NORs	6.0	5.0	1.197	0.876	0.250	-0.40 – 2.54
Productivity	1.13	1.56	-0.721	0.759	0.479	-1.55 – 0.73
LN Productivity	0.64	0.75	-0.450	0.671	0.649	-0.55 – 0.35
Adj Productivity	1.12	1.56	-0.721	0.759	0.477	-1.54 – 0.71
LN Adj Productivity	0.64	0.75	-0.450	0.671	0.652	-0.57 – 0.34

Analysis of Stock-Recruitment Curves

The third method compared stock-recruitment curves of the Chiwawa population during supplementation with those generated before supplementation. Specifically, we tested whether the regression parameters were equal between the pre- and post-supplementation periods, and whether the fitted curves coincided between the two time periods. We used the methods described earlier to fit the Ricker, Beverton-Holt, and smooth hockey stick curves to the two data sets. We tested the following hypotheses.

Parameter equivalence:

Ho: Stock-recruitment parameters (α and β) of the pre-supplementation period = Stock-recruitment parameters of the supplementation period.

Ha: Stock-recruitment parameters (α and β) of the pre-supplementation period ≠ Stock-recruitment parameters of the supplementation period.

Curve equivalence:

Ho: Modeled stock-recruitment curves from the pre-supplementation period = Modeled stock-recruitment curves from the pre-supplementation period.

Ha: Modeled stock-recruitment curves from the pre-supplementation period ≠ Modeled stock-recruitment curves from the pre-supplementation period.

We were only able to fit stock-recruitment curves to the post-supplementation data. Non-linear regression was unable to converge on a solution using only pre-supplementation data. Therefore, we were unable to use this method to test supplementation effects on the Chiwawa spring Chinook population. If we could have fit curves to both the pre- and post-supplementation periods, we would have used two-sided randomization tests to evaluate the null hypotheses of equal model parameters and that fitted curves coincided.

Before describing correlation approaches, it is important to note that comparing before-after data can sometimes be misleading. For example, the spawner abundance, NORs, and productivity data presented in Figure 22 suggest that supplementation is increasing the abundance and productivity of spring Chinook in the Chiwawa Basin. However, when we compared these trends to those from reference populations during the same time periods (Figures 9-11), it becomes clear that supplementation was not responsible for increasing the trends in spawner abundance, NORs, and productivity of the Chiwawa population. Thus, whenever possible, it is wise to compare before-after data with a reference population.

Correlation Analyses

A simple way to see if the supplementation program is increasing or decreasing productivity is to assess the association between the proportion of adult spawners that are made up of hatchery adults (pHOS) and productivity (recruits/spawner). If the supplementation program is working as planned, the increase in hatchery fish spawning naturally should increase the productivity of the population. It should not decrease the productivity of the population.

We tested the association between pHOS and adult productivity[23] using Pearson correlation. During the pre-supplementation period, productivity averaged 1.13 recruits/spawner; during the supplementation period, productivity averaged 1.39 recruits/spawner. This increase in productivity did not appear to be strongly correlated to pHOS (Figure 23). Correlation analysis showed that there was no significant association between pHOS and productivity, even though productivity increased with increasing pHOS.

23 Note that the analysis could also include juvenile productivity (e.g., smolts/spawner).

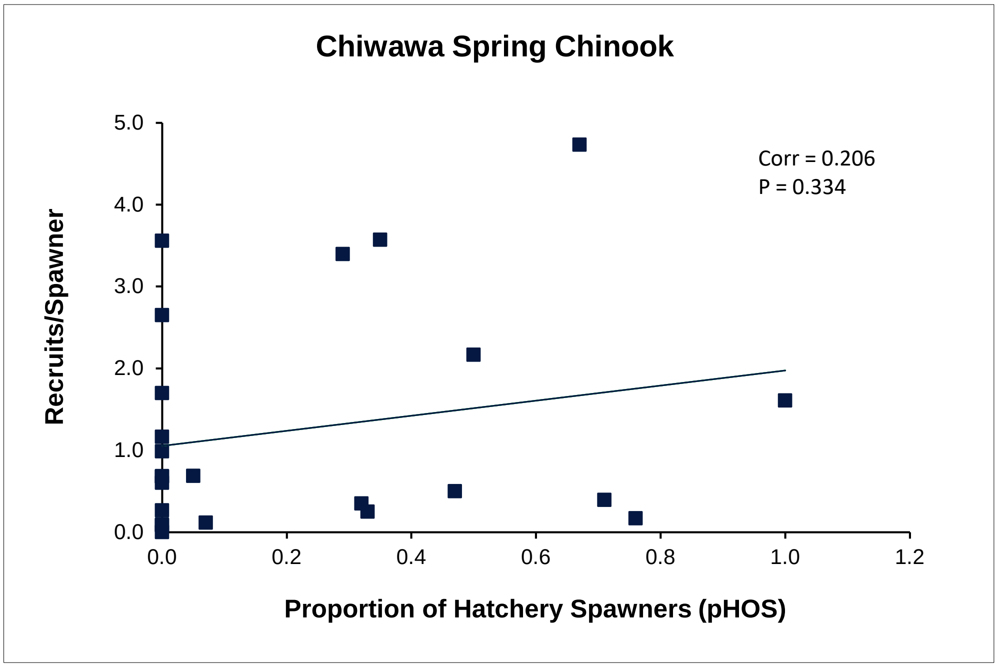

Figure 23. Association between the proportion of spawners that are made up of hatchery adults (pHOS) and the number of natural-origin recruits. The Pearson correlation coefficient (Corr) and its P-value (P) are shown in the figure.

The association between pHOS and productivity can also be assessed by testing the correlation between pHOS and the residuals from stock-recruitment curves fitted to the Chiwawa spawner and natural-origin recruitment data. This approach removes the effects of density dependence on the relationship between pHOS and productivity. A significant negative association provides evidence that hatchery-origin spawners may not be as productive as natural-origin spawners.

The Ricker, Beverton-Holt, and smooth hockey stick models were fit to the Chiwawa stock and recruitment data (including {S, R} data from both the pre- and post-supplementation period, 1981-2004) using methods described earlier. Residuals were calculated by subtracting the predicted recruitment values from the observed (modeled) values. Pearson correlation then tested the association between pHOS and the residuals from each model.

Although there was a negative trend in residuals with increasing pHOS, suggesting that hatchery-origin spawners may not be as productive as natural-origin spawners, the association was not significant (Figure 24). Thus, based on these analyses, there is no strong evidence that the supplementation program has significantly benefited or harmed the natural spring Chinook population.

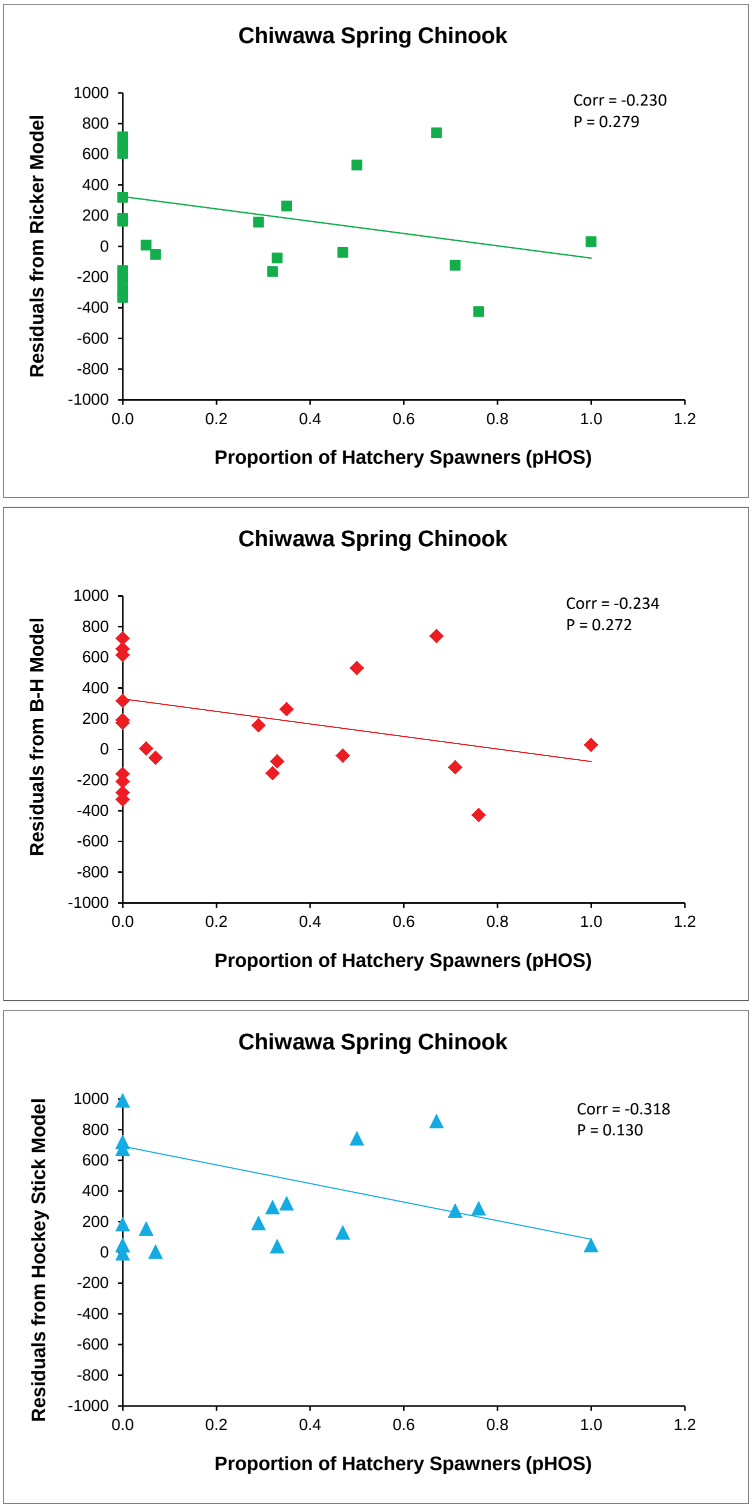

Figure 24. Association between the proportion of spawners that are made up of hatchery adults (pHOS) and the residuals from Ricker, Beverton-Holt (B-H), and smooth hockey stick stock-recruitment models. The Pearson correlation coefficient (Corr) and its P-value (P) are shown in the figures.

Comparison to Standards

In those cases in which suitable reference populations are not available and there are no pre-supplementation data, the investigator is left with comparing population parameters to relevant standards. Standards can include performance of natural-origin fish in similar environments (a type of reference condition), mitigation requirements, quantitative objectives of the program, Biological Assessment and Management Plan (BAMP) values, or other appropriate standards. An example of a statistical hypothesis would be:

Ho: Productivity (Recruits/Spawner) of the supplemented population ≥ standard productivity.

Ha: Productivity (Recruits/Spawner) of the supplemented population < standard productivity.

For these analyses to be useful, the standards must be based on biological reality.

Conclusions and Recommendations

Hatcheries are an important component of fish production within the Upper Columbia Basin. The goal of some of these programs is to supplement natural production in declining populations. The supplementation programs generally use both hatchery and natural (spawned and reared in nature from either wild or hatchery parents) adults for hatchery broodstock. These programs are designed to supplement natural populations by increasing natural reproduction while preventing the establishment of a domesticated hatchery stock. Thus, the programs should increase total spawning escapement and NORs, and not reduce the productivity of the natural population. Measuring the success of these programs is challenging and expensive.

In this paper, we described methods that can be used to determine if supplementation programs are achieving some of their goals. This paper focused on the use of reference populations to determine if the supplementation programs increase total spawning escapement, NORs, and maintain or increase productivities. In some cases, suitable reference populations may not be available (e.g., we found no suitable reference populations for Upper Columbia steelhead and sockeye). In these cases, alternative methods are needed to assess supplementation effects. We also described these alternative methods in this paper.

Identification of Reference Populations

Finding suitable reference populations that match well with supplemented populations is a difficult and time-consuming process. Our three-step selection process included identification of populations with similar life-history characteristics, few or no hatchery spawners, a long time series of accurate abundance and productivity estimates, and similar freshwater habitat impairments and out-of-basin effects. Those populations that met these criteria were then examined for their relationship with the supplemented population (in this case, the Chiwawa spring Chinook population). Several criteria were scored, including pNOS, correlation, trend, and effect size. Reference populations with total weighed scores of 81 or greater were selected as suitable reference populations.

This selection process provided a valuable framework for selecting suitable reference populations for supplemented populations. Interestingly, we found that a given reference population may match well with one parameter of the supplemented population (e.g., spawning escapement), but not for all parameters (e.g., not NORs or productivity). The reason for this may be related to errors

in the estimation of population parameters and/or differential factors limiting population parameters of supplemented and reference populations. Therefore, depending on the parameter analyzed, a different suite of reference populations may be needed.

An important assumption in the use of reference populations is that the supplemented and reference populations that tracked each other before supplementation would continue to track each other in the absence of supplementation. Given that the reference populations did not match the Chiwawa population on all criteria examined, and some reference populations tracked the Chiwawa population more poorly than others, there may be some uncertainty as to whether differences observed between the supplemented and reference populations during the supplementation period are associated with the hatchery program, or other unaccounted factors. For example, any large-scale change (man-made or natural) within the reference or supplemented population could affect our ability to assess the effectiveness of the supplementation program.

To account for some of these uncontrollable factors, we recommend the use of a "causal-comparative" approach to strengthen the certainty of our inferences. This approach relies on correlative data to try and make a case for causal inference. We recommend that the following state variables be measured and tracked within the supplemented and reference populations: mean annual precipitation, total and riparian forest cover, road density, impervious surface, and alluvium. These variables can be used to describe differences in water temperatures at different life stages (pre-spawning, egg incubation, and summer rearing) and substrate characteristics, including fine sediments and embeddedness. These state variables can be used to help explain possible changes in spawner abundance, NORs, and productivity that are independent of supplementation. In addition, the use of multiple reference streams reduces the possibility that man-made changes to a single reference stream will influence the interpretation of the results.

Analyses with Reference Populations

Using reference populations, we evaluated the effects of supplementation on natural-log transformed and untransformed total spawning escapement, NORs, and productivity by comparing trends, analyzing mean differences, ratios, and rates, and comparing stock-recruitment curves and their parameters. For trend analysis, we compared the slopes of the trends between each supplemented/reference pair before and during supplementation. If the hatchery program is successfully supplementing the natural population, trends in spawner abundance and NORs should deviate significantly during the supplementation period (i.e., the slope of the supplemented population should be greater than the slopes of the reference populations during the supplementation period), but not during the pre-supplementation period. For productivity, the slope of the supplemented population, relative to the reference population, should increase or remain the same.

Because trend analysis only tests the slopes of the trend lines, it does not test for differences in elevations of the trend lines, additional analyses were needed to determine if supplementation increased spawner abundance, NORs, and productivity of the target population without changing the slopes of the trend lines. To do this, we derived three different response variables using natural-log transformed and untransformed spawner abundance, NORs, and productivity data. The first derived variable included difference scores, which were calculated as the difference between paired treatment and reference data (T-R). The second included ratios, which were calculated as the ratio of paired treatment and reference data (T/R). Finally, we calculated the differences in annual changes in paired treatment and reference population data (ΔT-ΔR). If the hatchery

program is successfully supplementing the natural population, the mean difference or ratio score of paired spawner abundance data and NORs during the supplementation period should be greater than the pre-supplementation period. For productivity, the mean difference or ratio score during the supplementation period should be equal to or higher than the pre-supplementation period.

As a final set of analyses, we compared the stock-recruitment curves of the supplemented population (using stock and recruitment data only from the supplementation period) to the reference populations (using all available stock and recruitment data). Specifically, we tested whether the regression parameters were equal between the supplemented population and the reference populations, and whether the fitted curves coincided between populations. Here, we were most interested in comparing the productivity parameters in the models.

Surprisingly, these different analyses yielded similar results when they were applied to the Chiwawa spring Chinook and reference population data. Trend analysis was unable to detect a significant difference in trends between the supplemented and reference populations during the supplementation period. Even though we measured an increasing trend in spawner abundance, NORs, and productivity in the supplemented population during the supplementation period, these same parameters trended upward in the reference populations. Likewise, we were unable to detect a significant supplementation effect using difference scores, ratios, and differences in annual changes. However, we found the results from analysis of mean differences of annual change difficult to interpret and they may be insensitive to treatment effects. A simpler analysis, which is also easier to interpret, is to use trend analysis. Finally, comparing stock-recruitment curves and their parameters did not provide strong evidence that supplementation has affected the productivity of the natural population.

Based on these results, we do not recommend using difference scores of annual change (ΔT-ΔR), nor do we recommend comparing stock-recruitment curves and their parameters. As noted above, difference scores of annual change are difficult to interpret and may be redundant with trend analysis. Testing stock-recruitment curves and their parameters appears redundant with testing differences in productivity using difference scores or ratios. In addition, the analyses are computer intensive and do not appear to be very sensitive to changes.

There was little difference in results using difference scores and ratios. It appears that ratios may be more sensitive to change than difference scores (e.g., we found significant differences in some comparisons using ratios but not with difference scores), but ratios can be more difficult to interpret than difference scores. Nevertheless, we recommend the use of ratios in future analyses.

Correcting for Density Dependence and Carrying Capacity

The analyses described so far assumed that the density of spawners or recruits did not affect the survival and productivity of fish. However, without controlling for density effects, productivity of the population would continue to decline with increasing abundance. This scenario could occur in supplementation programs that increase the number of spawners, and could result in lower productivities relative to reference populations. In addition, lower productivities may be caused by differential environmental carrying capacities rather than the capacity of the supplemented fish to produce offspring. Therefore, we described two different methods for deriving density-corrected estimates of productivity. The first controlled the effects of density on productivity by partitioning observed productivities into density-independent and density-dependent productivity. These productivities were then combined in a single test. The second method corrected for differences in carrying capacities between the supplemented and reference populations. This was accomplished

by calculating the percent saturation of NORs, which was estimated as the ratio of observed NORs to the maximum number of NORs that the habitat could support.

We fit Ricker, Beverton-Holt, and smooth hockey stick models to stock and recruitment data to estimate the maximum number of NORs (NORs at carrying capacity) and the maximum number of spawners needed to produce maximum NORs. We fit models to the supplemented and reference populations. Using information-theoretic criterion and evaluating the precision of estimated parameters, we found that the smooth hockey stick model provided the best estimates of maximum NORs and spawners. We used these modeled values to estimate density-independent and density-dependent productivities, and saturation of NORs.

Statistical analyses, using difference scores and ratios of adjusted Chiwawa spring Chinook productivity data, found no significant effects of supplementation on the productivity of the supplemented population. Indeed, the results from correcting for density dependence were similar to those without correcting for density dependence. This is in part because the abundance of the supplemented and reference populations has been below their respective carrying capacities in most years. This was clearly demonstrated in the analyses of NORs corrected for carrying capacity. In the supplemented population, the mean fraction of the carrying capacity filled with NORs decreased significantly during the supplementation period. In other words, the carrying capacity was filled with more NORs during the pre-supplementation period than during the supplementation period, which is contrary to the goal of supplementation. By comparison, two of the reference populations showed a similar decrease in saturation, while the other two reference populations actually increased in saturation. Analyzing the saturation scores using BACI-design analyses indicated that two of the four pairings differed significantly. That is, the percent saturation of the supplemented population decreased significantly relative to two reference populations.

Because productivity can be affected by the abundance of spawners and recruits, we recommend that future analyses comparing supplemented and reference populations adjust for density-dependent effects and differential carrying capacities. Although we detected only slight differences between adjusted and unadjusted results, as supplemented stocks recover, it will become more important to adjust productivities to account for density dependence. Importantly, the analyses using percent saturation placed NORs in the context of the carrying capacity of the environment. This will help managers determine if supplementation programs are filling or over-filling the capacity of the habitat with NORs.

As we noted earlier, analyses using productivities adjusted for density dependence assume that there is a spawner abundance at which density-independent effects end and density-dependent effects begin. In reality, density-dependent effects occur at low spawning abundance and intensify as spawning abundance increases. We did not account for these increasing density-dependent effects at lower spawner abundances. This is an area that needs additional attention.

Analyses without Reference Populations

Because of the rigorous criteria we used to select reference populations, it is likely that reference populations may not exist for making comparisons with supplemented populations. For example, we used the criteria described in this paper to identify reference populations for supplemented steelhead and sockeye populations in the Upper Columbia Basin. We were unsuccessful in identifying any suitable reference populations. Therefore, in the absence of suitable reference populations, it is important to have alternative methods for assessing supplementation effects. We described three different types of analyses one can use to assess supplementation effects in the

absence of reference populations. They include before-after comparisons, correlation analysis, and comparisons to standards.

Before-after analyses compare population metrics before supplementation with those during supplementation. In this case, data collected before supplementation represent the reference condition. The assumption is that population trajectories measured during the pre-supplementation period would continue in the absence of supplementation. We compared trends in spawner abundance, NORs, and productivity before and after supplementation. In addition, we compared mean scores in these three parameters before and after supplementation. Finally, we attempted to compare stock-recruitment parameters before and after supplementation. The hypotheses examined were that the spawner abundance and NORs would be greater during the supplementation period, and that productivities would not decline during the supplementation period.

Trend analysis indicated that the all three Chiwawa spring Chinook population parameters trended downward during the pre-supplementation period, but trended upward during supplementation. On the other hand, mean spawner abundance and NORs were lower during the supplementation period than during the pre-supplementation period. Mean productivities increased, but not significantly, during the supplementation period. We were unable to compare pre- and post-supplementation stock-recruitment curves because we were unable to fit stock-recruitment models to the pre-supplementation data.

We used correlation analyses to determine if the proportion of hatchery-origin fish that spawn naturally on the spawning grounds (pHOS) increased productivity. In addition, we used correlation to assess the association between pHOS and the residuals from stock-recruitment relationships. A significant negative association provides evidence that hatchery-origin spawners may not be as productive as natural-origin spawners. The analysis indicated that the productivity of Chiwawa spring Chinook increased with increasing pHOS, but the association was not significant. In contrast, there was a negative association between pHOS and the stock-recruitment residuals, but again the association was not significant. The latter analysis accounts for density-dependent effects.

In concert, the before-after comparisons and correlation analyses do not provide conclusive evidence that the supplementation program has increased spawner abundance and NORs, or that it has significantly reduced the productivity of the supplemented population. Although increasing the number of hatchery fish on the spawning grounds appears to reduce NORs and productivity, mean productivity actually increased during the supplementation period compared to the pre-supplementation period.

It is important to note that relying on only one set of analysis could result in drawing a wrong conclusion. For example, if we had only conducted trend analysis, we may have concluded wrongly that the Chiwawa spring Chinook supplementation program significantly increased spawner abundance, NORs, and productivity in the supplemented population. The analysis of mean scores and correlations indicates that the supplementation program has not increased spawner abundance or NORs in the supplemented population. Therefore, in the absence of suitable reference populations, we recommend that analyses include the evaluation of trends, means scores, and correlations. By conducting more than one set of analyses, one can use weight-of-evidence to assess the effects of supplementation programs.

Under the scenario that there are no reference populations or pre-supplementation data, one is left with comparing population parameters to relevant standards. These standards could come from mitigation requirements, quantitative objectives, or published or unpublished standards. One could also use correlation to evaluate the association between productivity and pHOS, but this requires a wide range in pHOS values to be most effective. A more extreme approach, which probably would not gain much traction with managers, is to shutoff the supplementation program for some time and then evaluate the effects of the program in a before-after design. The Entiat spring Chinook hatchery program provides a unique opportunity to evaluate this type of management decision.

Some Concerns and Limitations

No matter how hard we try to explain different sources of variation in population data, we are limited by the quality of the data. Teasing out the effects of supplementation requires long time series of population data. Because funding levels and methods change over time, the quality (i.e., accuracy and precision) of the data also changes over time. Importantly, the population parameters examined in this paper (spawner abundance, NORs, and productivity) are rarely measured directly in the field. That is, other population metrics, such as numbers of redds, number of fish counted at weirs or dams, scales, tags, etc., are sampled in the field. These metrics are then used to calculate spawner abundance[24], NORs, and productivity, often based on assumptions about fish/redd, pre-spawning loss, marking rates, and sampling rates. This has a tendency to increase the variability in the data independent of supplementation programs. In our studies, we can only control sampling within the supplemented populations, and even that is limited by available funding. We have no control over the sampling within reference populations. Thus, we have to assume that sampling within the reference populations will continue and that sampling effort will remain comparable to that in the supplemented populations.

In our analyses, we included both the Entiat and Little Wenatchee populations as references for the Chiwawa population. In the analyses, we treated them as equivalent to the other reference populations. That is, the statistical procedures used to compare the supplemented population to each reference population were identical. This is appropriate. However, the interpretation of the results must be different when comparing the Entiat and Little Wenatchee to the supplemented population, because they are populations that were influenced by hatchery fish. As noted earlier, the Entiat spring Chinook hatchery program has been discontinued. Therefore, it provides a unique type of reference where the comparison changes from both populations being supplemented to only one population being supplemented. For the Little Wenatchee, nearly all the strays came from the Chiwawa program. Straying should stop or be greatly reduced with the change in water supply to the Chiwawa Rearing Ponds. In sum, one must be careful in how they interpret these test-reference results.

Finally, it is important to point out that for this paper, we conducted 463 statistical tests. Because we set our Type I error rate at 0.05, by random chance alone, we may have incorrectly rejected about 23 null hypotheses. Inasmuch as this work was designed to evaluate different ways to analyze test-reference data, the number of future analyses will be greatly reduced based on the results from this work. However, if the Type I error rate is a concern to managers, researchers can

[24] The smooth hockey stick model, which we used to estimate density-dependent correction factors for productivity and NORs, is sensitive to errors in spawner escapement estimates. Therefore, it is important to use accurate and precise estimates of spawner escapement.

use a lower error rate, such as α = 0.01. Another option is to analyze test-reference data graphically. Although this is subjective, there are no statistical analyses and therefore no concerns with violating assumptions of statistical tests, including temporal correlation. We believe researchers should use the statistical procedures recommended in this report to support graphic analysis.

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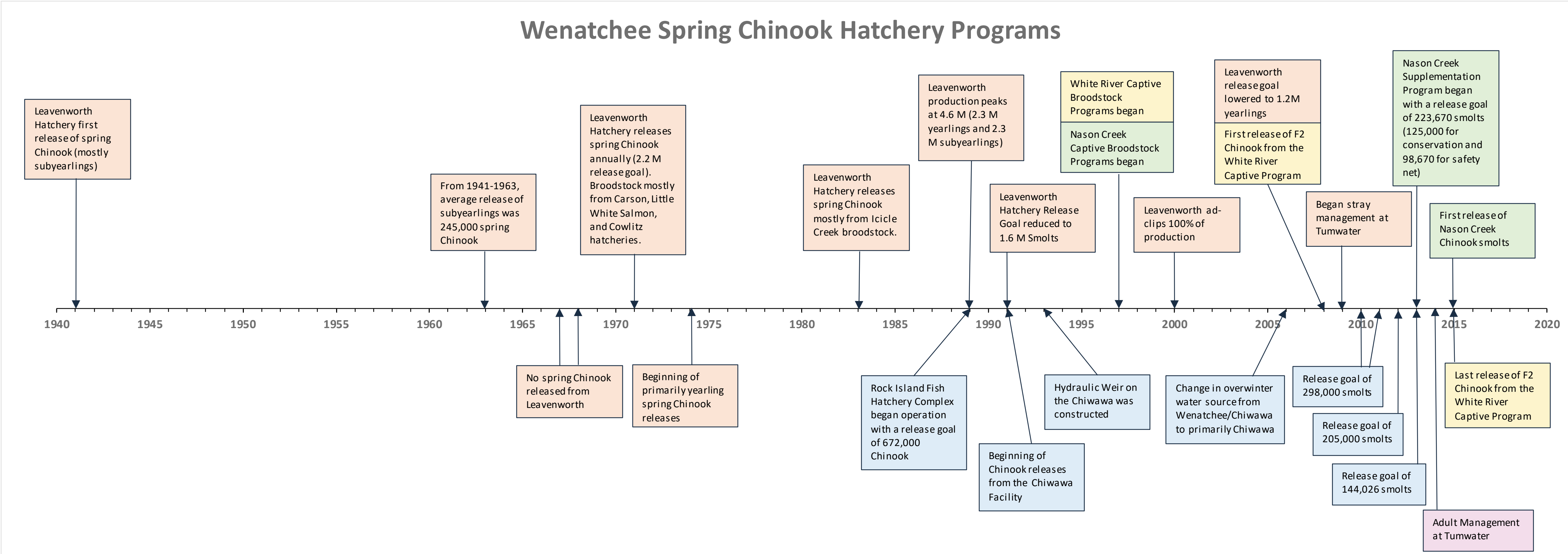
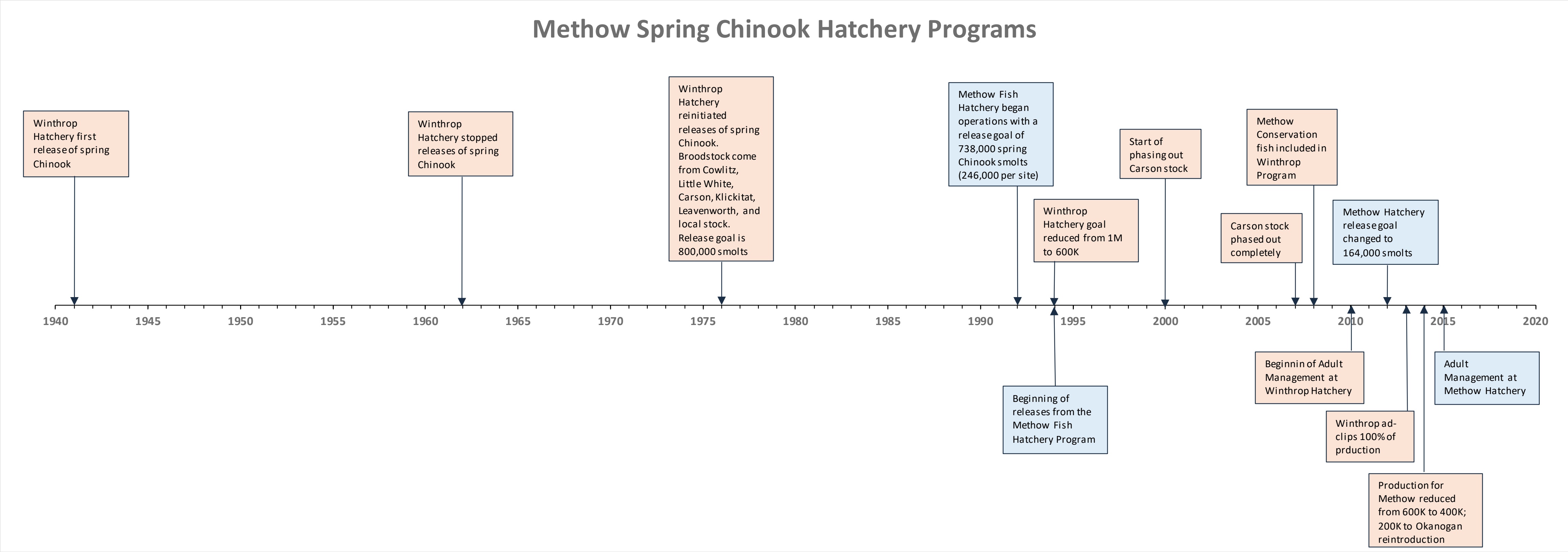

Wenatchee Spring Chinook Hatchery Programs
Leavenworth Hatchery first release of spring Chinook (mostly subyearlings)
From 1941-1963, average release of subyearlings was 245,000 spring Chinook
Leavenworth Hatchery releases spring Chinook annually (2.2 M release goal). Broodstock mostly from Carson, Little White Salmon, and Cowlitz hatcheries.
Leavenworth Hatchery releases spring Chinook mostly from Icicle Creek broodstock.
Leavenworth production peaks at 4.6 M (2.3 M yearlings and 2.3 M subyearlings)
Leavenworth Hatchery Release Goal reduced to 1.6 M Smolts
White River Captive Broodstock Programs began
Nason Creek Captive Broodstock Programs began
Leavenworth ad-clips 100% of production
Leavenworth release goal lowered to 1.2M yearlings
First release of F2 Chinook from the White River Captive Program
Began stray management at Tumwater
Nason Creek Supplementation Program began with a release goal of 223,670 smolts (125,000 for conservation and 98,670 for safety net)
First release of Nason Creek Chinook smolts
1940
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020
No spring Chinook released from Leavenworth
Beginning of primarily yearling spring Chinook releases
Rock Island Fish Hatchery Complex began operation with a release goal of 672,000 Chinook
Beginning of Chinook releases from the Chiwawa Facility
Hydraulic Weir on the Chiwawa was constructed
Change in overwinter water source from Wenatchee/Chiwawa to primarily Chiwawa
Release goal of 298,000 smolts
Release goal of 205,000 smolts
Release goal of 144,026 smolts
Adult Management at Tumwater
Last release of F2 Chinook from the White River Captive Program


Methow Spring Chinook Hatchery Programs
Winthrop Hatchery first release of spring Chinook
Winthrop Hatchery stopped releases of spring Chinook
Winthrop Hatchery reinitiated releases of spring Chinook. Broodstock come from Cowlitz, Little White, Carson, Klickitat, Leavenworth, and local stock. Release goal is 800,000 smolts
Methow Fish Hatchery began operations with a release goal of 738,000 spring Chinook smolts (246,000 per site)
Winthrop Hatchery goal reduced from 1M to 600K
Start of phasing out Carson stock
Carson stock phased out completely
Methow Conservation fish included in Winthrop Program
Methow Hatchery release goal changed to 164,000 smolts
1940
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020
Beginning of releases from the Methow Fish Hatchery Program
Beginnin of Adult Management at Winthrop Hatchery
Adult Management at Methow Hatchery
Winthrop ad-clips 100% of prduction
Production for Methow reduced from 600K to 400K; 200K to Okanogan reintroduction

UPPER COLUMBIA SALMON
RECOVERY BOARD

INTEGRATED RECOVERY

HATCHERIES

GREER MAIER
Science Program Manager

WWW.UCSRB.ORG

WHO WE ARE

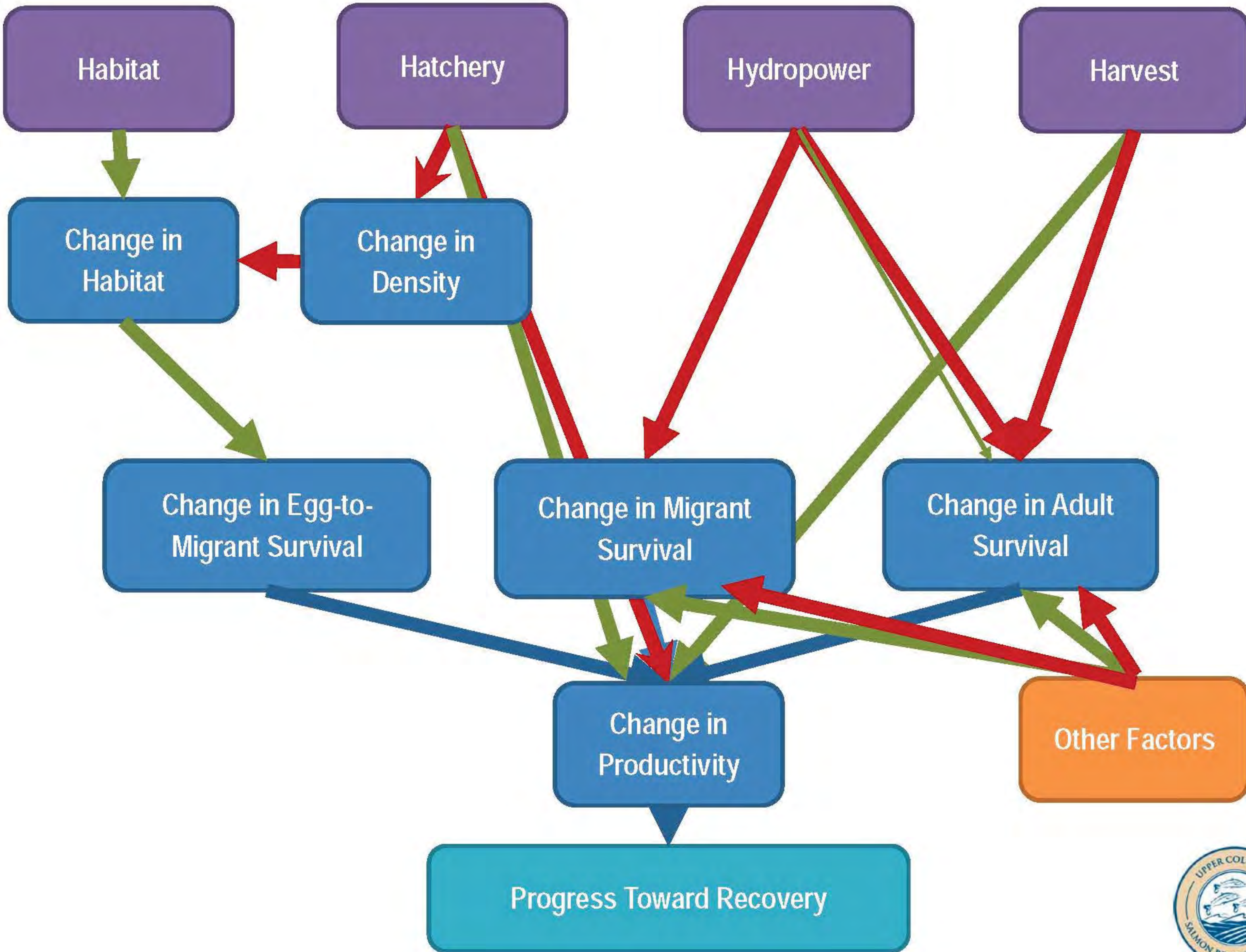
The UCSRB is a non-profit corporation of WA State, recognized as a 501(c)(3). The UCSRB fosters collaboration and cooperation among participating stakeholders, or those who are simply interested in river and forest restoration activities in the Upper Columbia region. Our board consists of three county commissioners and two tribal representatives.

WHAT WE DO

Our mission is to restore viable and sustainable populations of salmon, steelhead and other at-risk species through collaborative, economically sensitive efforts, combined resources, and wise resource management of the Upper Columbia region. Since 1999, the Upper Columbia Salmon Recovery Board (UCSRB) has been the forum for local collaboration to understand and address the complexities that our communities face in the wake of three federally listed salmonids (spring Chinook salmon, steelhead and bull trout).

“It is presumed that actions within all sectors (i.e., all Hs) are necessary to achieve recovery (see Section 5.6), but because different sectors involve different parties, different decision-making processes, and different timelines, this plan respects those differences and does not attempt to prioritize actions across Hs. Actions within each sector, however, have been identified by those parties and processes and are described and categorized in this plan as short-term (those that prevent extinction or decline of populations) and long-term (those that lead to recovery) actions.”

Upper Columbia Salmon and Steelhead Recovery Plan


Habitat
Hatchery
Hydropower
Harvest
Change in Habitat
Change in Density
Change in Egg-to-Migrant Survival
Change in Migrant Survival
Change in Adult Survival
Change in Productivity
Other Factors
Progress Toward Recovery

UC Population Status & Recovery Goals

ESU	Independent Population	Minimum Adult Abundance Threshold[a,b]	Current Adult Abundance[c]	Productivity Threshold	Current Productivity[c]	Spatial Structure/ Diversity (SS/D) Risk Threshold	Current SS/D Risk[c]
Upper Columbia Summer Steelhead DPS	Wenatchee	1,000	1025	1.1	1.207	Moderate	High
	Entiat	500	146	1.2	0.434	Moderate	High
	Methow	1,000	651	1.1	0.371	Moderate	High
	Okanogan[d]	500	189	1.2	0.154	Moderate	High
Upper Columbia Spring Chinook ESU	Wenatchee	2,000	545	1.2	0.60	Moderate	High
	Entiat	500	166	1.4	0.94	Moderate	High
	Methow	2,000	379	1.2	0.46	Moderate	High
	Okanogan	Not defined (extinct)					

[a] *From UC Recovery Plan (UCSRB 2007)*

[b] *Viability criteria for Okanogan steelhead are for the U.S. portion of the population only.*

[c] *10-year geometric mean of natural-origin adult returns in each subbasin from NOAA (2016)*

INTEGRATED RECOVERY GOALS

1. Achieve recovery of Upper Columbia spring Chinook salmon and of Upper Columbia steelhead, which will require coordinated actions in all of the management sectors affecting salmon.

2. Engage and collaborate with sector managers in finding and implementing solutions to identified issues.

PROCESS

DIRECTION

direction from the UC Recovery Plan, the UCSRB board of directors, and partner input

STEPS

process in place since 2008 but has been modified over the years. The current process reflects changes implemented in 2017.

IMPLEMENTATION

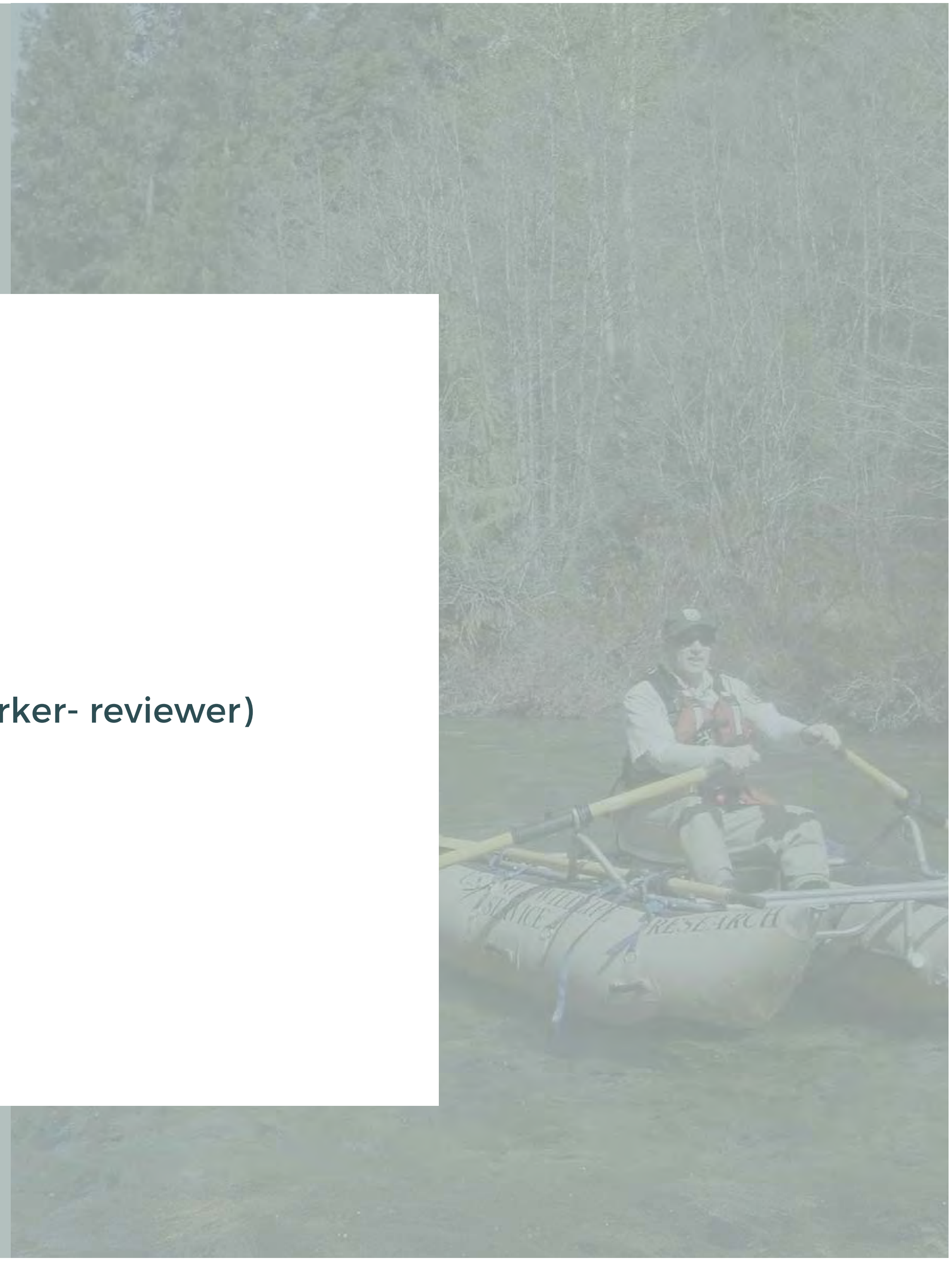
completed the "Habitat Report" in 2014 and the draft "Hatchery Summary" in 2017. Hydropower and Harvest in process.

TEAM

UCSRB

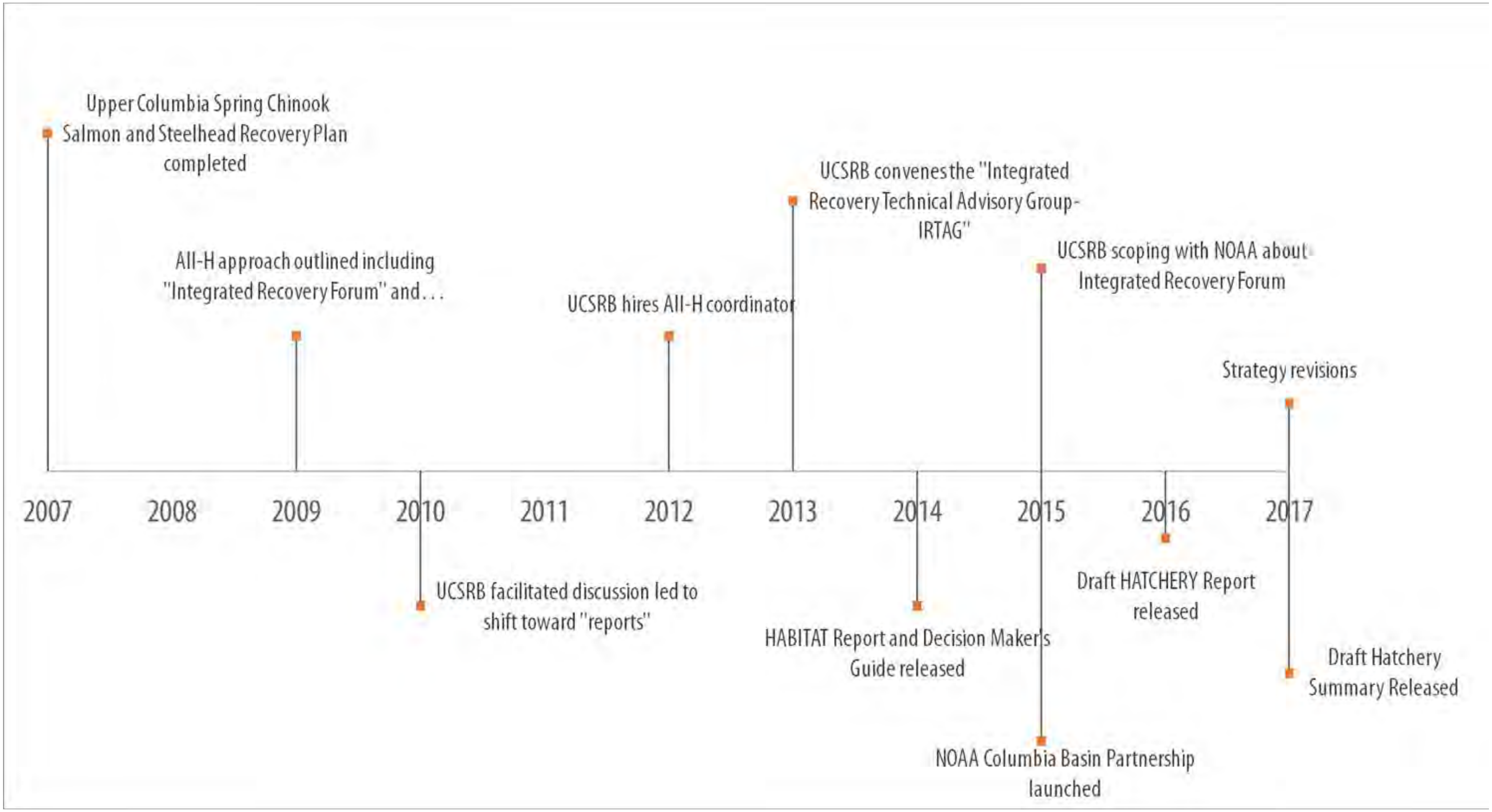
INTEGRATED RECOVERY TECHNICAL ADVISORY TEAM (IRTAG)

PARTNERS

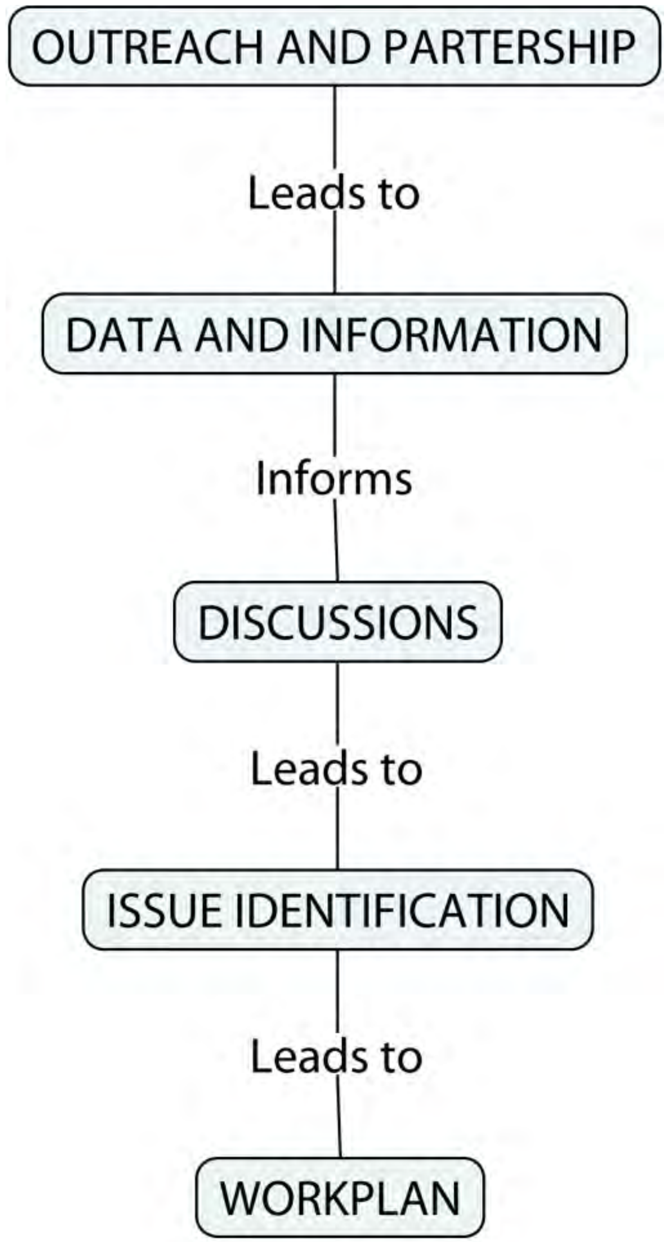


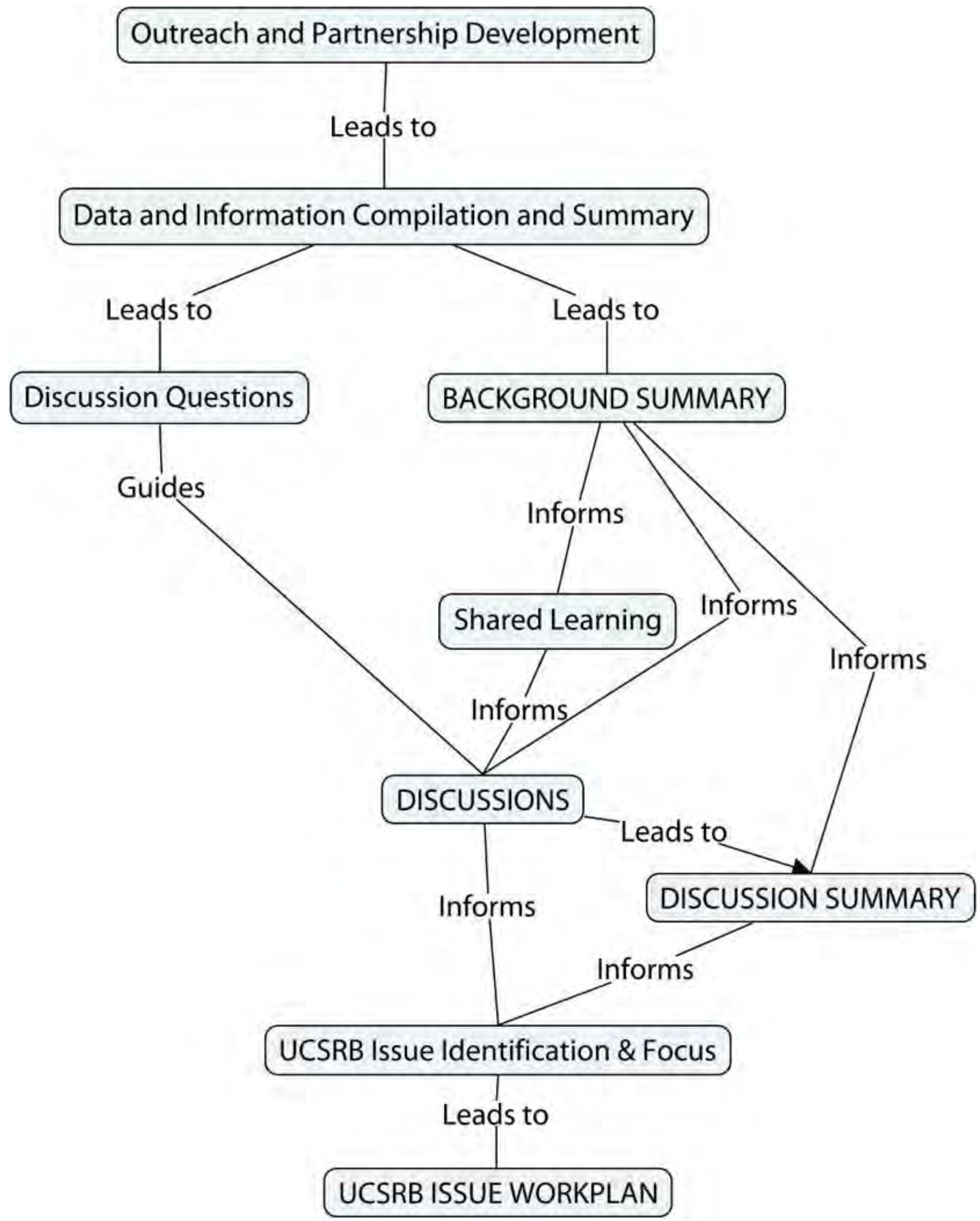
IRTAG

Tom Kahler- DPUD
Greg Fraser- FWS
Michael Humling- FWS
Matt Cooper- FWS
Keely Murdoch- YN (Steve Parker- reviewer)
Casey Baldwin- CCT
Andrew Murdoch- WDFW
Jeremy Cram- WDFW
Michael Tonseth- WDFW
Tom Cooney- NOAA
Jennifer Johnson- GSRO
John Crandall- MSRF


Upper Columbia Spring Chinook Salmon and Steelhead Recovery Plan completed
All-H approach outlined including "Integrated Recovery Forum" and...
UCSRB facilitated discussion led to shift toward "reports"
UCSRB hires All-H coordinator
UCSRB convenes the "Integrated Recovery Technical Advisory Group-IRTAG"
HABITAT Report and Decision Maker's Guide released
UCSRB scoping with NOAA about Integrated Recovery Forum
NOAA Columbia Basin Partnership launched
Draft HATCHERY Report released
Strategy revisions
Draft Hatchery Summary Released
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017

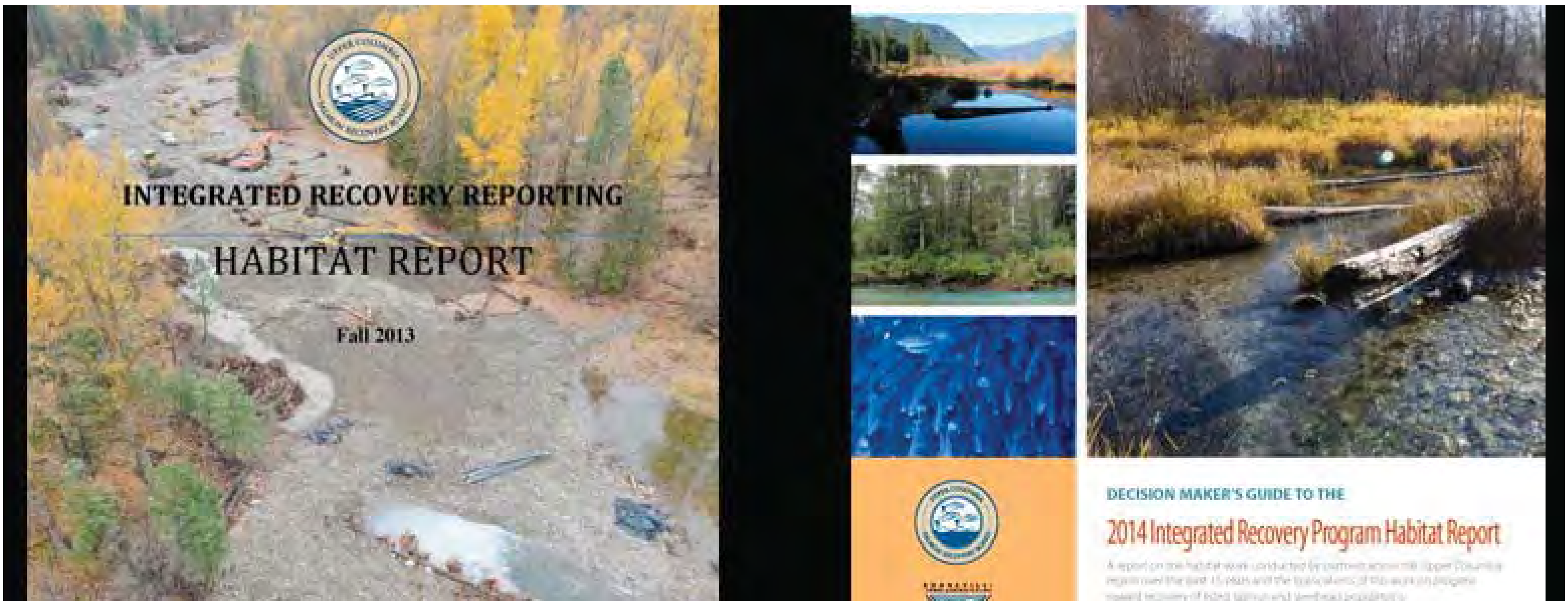
Revised Process



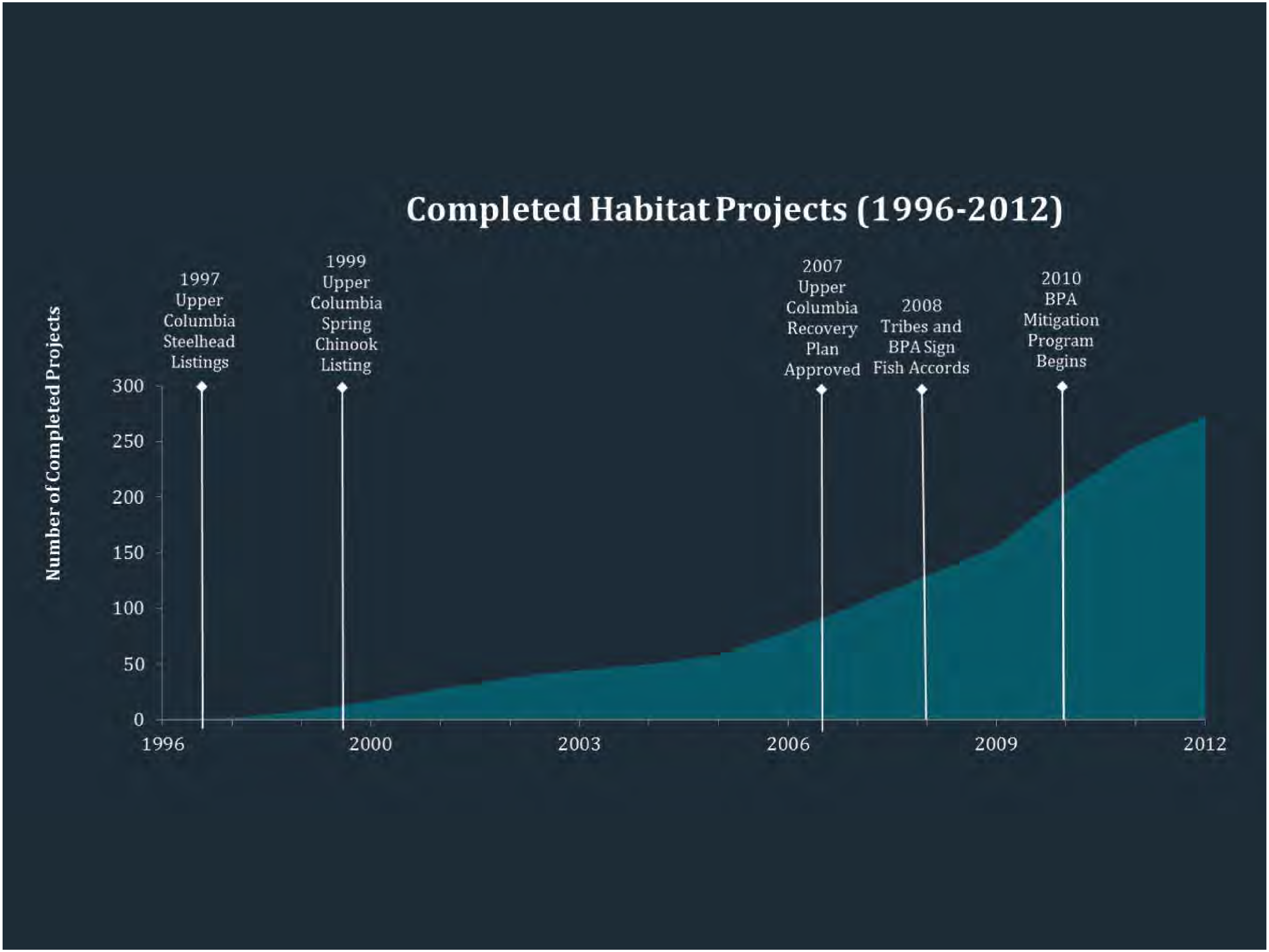


Revised Process

HABITAT REPORT



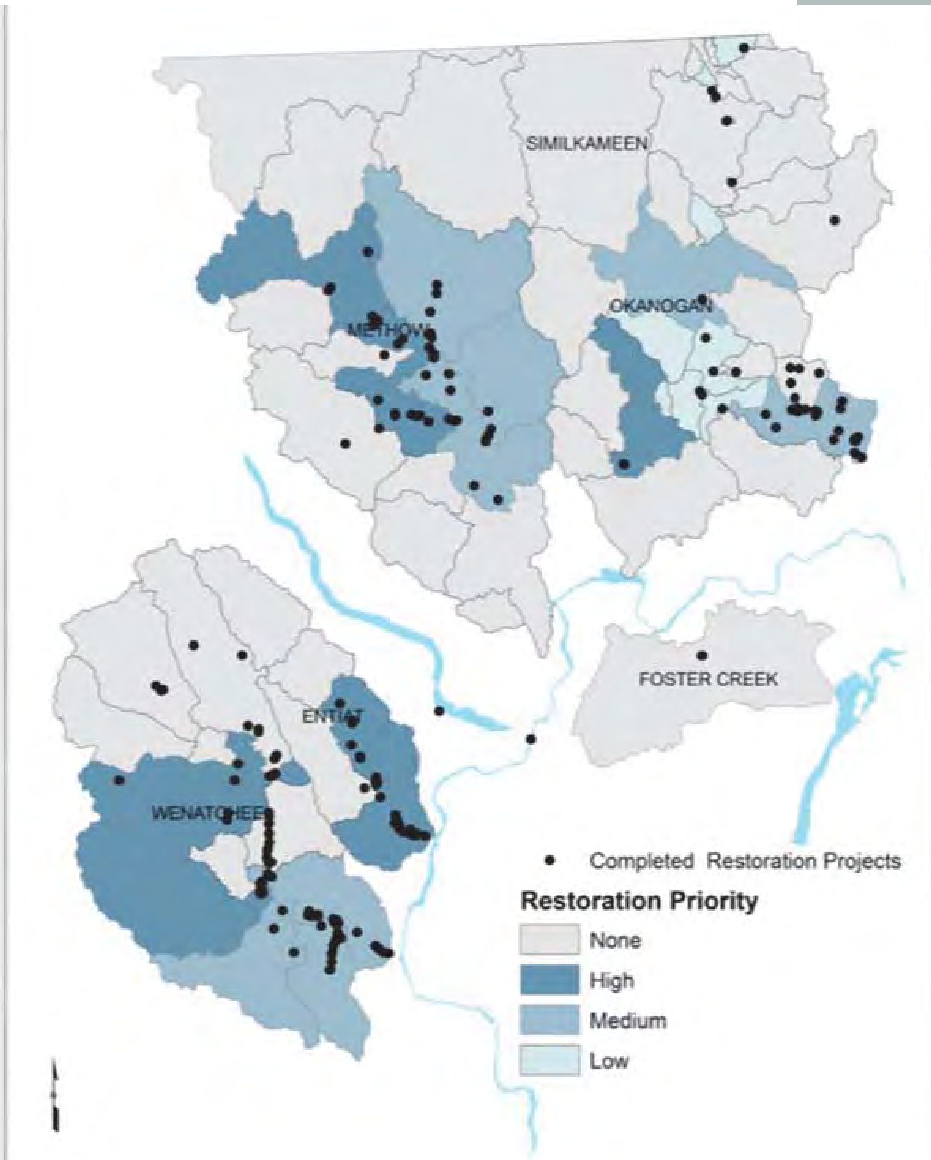
AVAILABLE AT WWW.UCSRB.ORG



Completed Habitat Projects (1996-2012)
Number of Completed Projects
300
250
200
150
100
50
0
1996
2000
2003
2006
2009
2012
1997 Upper Columbia Steelhead Listings
1999 Upper Columbia Spring Chinook Listing
2007 Upper Columbia Recovery Plan Approved
2008 Tribes and BPA Sign Fish Accords
2010 BPA Mitigation Program Begins

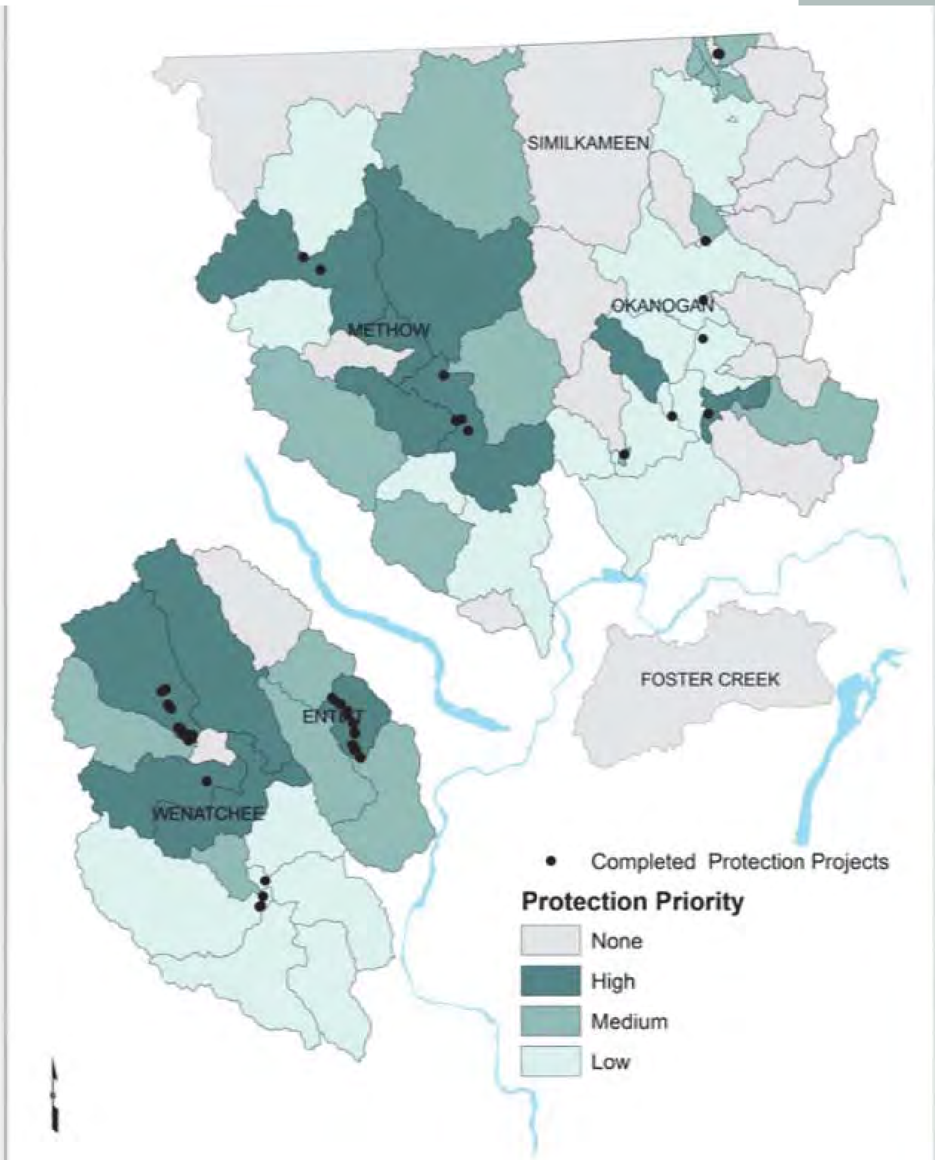
278 PROJECTS

22 miles of stream improved
518 instream structures placed
28 miles of restored flow
11 miles of off-channel habitat created
93 barriers removed
282 miles opened to fish
127 acres of riparian habitat improved
3,379 acres protected
47 miles of stream protected



75%

The number of restoration projects that were within priority areas as identified in the RTT's Biological Strategy.



100%

The number
of protection projects that
were within priority areas
as identified in the RTT's
Biological Strategy.

15%

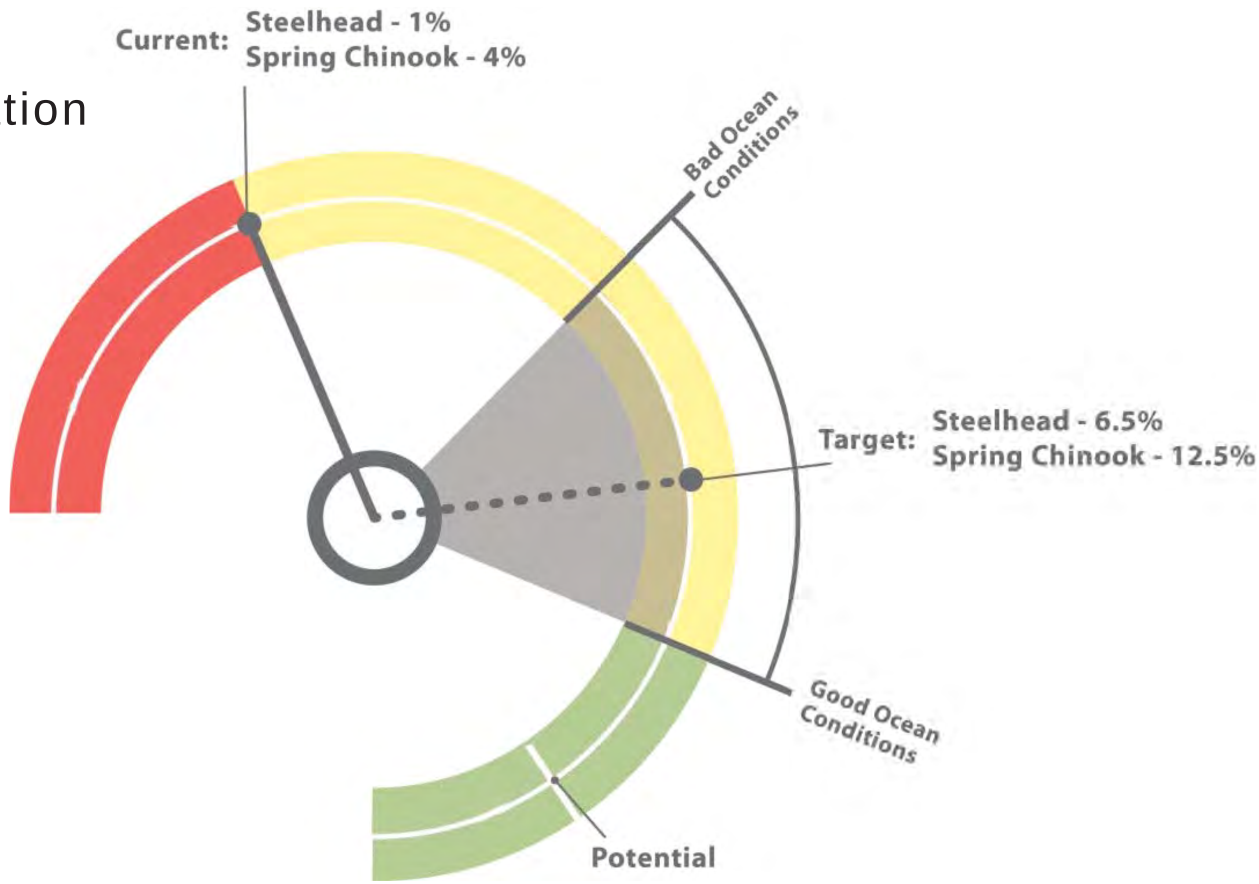
estimated habitat restoration potential

1.3%

estimated egg-to-emigrant survival for steelhead

4.4%

estimated egg-to-emigrant survival for spring Chinook



HATCHERY SUMMARY

BACKGROUND SUMMARY

- Hatchery Management
- Hatchery Programs
- Documented outcomes
- Uncertainties and Data gaps

SHARED LEARNING

- Concepts
- Science
- Policy
- Management

DISCUSSIONS

- Interpretation
- Challenges
- Progress toward recovery

DATA & INFORMATION

PUD annual reports
PUD 5-Year report
FWS memos and reports
Other reports
Literature
WDFW and PUD data

BACKGROUND SUMMARY

Introduction

Hatchery Policies

Hatchery RM&E

Hatchery Reviews

Historic Hatchery Programs

Current Hatchery Programs

Smolt Production and Survival

Adult Returns and Straying

Broodstock Collection and Adult Management

Hatchery Spawners and Hatchery Progeny

Ecological Interactions

VSP Parameters

Uncertainties and Data Gaps

UC RECOVERY PLAN HATCHERY OBJECTIVES

Short-Term (0-15 years)

• Continue to use artificial production to maintain critically depressed populations in a manner that is consistent with recovery and avoids extinction.
• Use artificial production to seed unused, accessible habitats.
• Use artificial production to provide for tribal and non-tribal fishery obligations as consistent with recovery criteria.
• Use harvest or other methods to reduce the proportion of hatchery-produced fish in naturally spawning populations
• To the extent possible use local broodstock in hatchery programs.
• To the extent possible, integrate federal, state, and tribal-operated hatchery programs that use locally derived stocks.
• Reduce the amount of in-basin straying from current hatchery programs.

UCSRB 2007

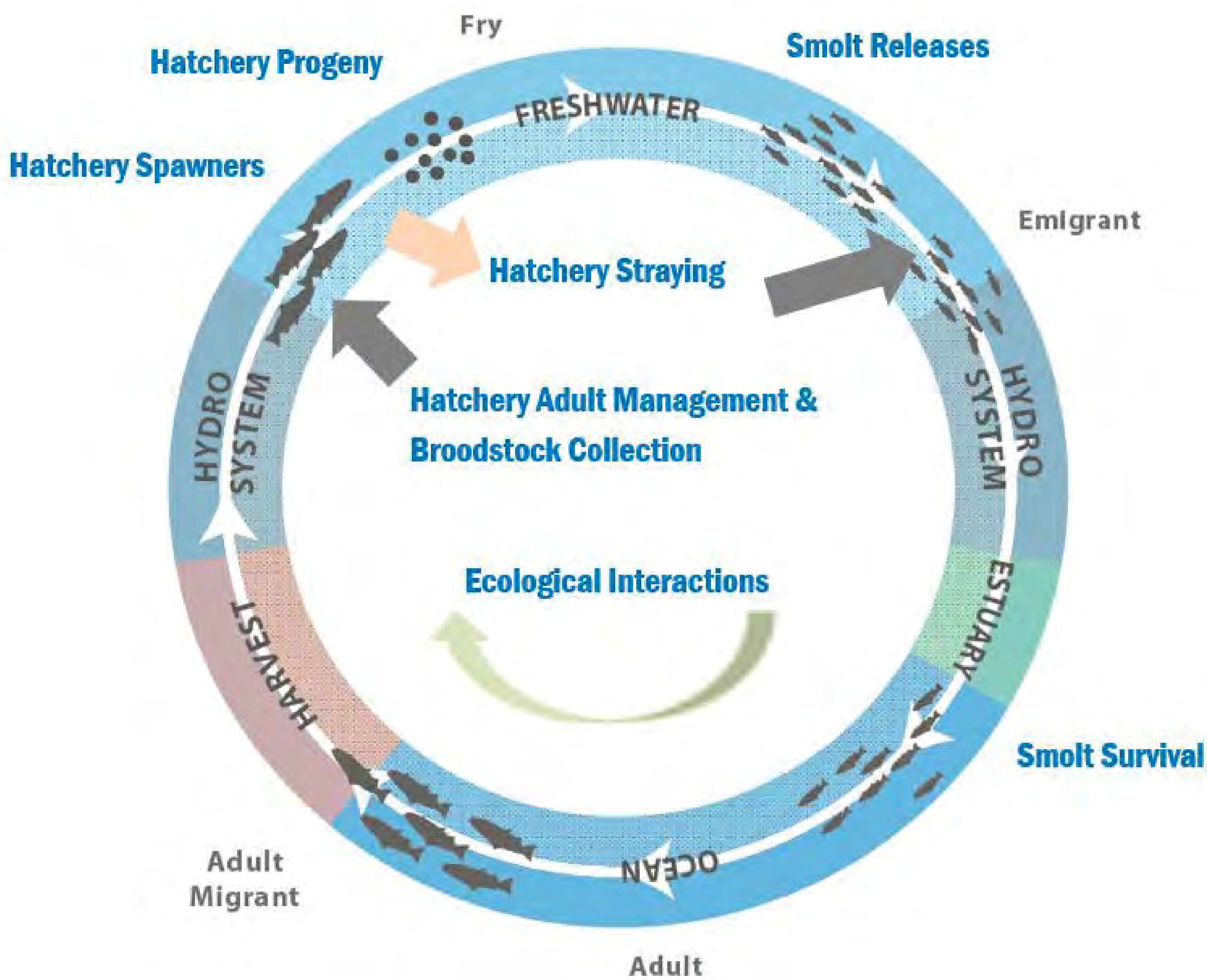
UC RECOVERY PLAN HATCHERY OBJECTIVES

Long—Term (50-100 years)

• Phase out the use of out-of-basin stock in the federal programs at Leavenworth and Entiat National Fish Hatcheries if continued research indicates that the programs threaten recovery of listed fish and those threats cannot be minimized through operational or other changes.

• Help develop ongoing hatchery programs that are consistent with recovery.

UCSRB 2007


Fry
Hatchery Progeny
Smolt Releases
FRESHWATER
Hatchery Spawners
Emigrant
Hatchery Straying
HYDRO
SYSTEM
Hatchery Adult Management &
Broodstock Collection
HYDRO
SYSTEM
ESTUARY
Ecological Interactions
HARVEST
Smolt Survival
OCEAN
Adult
Migrant
Adult

POLICY & MANAGEMENT

RESEARCH & MONITORING

HATCHERY REVIEWS

HISTORIC PROGRAMS

CURRENT PROGRAMS

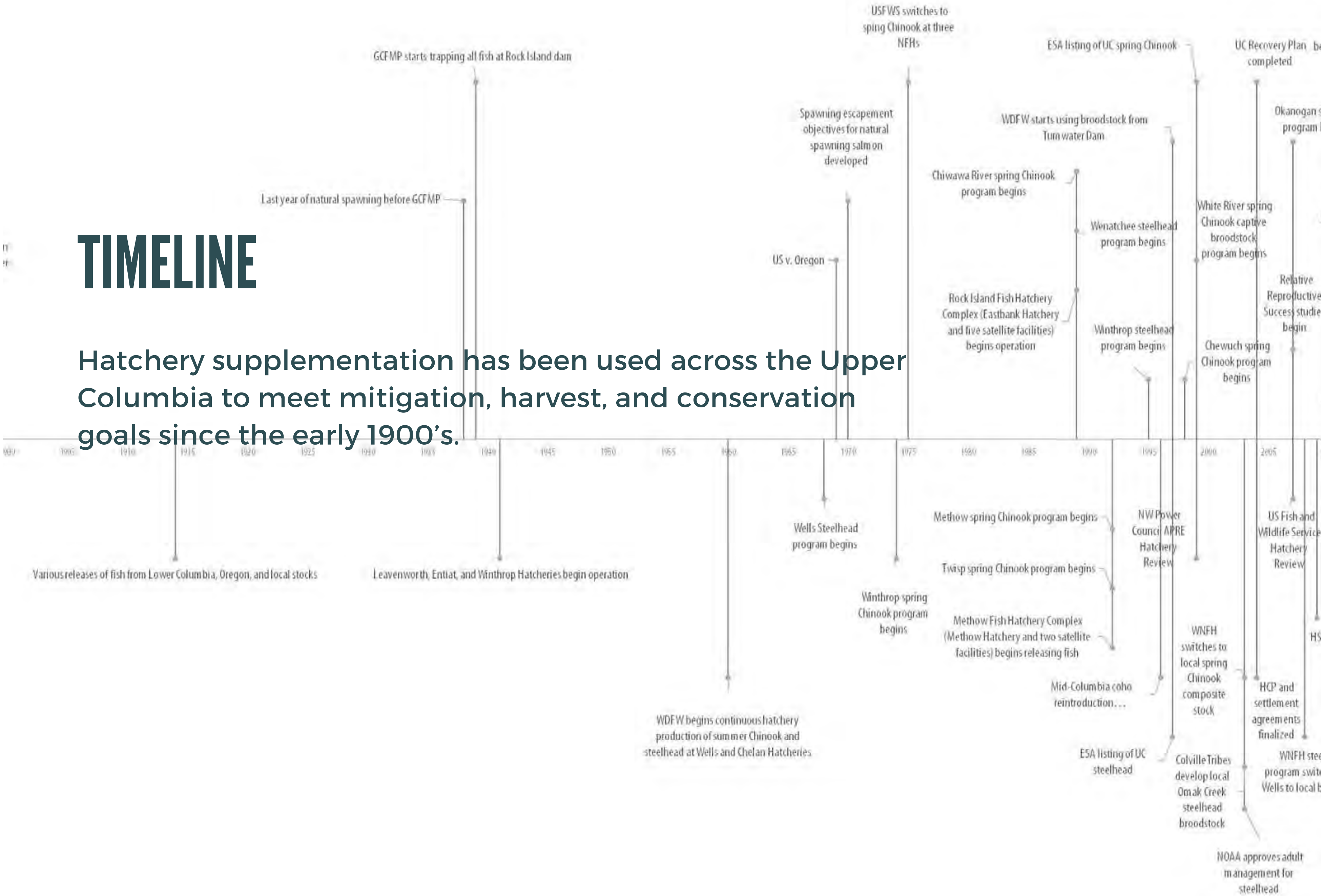
Species	Program	Subbasin	Program Components	Goals	Production Goal	Operator	Funding Entity[a]
Spring Chinook	Wenatchee Spring Chinook	Wenatchee	Nason, White[b], Chiwawa	Conservation	269,026	WDFW	C, G
	Wenatchee Spring Chinook	Wenatchee	Nason	Safety-Net	98,670	WDFW	C, G
	Methow Spring Chinook	Methow	Methow, Twisp, Chewuch	Conservation	223,765	DPUD	C, D, G
	Winthrop Spring Chinook	Methow		Safety-Net	400,000	FWS	BOR
	Leavenworth Spring Chinook	Wenatchee		Harvest	1,200,000	FWS	BOR
	Chief Joseph Spring Chinook	Okanogan		Harvest	700,000	CCT	BPA
	Chief Joseph Spring Chinook	Okanogan		Reintroduction	200,000	CCT	BPA, C, D, G
Steelhead	Wenatchee Steelhead	Wenatchee		Conservation	123,650	WDFW	C
	Wenatchee Steelhead	Wenatchee		Safety-Net	123,650	WDFW	C
	Wells Steelhead	Methow, Columbia	Methow, Wells	Safety-Net	260,000	DPUD	D
	Twisp Steelhead	Methow	Twisp	Conservation	48,000	DPUD	D
	Winthrop Steelhead	Methow		Conservation	200,000	FWS	BOR
	Okanogan Steelhead	Okanogan		Conservation	100,000	WDFW	G
Coho	Mid-Columbia Coho	Wenatchee, Methow	Wenatchee, Methow	Reintroduction	1,500,000	YN	BPA, C, D, G
Summer/Fall Chinook	Priest Rapids Fall Chinook	Columbia		Harvest	7,300,000	WDFW	G, ACE
	Ringold Springs Fall Chinook	Columbia		Harvest	3,500,000	WDFW	ACE
	Chelan Falls Summer Chinook	Columbia		Harvest	576,000	WDFW	C
	Wells Summer Chinook	Columbia		Harvest	804,000	WDFW	D
	Wenatchee Summer Chinook	Wenatchee		Harvest	500,000	WDFW	C, G
	Entiat Summer Chinook	Entiat		Harvest	400,000	FWS	BOR
	Methow Summer Chinook	Methow		Harvest	200,000	WDFW	G
	Chief Joseph Summer/Fall Chinook	Columbia		Harvest	900,000	CCT	BPA, C, D, G
	Chief Joseph Summer/Fall Chinook	Okanogan		Conservation/Harvest	1,200,000	CCT	BPA, C, D, G
Sockeye	Okanogan Sockeye	Okanogan		Reintroduction/Harvest	5,000,000	ONA	C, G

D-Douglas PUD, G-Grant PUD, C-Chelan PUD, BPA- Bonneville Power Administration, ACE- Army Corps of Engineers, BOR- Bureau of Reclamation

[b]The last release of juveniles from the captive brood program occurred in 2015.

TIMELINE

Hatchery supplementation has been used across the Upper Columbia to meet mitigation, harvest, and conservation goals since the early 1900's.



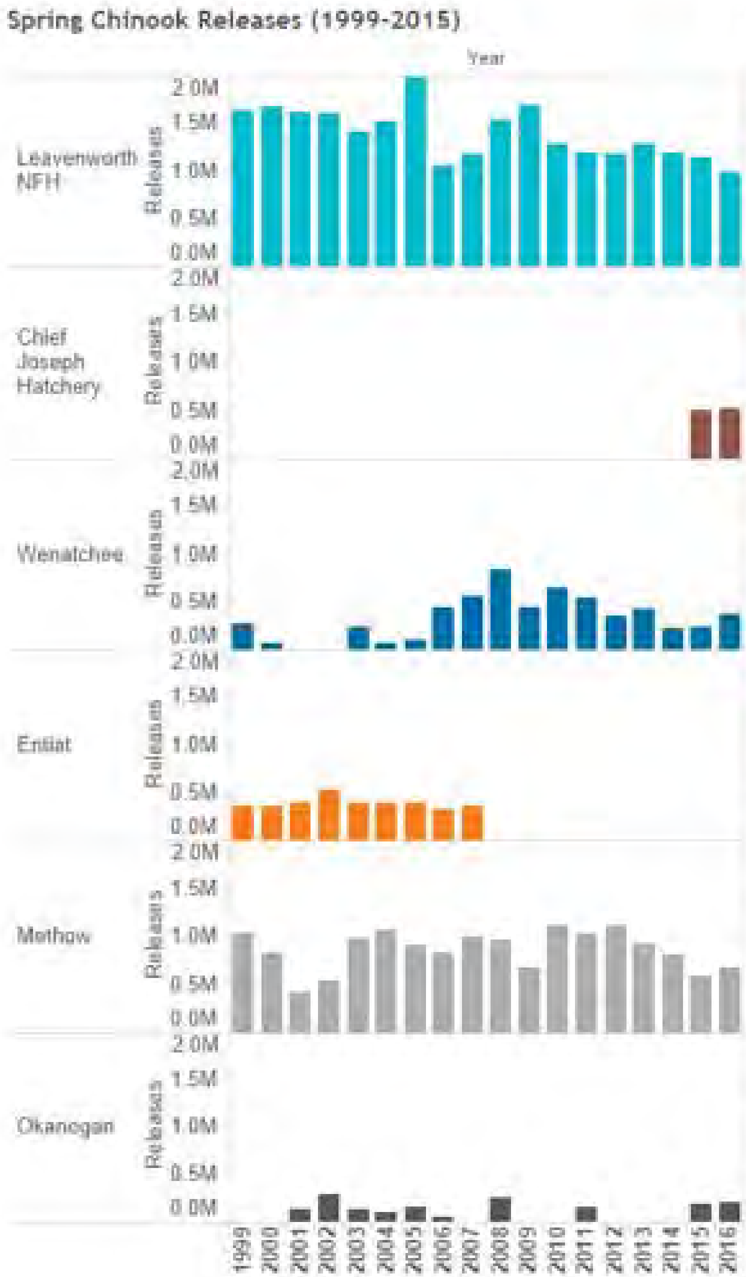
	Smolt Productior		
Species	*Conservation*	*Harvest*	*Reintro*
Listed Spring Chinook	492,790		
Listed Steelhead	471,650		
Unlisted Spring Chinook		1,900,000	200,
Summer/Fall Chinook		4,580,000	
Coho			1,500
Sockeye		1,143,000	
Grand Total	964,440	7,623,000	1,700

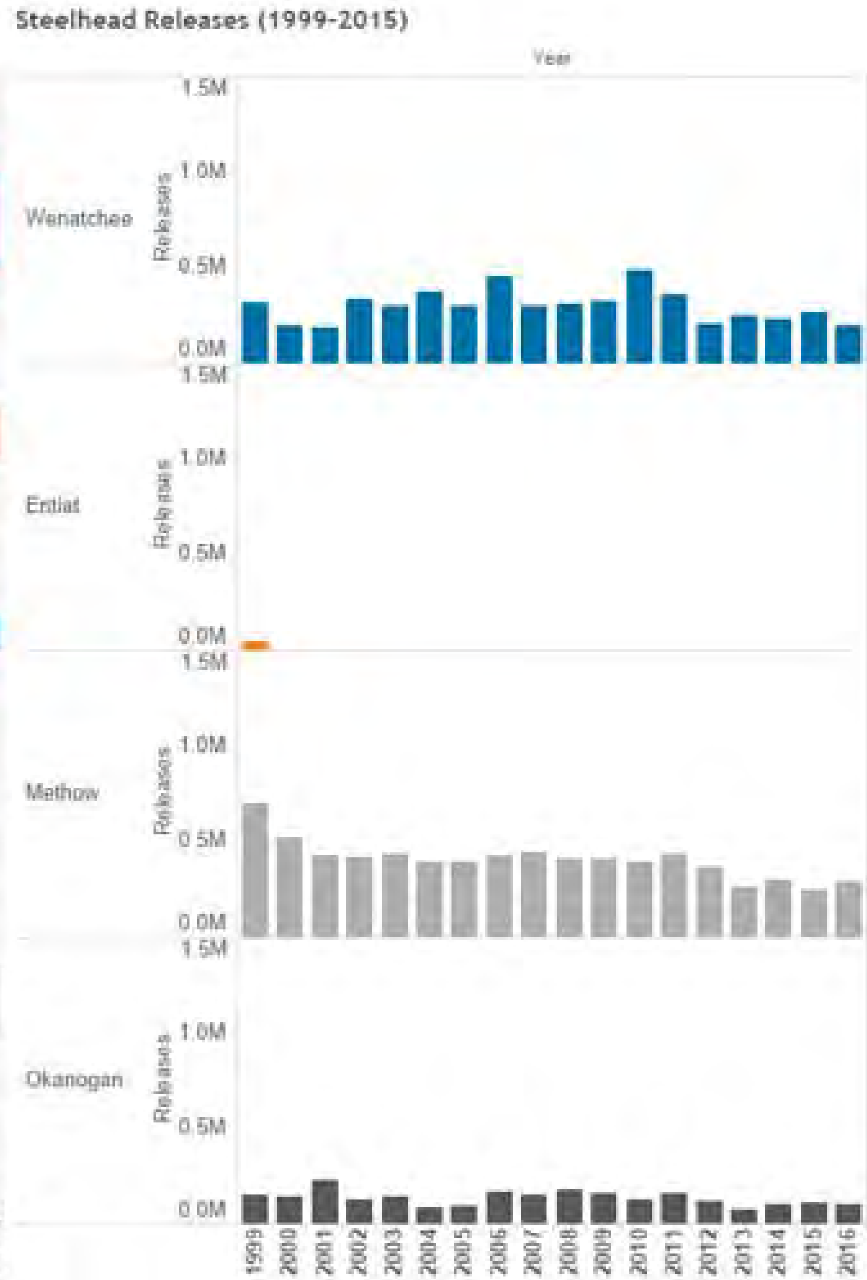
** up to 10.8 million upriver bright fall Chinook are reared and released at Priest Rapi Hatchery at the lower extent of the Upper Columbia region and these releases are not*

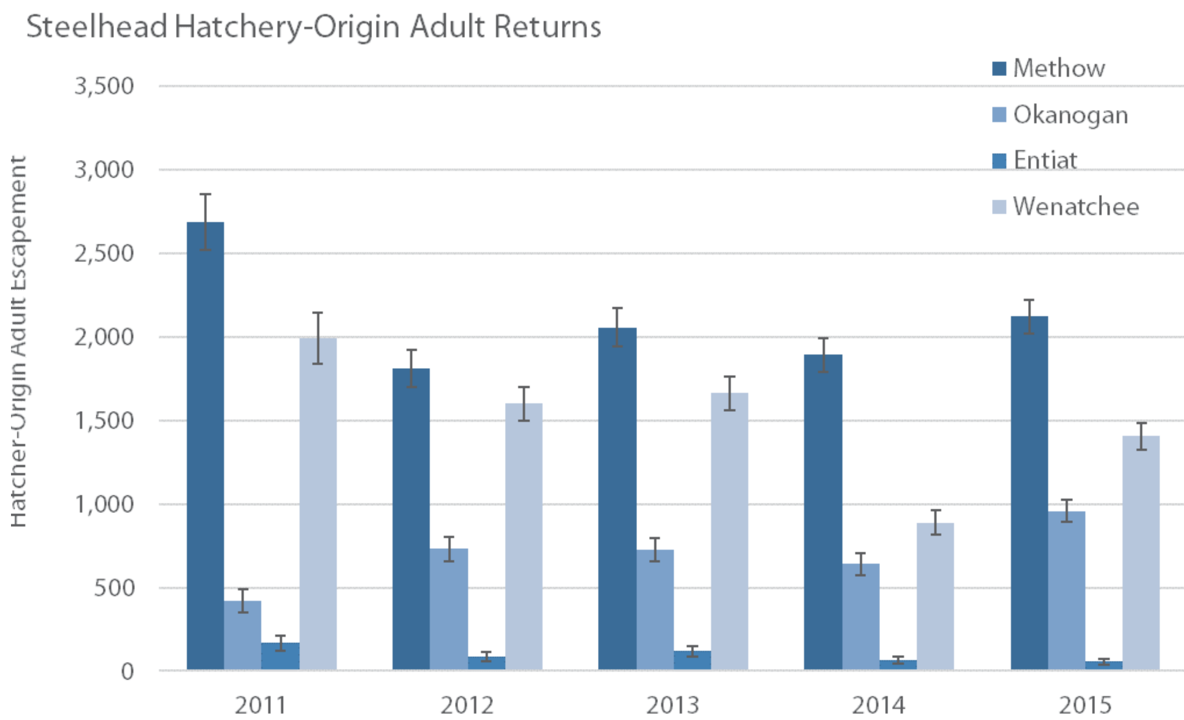
11 MILLION

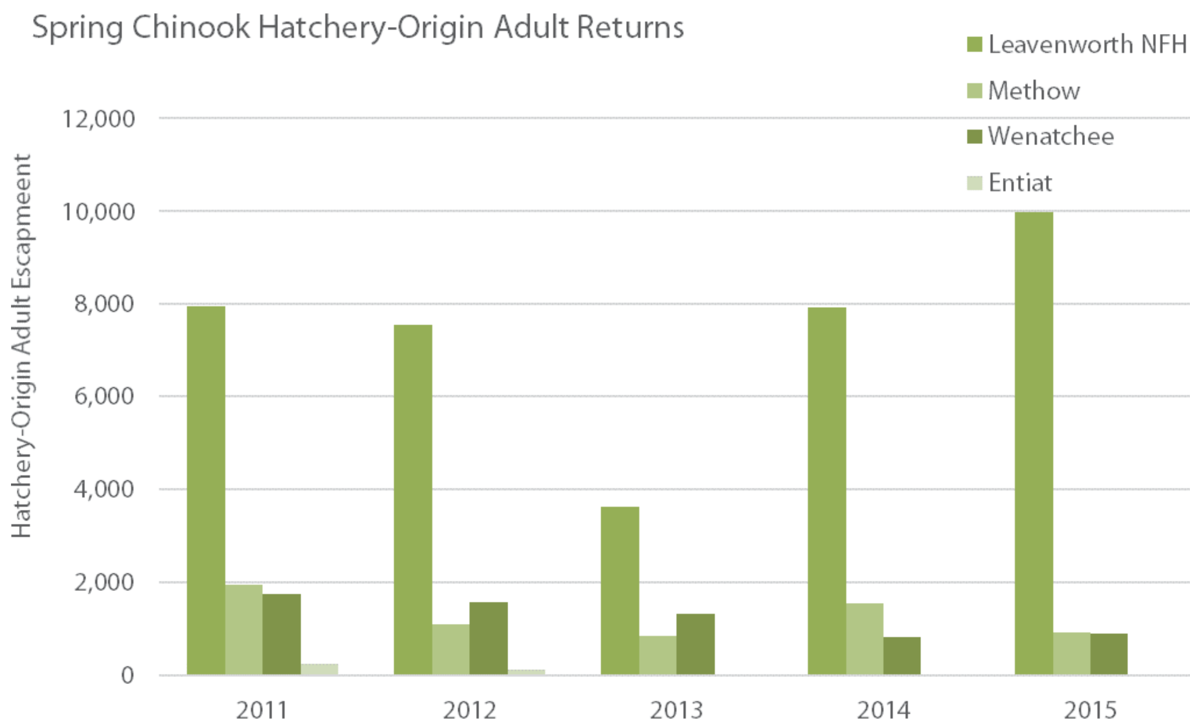
the number of hatchery smolts released from the Upper Columbia

1 Million Listed Spring Chinook
855K Listed Steelhead


Spring Chinook Releases (1999-2015)
Year
Leavenworth NFH
Chief Joseph Hatchery
Wenatchee
Entiat
Methow
Okanogan
Releases
2.0M
1.5M
1.0M
0.5M
0.0M
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016


Steelhead Releases (1999-2015)
Year
Wenatchee
Entiat
Methow
Okanogan
Releases
1.5M
1.0M
0.5M
0.0M
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016





17,900 HATCHERY SPRING CHINOOK

2011-2015 SASI and SPS

8,168 HATCHERY STEELHEAD

2011-2015 Rock Island Dam counts

ADULT STRAYING

In terms of its relevance to hatchery management, straying of hatchery-produced fish and the subsequent interactions between stray hatchery-origin fish and natural-origin fish on the spawning grounds has been cited as a concern in some cases (Araki et al. 2008; Kostow 2009; Brenner et al. 2012). The level of concern for stray rates is related to the degree of relatedness between the hatchery- and natural-origin fish in a watershed. Hatchery fish derived from a local population may be allowed to stray into natural production areas at higher rates than those having out-of-basin ancestry. Low stray rates can maximize hatchery benefits and minimize hatchery risks by helping maintain local adaptation and genetic variation between stocks (Hillman et al. 2012).

Spring Chinook		Brood-Years (BYs) Assessed	Hatchery Program Avg BY Stray Rate
	Chiwawa Program	BY 05-09	37%
	Methow Program	BY 05-09	3%
	Twisp Program	BY 05-09	36%
	Chewuch Program	BY 05-09	39%
	WNFH Program	BY 05-09	36.5%
	LNFH Program (non-listed harvest)	BY 05-09	4.2%

1098

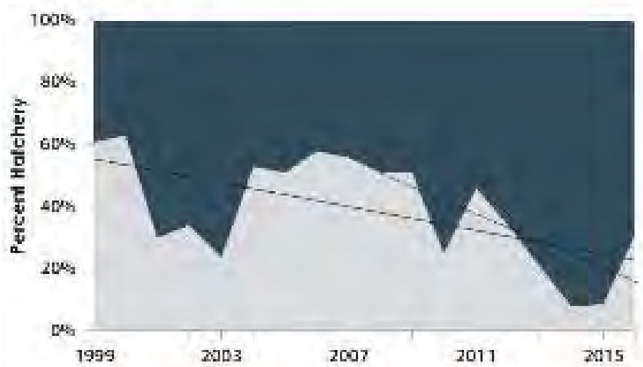
target number of natural-origin and hatchery-origin adult spring Chinook and steelhead collected for conservation program broodstock

610 SPRING CHINOOK (45% NOB)
488 STEELHEAD (45% NOB)

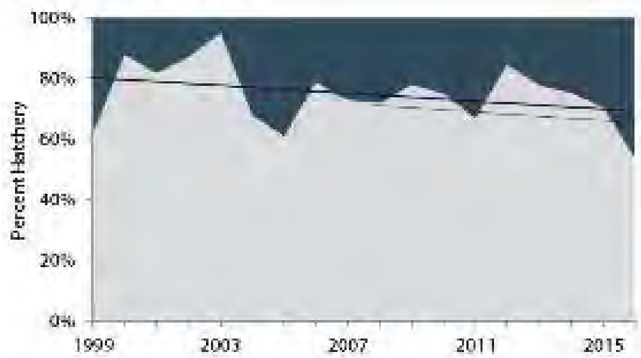
ADULT MANAGEMENT

defined as the intentional allocation of returning adult hatchery-origin adults to directly influence the number and origin composition of fish on spawning grounds. The primary goal of "adult management" is to enhance the numbers and success of naturally spawning adults. The primary objective of adult management is to attain as high a proportion of natural origin (NOR) adults on the spawning grounds as possible, while concurrently achieving an optimum spawning escapement goal and retaining appropriate numbers of broodstock (WDFW 2010).

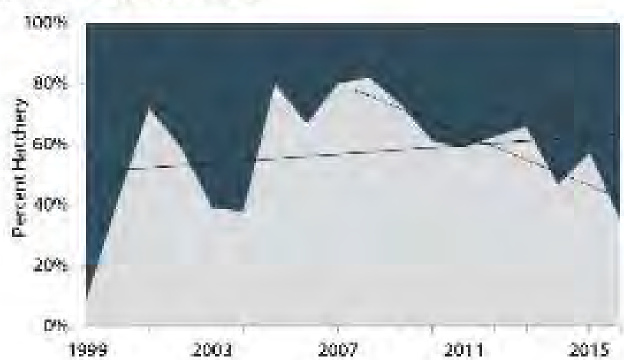
Entiat Spring Chinook



Methow Spring Chinook



Wenatchee Spring Chinook

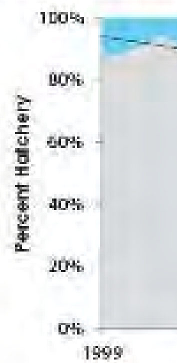


Percent Hatchery

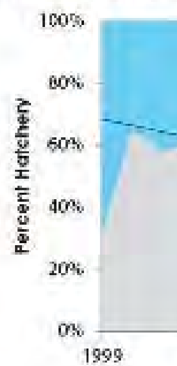
Recent pHOS Trend

Entiat Steelhead

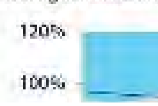
Methow Steelhea



Wenatchee Steelhe



Okanogan Steelhe

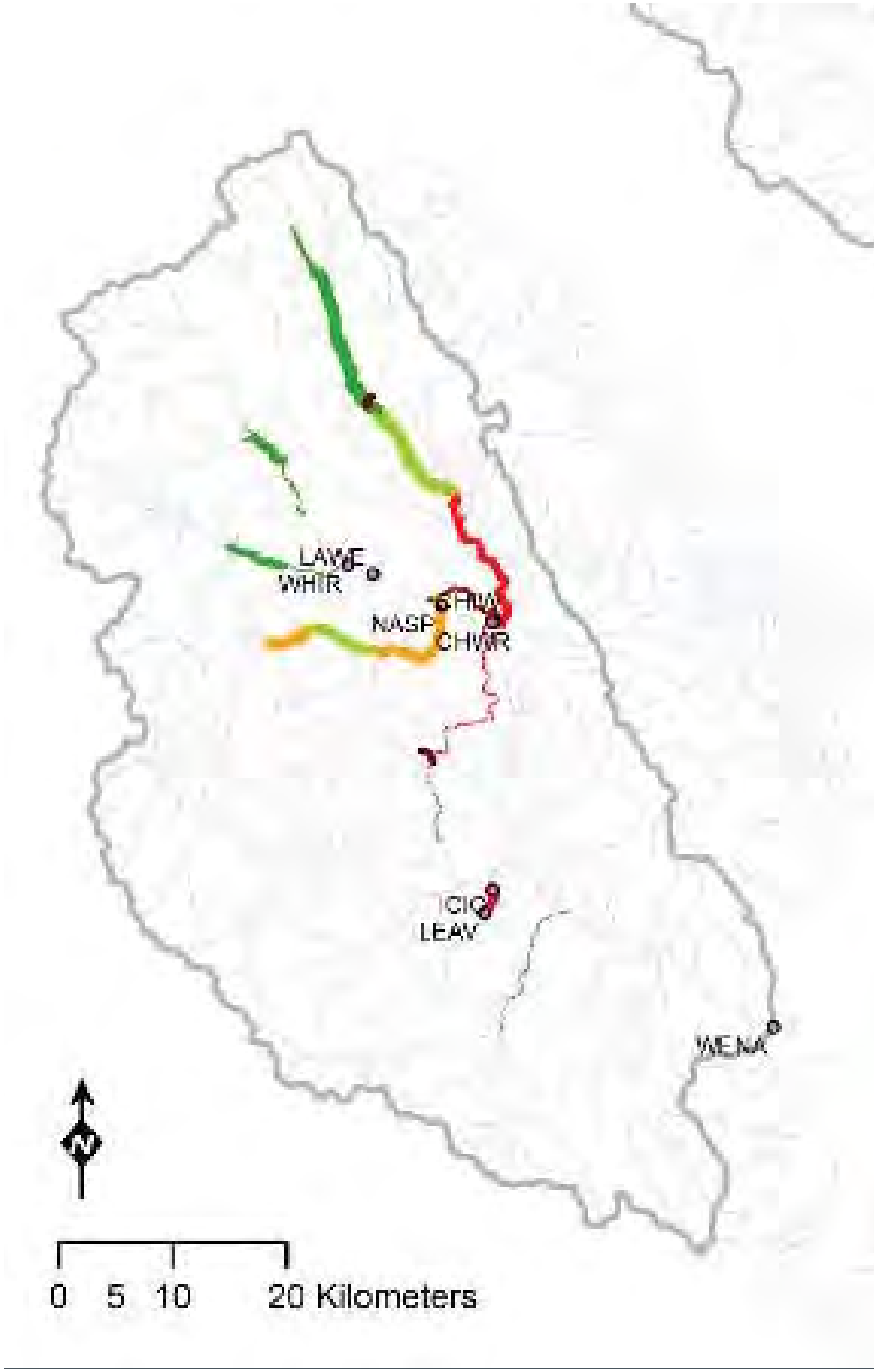


52%

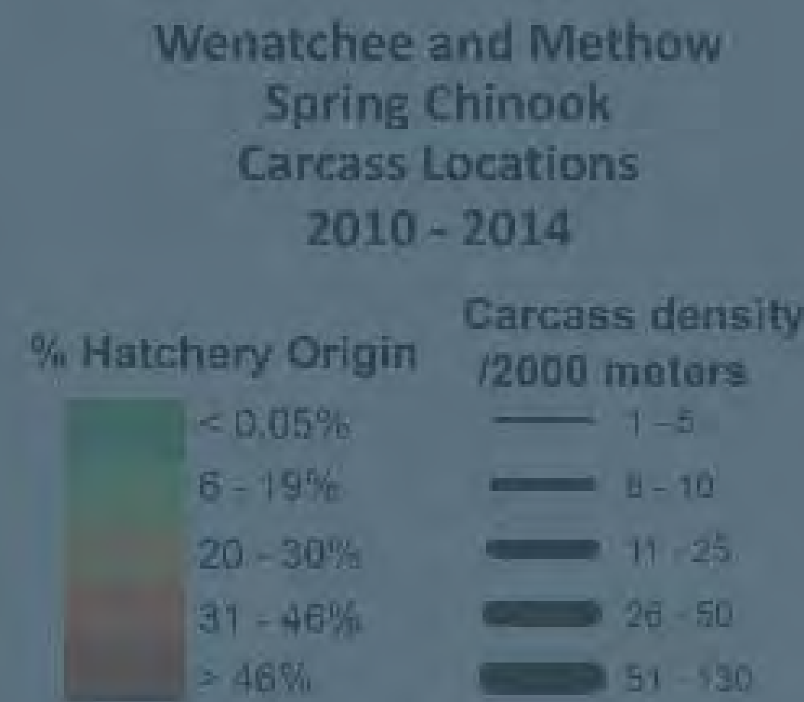
Average pHOS of spring Chinook in Upper Columbia spawning areas, ranging from 75% in the Methow to 24% in the Entiat (WDFW SaSI data 2016). Approximately 57% of steelhead spawners are hatchery-origin, ranging from 84% in the Okanogan to 30% in the Wenatchee.

57%

average pHOS of steelhead in Upper Columbia spawning areas, ranging from 84% in the Okanogan to 30% in the Wenatchee.

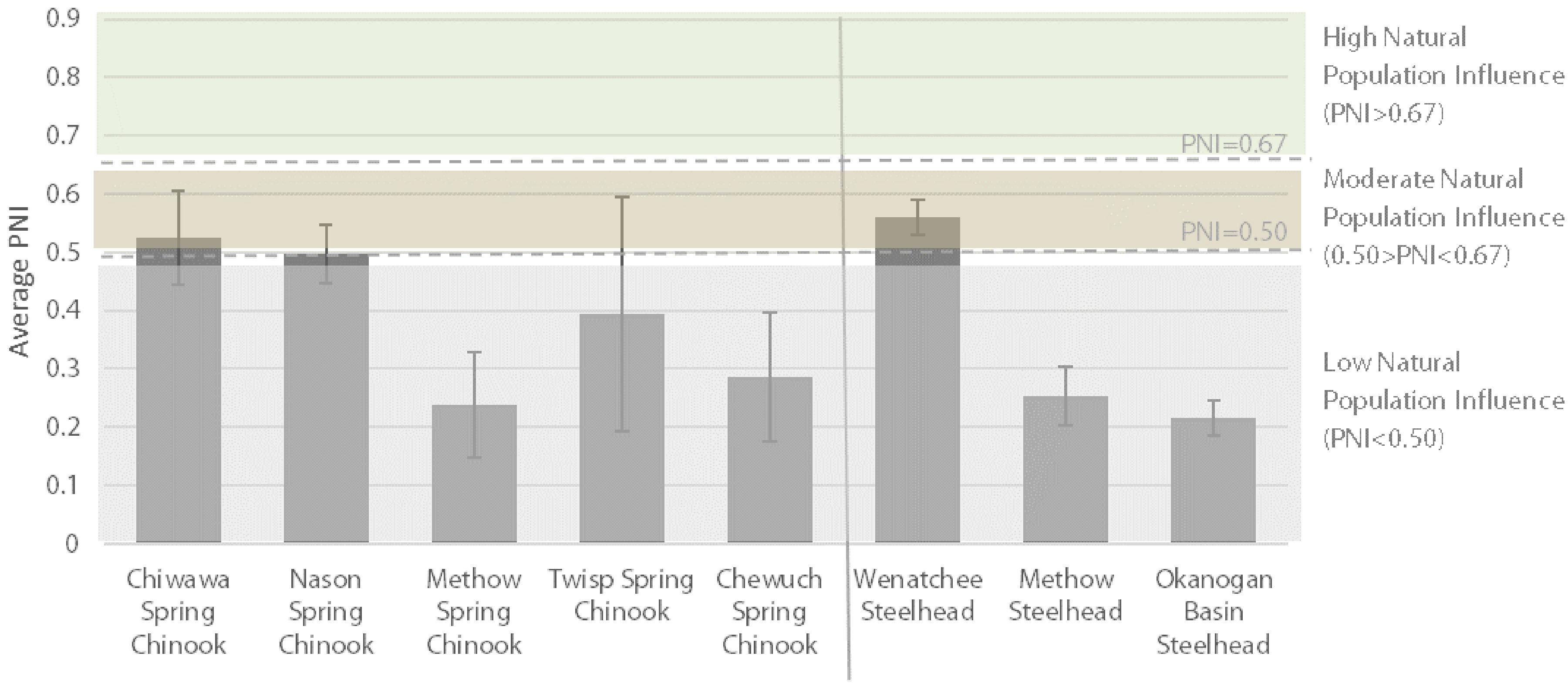


Values of pHOS vary by species, location, and year, and the scale at which it is measured is important to consider (population versus reach). Based on spawning surveys by WDFW, most hatchery-origin fish tend to spawn within a few kilometers of their release site (usually an acclimation or hatchery facility)



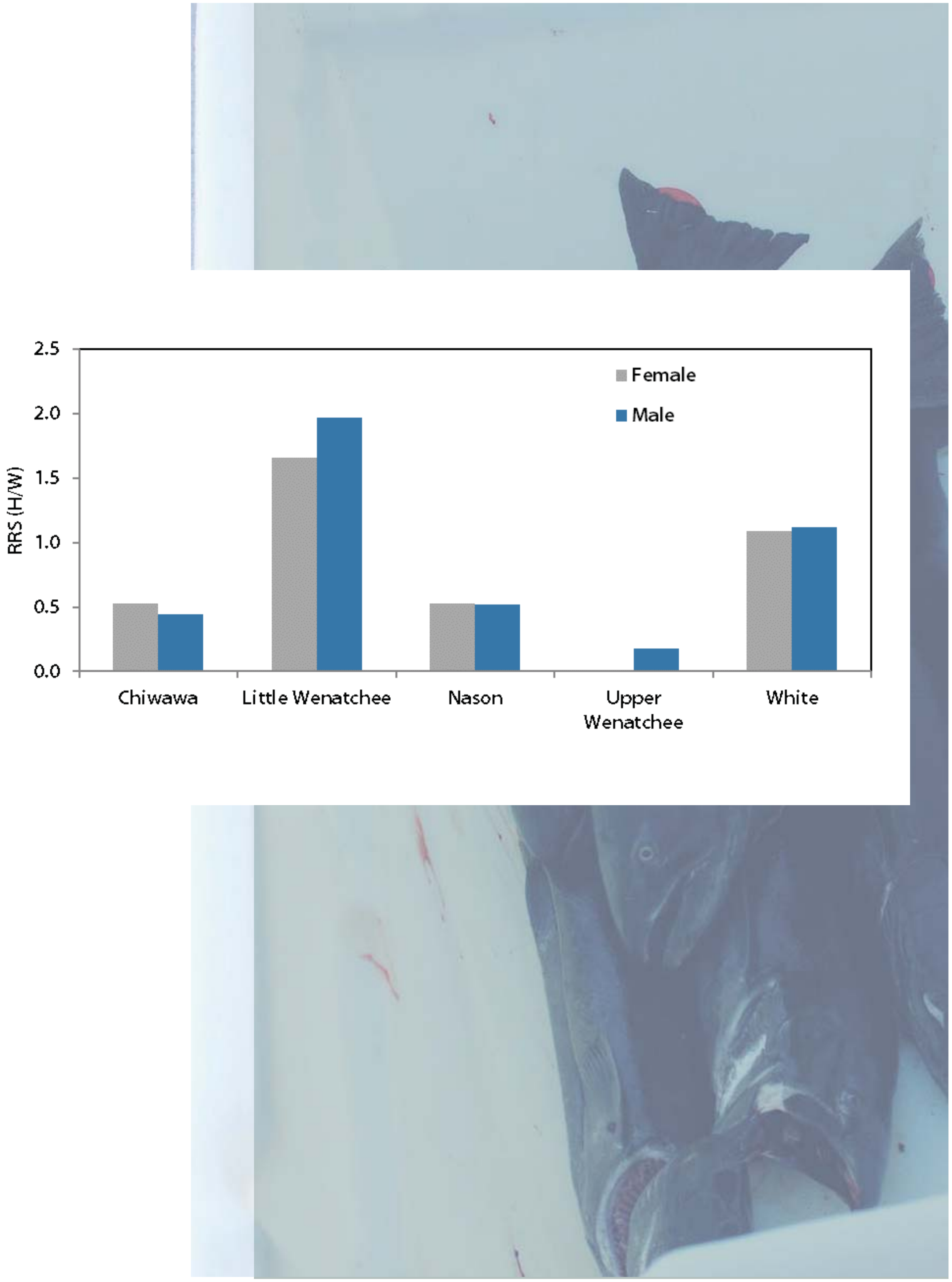
PNI

PNI by Supplemented Spawning Population (2011-2015)



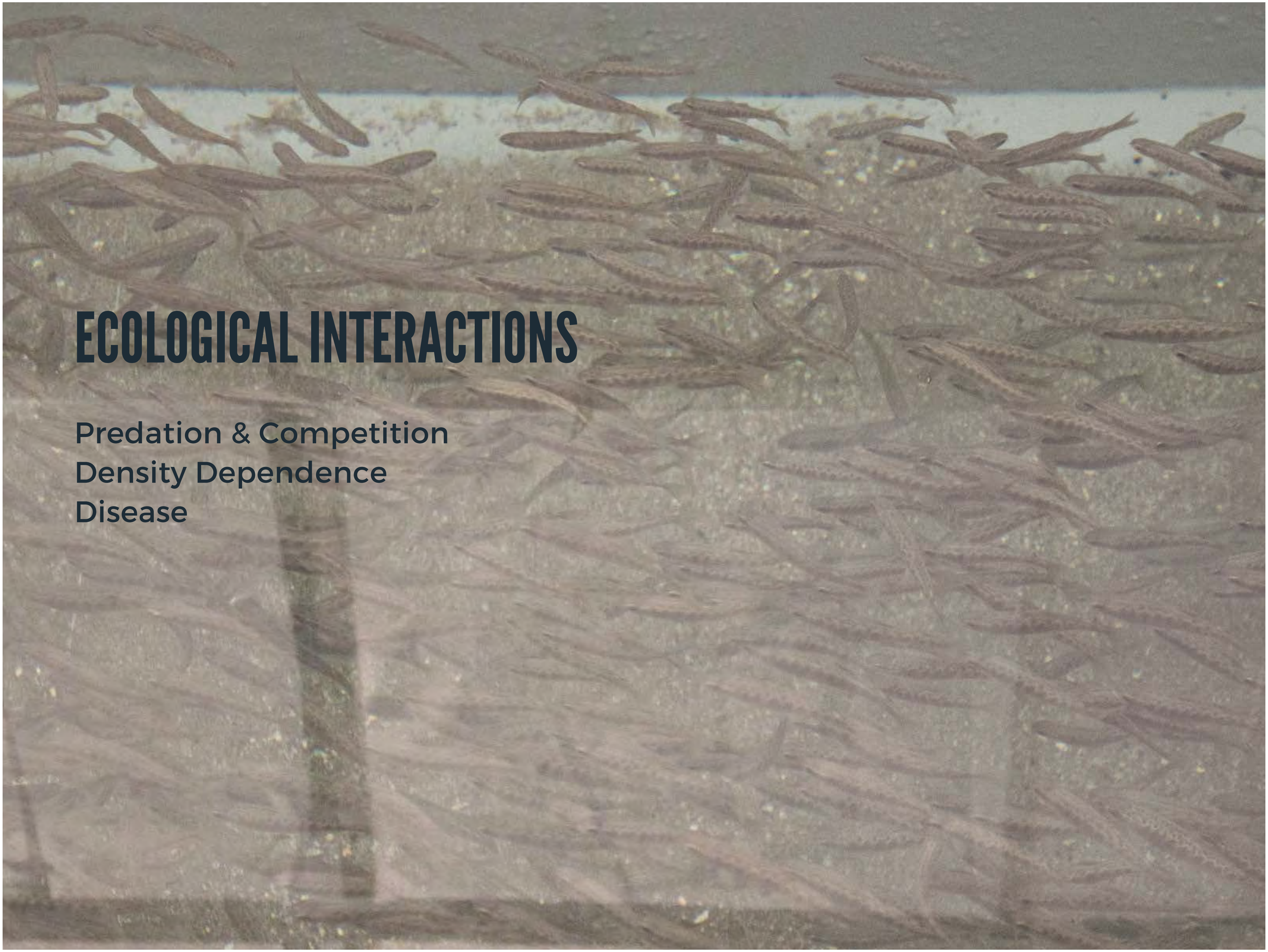
HATCHERY PROGENY

Results from these local studies suggest that productivity of hatchery-origin fish in the natural environment, at both the smolt and adult life stages, is significantly lower than that of naturally-produced fish. These results are consistent with those reported in others RRS studies outside the Upper Columbia (e.g. Ford et al. 2015; Berntson et al. 2011; Araki et al. 2007).



ECOLOGICAL INTERACTIONS

Predation & Competition
Density Dependence
Disease



ABUNDANCE

+

PRODUCTIVITY

=

SPATIAL STRUCTURE

+

DIVERSITY

+ or -

UNCERTAINTIES AND DATA GAPS

- Movement and returns
- Causal mechanisms for differences
- Reference streams
- Capacity and bottlenecks
- Interactions

KEY POINTS

- Hatchery supplementation has been underway since the early 1900's.
- 21 hatchery programs in the Upper Columbia
- Conservation hatchery programs play a role in helping depressed populations avoid extinction and depensation.
- Hatchery programs are supported by extensive research and monitoring programs
- Between 2010-2015 an average of 9.6 million hatchery-origin fish were released annually.

KEY POINTS CONT...

- Thousands of hatchery-origin adults return to the Upper Columbia each year.

- Hatchery-origin adults returning to the region are managed based on permit requirements and the goals of the program from which they originate.

- There is still considerable uncertainty related to the influence of hatchery programs (both past and present).

- Total spawner abundance of salmon and steelhead in the Upper Columbia has increased over the past decade.

OPPORTUNITIES TO ENGANGE

SUMMARY

review compiled information in Background Summary for accuracy and content.

November-December

SHARED LEARNING

identify topics and presenters for regional learning.

2018 Board meetings

DISCUSSIONS

engange in regional discussions about challenges and opportunities. Help identify areas for Board engagement.

2018-2019

NEXT STEPS

November 20th - Hatchery Summary IRTAG group review and edit
December 21st - Hatchery Summary UCSRB Board approval
2018- Shared learning at UCSRB meetings and science conference
2018 - Develop Hydropower and Harvest Summaries

THANK YOU!

greer.maier@ucsrb.org

Appendix C
Habitat Conservation Plan Tributary Committees 2017 Meeting Minutes

Wells, Rocky Reach, and Rock Island HCP Tributary Committees Notes 12 January 2017

Members Present: Lee Carlson (Yakama Nation), Jeremy Cram (WDFW), Steve Hays (Chelan PUD), Tom Kahler (Douglas PUD; on phone), Kate Terrell (USFWS), Justin Yeager (NOAA Fisheries), and Tracy Hillman (Committees Chair).

Members Absent: Chris Fisher (Colville Tribes)

Others Present: Becky Gallaher (Tributary Project Coordinator), Chas Kyger (Douglas PUD), and Jason Schilling (Douglas PUD). Cody Gillin (Trout Unlimited), Robes Parrish (USFWS), and Jennifer Hadersberger (Chelan County Natural Resources Department) attended the meeting for the presentations.

The Wells, Rocky Reach, and Rock Island Hydroelectric Projects Habitat Conservation Plans Tributary Committees met at Grant PUD in Wenatchee, Washington, on Thursday, 12 January 2017 from 9:30 am to 12:45 pm.

I. Review and Adopt Agenda

Tracy Hillman welcomed everyone to the meeting and the Committees adopted the proposed agenda.

II. Review and Approval of Meeting Minutes

The Committees reviewed and approved the 8 December 2016 meeting notes.

III. Monthly Update on Ongoing Projects

Becky Gallaher gave an update on funded projects. Most are progressing well or had no salient activity in the past month.

- MVID Instream Flow Improvement Project – The project sponsor (Trout Unlimited; TU) reported that the project is almost complete. There are five wells that need to be decommissioned and one well that may need to be re-drilled. This work will be completed during the spring.
- Twisp-to-Carlton Reach Assessment Project – This project is complete. The sponsor (Cascade Columbia Fisheries Enhancement Group; CCFEG) will submit a final report soon.
- Entiat Stillwaters Gray Reach Acquisition – The sponsor (Chelan-Douglas Land Trust; CDLT) did not provide an update on this project.
- Clear Creek Fish Passage and Instream Flow Project – The sponsor (TU) has been working on administrative and permitting tasks associated with the water-right change process and the Washington Department of Health New Source Approval process. The landowner finalized easement documents for Chelan PUD, who will pull cables and install a new transformer. The sponsor plans to submit the Ecology Report of Examination at the Chelan County Water Conservancy Board meeting in January.

- Barkley Irrigation – Under Pressure Project – The sponsor (TU) reported that they met with Barkley on several occasions to discuss various pump alternatives. Each option was evaluated based on construction opinions, estimated pipe alignment and sizes, pump configuration, O&M, and replacement scheduling. They will meet again on 10 January to discuss options.
- Methow Watershed Beaver Reintroduction Project – The sponsor (Methow Salmon Recovery Foundation; MSRF) reported that there was no new activity on this project. Trapping in 2016 is complete with a total of 36 beavers captured in 2016. The final report will be submitted in March 2017.
- Similkameen RM 3.8 Project – The project sponsor (Okanogan Conservation District) reported that Cardno is refining the preferred design.
- White River Floodplain (RM 3.4) Connection Project – The sponsor (CCFEG) reported that there is no new activity on this project.
- Icicle Boulder Field Project – The sponsor (TU) reported that they have completed the design phase of the project and have started permitting discussions.
- Peshastin Creek RM 10.5 PIT-Tag Detection Site Project – The sponsor (WDFW) reported that the project is complete. The sponsor submitted their annual monitoring report, which was uploaded to the Extranet site.
- Permitting Nutrient Enhancement Project – The sponsor (CCFEG) reported that they are writing a summary of findings and recommendations for nutrient enhancement monitoring in the Chiwawa River and will present their findings to the Forest Service later in January.
- Burns-Garrity Design Project – The sponsor (CCFEG) reported that Rio Applied Science and Engineering (the contractor for the project) visited the site in November and performed an initial geomorphic assessment. Rio developed a document describing their initial findings and identified several alternative restoration actions. Rio will further flesh out the alternatives once they receive the hydraulic model from the Bureau of Reclamation.
- Beaver Fever Project – The sponsor (TU) reported that they have been working on landowner outreach. They are researching landownership within the Colockum drainage because there are several reaches within this drainage that show promise for beaver dam analog (BDA) implementation. The sponsor has also reached out to Weyerhaeuser hoping to implement structures on their properties.

IV. ORRI Phase II Side Channel Reconnection Project

Although Chris Fisher was unable to attend the meeting, he sent an email to the Committees asking them to consider techniques or alternatives for the ORRI Phase II project. The project, which was implemented in 2013, reconnected a side channel to the mainstem Okanagan River. The side channel was to remain connected with the mainstem at all flows. Over the past few years, monitoring has indicated that there is a blockage issue within the approach channel and flows in the side channel are too low to provide rearing habitat for native fish during low flow conditions. The information provided by Chris not only indicated a sediment blockage issue in the approach channel, but also a breach of the approach channel in 2016.

After considering the information Chris provided, the Committees agreed that measures should be implemented that maintain the side-channel reconnection at all flows. To that end, they offered the following suggestions: (1) add another riffle or expand the existing riffle in the main channel; (2) excavate to design grade; (3) widen the approach channel; and (4) add a high-flow return.

V. Beaver Fever Project Presentation

In 2016, Trout Unlimited submitted a proposal to the Committees titled, "Beaver Fever: Restoring Ecosystem Function." The purpose of the project was to reestablish beavers and install BDAs in tributaries of the Wenatchee or Entiat basins. The reintroduction of beavers and installation of BDAs should enhance salmonid habitat by increasing habitat complexity, moderating water temperatures, augmenting stream flows, trapping fine sediments, and improving riparian and off-channel connectivity. The Rock Island Tributary Committee agreed to fund the installation of BDAs in tributaries. Last month, the sponsor asked to share with the Committees some of the results from running the BRAT (Beaver Restoration Assessment Tool) model and their findings during site visits.

Cody Gillin (TU) and Robes Parrish (USFWS) provided a short presentation to the Committees on their work (see Attachement 1). So far, they have evaluated 10 drainages and found some potential areas for implementation of BDAs. In the Entiat, areas in Mud, Potato, and Roaring creeks are good candidates for BDA enhancement. They asked the Committees what should be their primary objective (e.g., water yield/storage, temperature amelioration, vegetation enhancement, habitat complexity, etc.), what is an appropriate spatial scale for implementing BDAs (e.g., focus efforts in a single watershed or disperse efforts across several watersheds), what should be monitored, and should they explore partnerships.

The Committees indicated that they would like to see enhancement work focused in one watershed. They suggested working in Mission, Peshastin, or Roaring creeks. The Committees also noted that they want TU to evaluate the effects of BDAs on water temperature, stream flows, and salmonid abundance (this is consistent with the recommendations outlined in the letter sent from the Rock Island Tributary Committee to TU in September 2016 asking the sponsor to submit a monitoring proposal to the Committees). Finally, the Committees recommended that the sponsor establish partnerships with other interested entities. They have already established a partnership with the USFWS. Establishing a partnership with WDFW and perhaps a contactor to help with monitoring would be appropriate.

VI. Nason Creek RM 4.6 Channel Reconnection Project Presentation

In 2013, the Rock Island Tributary Committee agreed to partially fund the Nason Creek RM 4.6 Side Channel Reconnection Construction Project, which was submitted by Chelan County Natural Resources Department (CCNRD). The purpose of this project was to provide high-flow refugia and rearing habitat for adult and juvenile salmonids in Nason Creek. The project would reconnect a 4.6-acre, high-flow channel to the mainstem near RM 4.6. Because the County was unable to secure a cost share (the Committee agreed to fund $88,000 of the $525,030 project), the sponsor has been unsuccessful in implementing the project. The sponsor requested a meeting with the Committee to discuss the status of the project.

Jennifer Hadersberger (CCNRD) gave a short presentation on the status of the project (see Attachment 2). She provided a brief history of the project and then described the benefits of reconnection projects in Nason Creek and elsewhere. She stated that their approach at this time is only to reconnect the downstream end of the side channel. The reason for this is because the Forest Service is unwilling to approve reconnecting the upstream end of the side Channel. The Forest Service is concerned that if the upstream end is reconnected, water will be on both sides of the road and that will increase the likelihood of the road prism being eroded during high flows. Jennifer said Washington Department of Transportation has not voiced this concern. Jennifer stated that with only a downstream connection, the project will still benefit rearing salmonids.

Jennifer asked the Rock Island Tributary Committee if they would support a downstream-only connection. The Committee indicated that this is a significant departure from the original project; therefore, the County would need to submit a new proposal. The Committee recommended that the County try to secure funding for the downstream connection through the BPA targeted solicitation process. They also recommended that the County continue to seek approval from the Forest Service to reconnect the upstream end. Once the Forest Service approves the upstream connection, funds from the Rock Island Plan Species Account can be used to reconnect the upstream end of the channel. Jennifer said the County does not want to push the Forest Service on this issue at this time.

VII. Silver Side-Channel Rehabilitation Project Presentation

Robes Parrish (USFWS) gave a presentation on the enhancement work implemented in the lower portion of the Silver Side Channel in the Methow River basin (see Attachment 3). The purpose of the project was to increase habitat quality and quantity for salmonids within the side channel and floodplain corridor. This would be accomplished by increasing sinuosity and groundwater input, improving channel geometry, adding structure and complexity appropriate to the flow regime, developing groundwater-fed alcoves, improving fish passage, adding wood cover throughout the channel, and re-vegetating the riparian zone and floodplain. The Rocky Reach Plan Species Account contributed funds for the design of the enhancement project.

Robes described the history of the project and showed aerial photos of the project site from the 1940s, 1950s, and more recently. He identified land uses and threats, and described the enhancement approach. He showed a series of photos depicting the enhancement process and panoramic views of the enhanced channel. He concluded by showing before and after pictures throughout the enhancement reach. He noted that some of the vegetation may remain dormant for a year or two. They will continue to monitor the success of the project.

VIII. Information Updates

The following information updates were provided during the meeting.

1. Approved Payment Requests in December and January:

   Rock Island Plan Species Account:

   - $136.00 to Clifton Larson Allen for Rock Island financial administration in December 2016.
   - $839.19 to Chelan County PUD for project coordination and administration during the fourth quarter of 2016.

   Rocky Reach Plan Species Account:

   - $136.00 to Clifton Larson Allen for Rocky Reach financial administration in December 2016.
   - $791.62 to Chelan County PUD for project coordination and administration during the fourth quarter of 2016.
   - $11,144.68 to Cascade Columbia Fisheries Enhancement Group for the Burns-Garrity Restoration Design Project.

   Wells Plan Species Account:

   - $446.75 to Chelan County PUD for project coordination and administration during the fourth quarter of 2016.
   - $23,444.46 to Trout Unlimited for the MVID Instream Flow Improvement Project.

2. The Committees discussed the need to add language in the Policies and Procedures document indicating that approved projects must have a signed contract within a certain time period (e.g., five years) or the Committees will cancel funding for the project. The Committees noted that there are a few projects that were approved several years ago, but the sponsors have not been able

to move the projects forward because of a lack of additional funds (cost share) and/or a lack of landowner support. As such, the sponsors have not signed contracts with the Tributary Committees. The Committees directed Tracy Hillman to include draft language in the Policies and Procedures document for review during the next meeting.

3. During the September meeting, members of the Committees identified possible funded projects they would like to visit in 2017 (see Item #2 on page 4 of the September 2016 meeting notes). Given the long list of possible projects, Tracy Hillman asked the Committees if they would like to refine the list so the tour would take no more than two days (one day for Okanogan/Methow projects and one day for Entiat/Wenatchee projects). In November, Chris Fisher recommended each member identify five projects they would like to visit. During the March meeting, members will combine their lists and identify which projects will be selected for a field visit in 2017.
4. Tracy Hillman said the Tributary Committees will continue to meet on the second Thursday of each month in 2017. Those meeting dates are as follows:
    - Jan 12
    - Feb 9
    - Mar 9
    - Apr 13
    - May 11
    - Jun 8
    - Jul 13
    - Aug 10
    - Sep 14
    - Oct 12
    - Nov 9
    - Dec 14
5. Tracy Hillman stated that John Ferguson (Chair of the HCP Coordinating Committees) sent letters to the Confederated Tribes of the Umatilla Indian Reservation and American Rivers inquiring about their interest in participating in a meeting with members of the HCP Coordination, Hatchery, and Tributary Committees. These parties were involved in negotiating the HCPs, but elected not to sign the HCPs. This is an opportunity for the Committees to provide the two parties with a progress report on implementation, as well as give them an opportunity to ask questions of the Committees members. The two entities are to provide a formal response to the invitation by 14 April 2017.

IX. Next Steps

The next meeting of the Tributary Committees will be on Thursday, 9 March 2017 at Grant PUD in Wenatchee.

Meeting notes submitted by Tracy Hillman (tracy.hillman@bioanalysts.net).

Attachment 1

Presentation by Cody Gillin on Beaver Fever Project

BDA PROJECT UPDATE

- Initial visits to about 10 drainages
- Sand, Mission, Brender, Camas, Colockum, Chiwawa, Big Meadow, Little Wenatchee, Nason area
- Some potential locations but scale and constructability would be limited due to various constraints
- Common constraints included: substrate, proximity to roads, land ownership, basin characteristics, wide channel, hydrology, uncertain sustainability

Colockum Creek

TROUT UNLIMITED


Big Meadow Creek


Colockum Creek

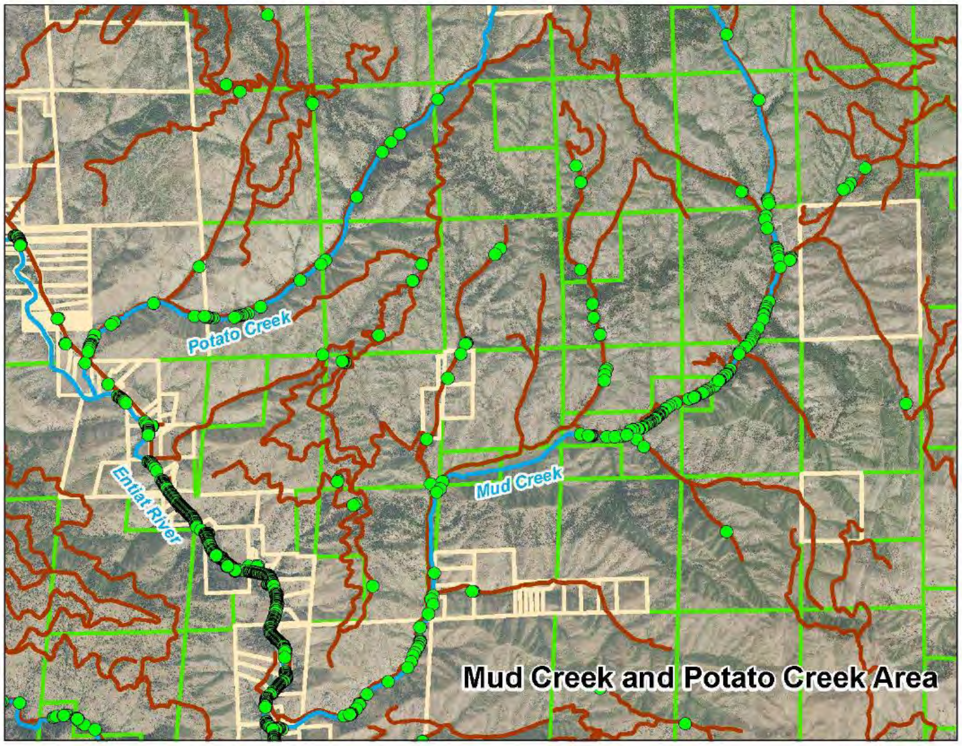

Camas Creek

OTHER LOCATIONS EXPLORED

- Kahler/Coulter Creeks: only recently secured access permission through Weyerhaeuser
- Mission/Sand Creeks: large substrate, surface bedrock, very close to roadway (Mission) or trails (Sand), confined valleys
- Chiwawa/Little Wenatchee: wide channels and large substrate
- Upper Peshastin: still need to get boots on the ground

EXPANDED SEARCH CRITERIA

- Original criteria (similar to BRAT): <9% slope, within 200 ft of roadway, suitable vegetation, Wenatchee sub-basin only
- BDA-specific criteria: <2% slope, within 200 ft of roadway, no vegetation criteria, all of Chelan County
- Mud/Potato Creeks (Entiat) were a hot spot; Roaring showed promise



Many beaver ponds

Diverse dam structures

Low gradient system

Lots of water

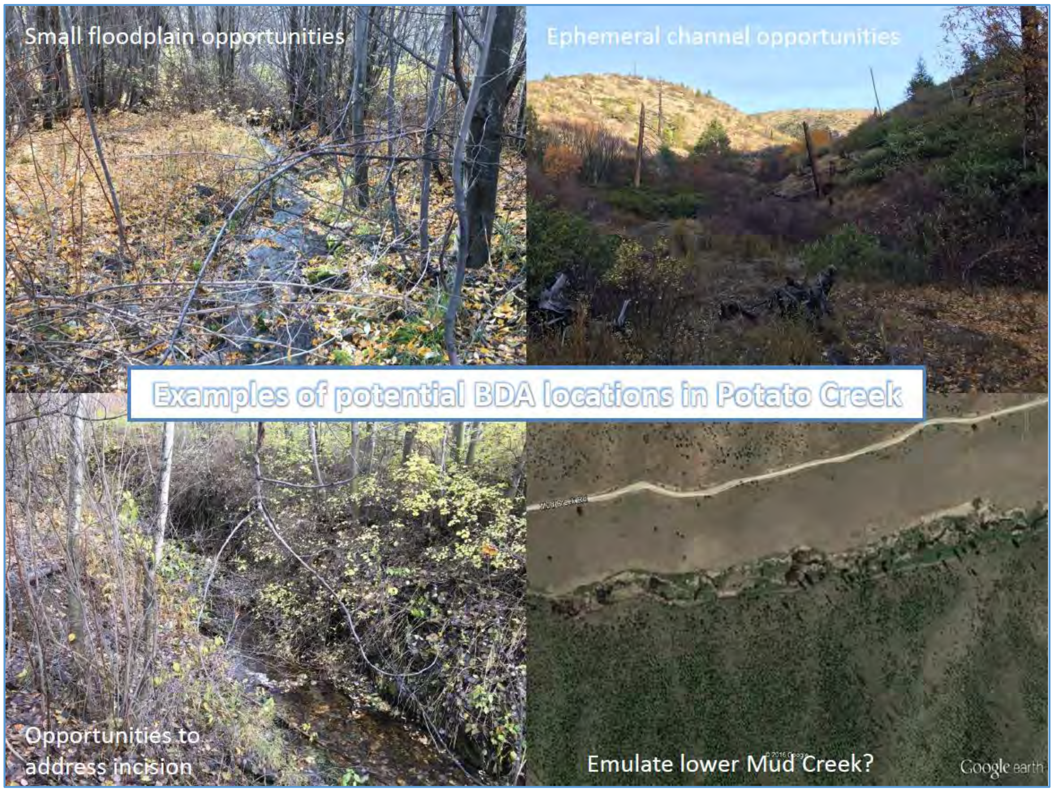
Disconnected floodplains

Mixed low and high gradient

Some channel incision

Some water

Limited active beaver sign



NEEDED GUIDANCE TO MOVE FORWARD:

- What should be our primary goals/objectives?
  - Water yield/storage?
  - Temperature amelioration?
  - Sediment reduction?
  - Vegetation expansion?
  - Direct habitat benefits?

- What is an appropriate spatial scale?
  - Single watershed (e.g., Potato Creek)? Low or high intensity?
  - Dispersed sites, multiple watersheds?

- Monitoring elements:
  - What is TRIB most interested in learning about BDAs?
  - Certain metrics are easier and less costly than others
  - Should we explore partnerships?

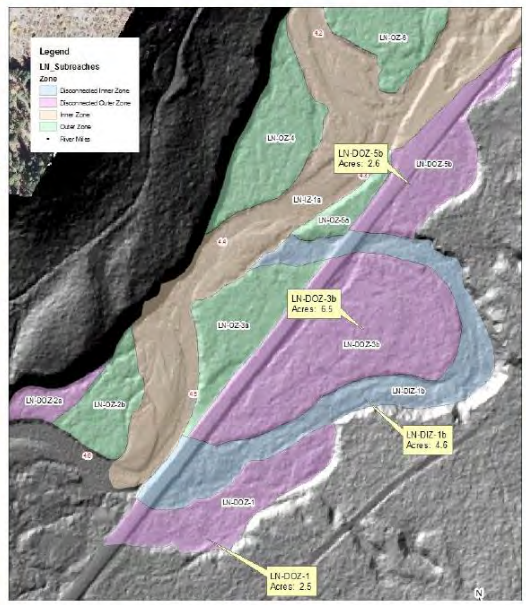
Attachment 2

Presentation by Jennifer Hadersberger on the Nason Creek RM 4.6 Channel Reconnection Project

Nason Creek RM 4.6 Floodplain Side Channel Reconnection Construction

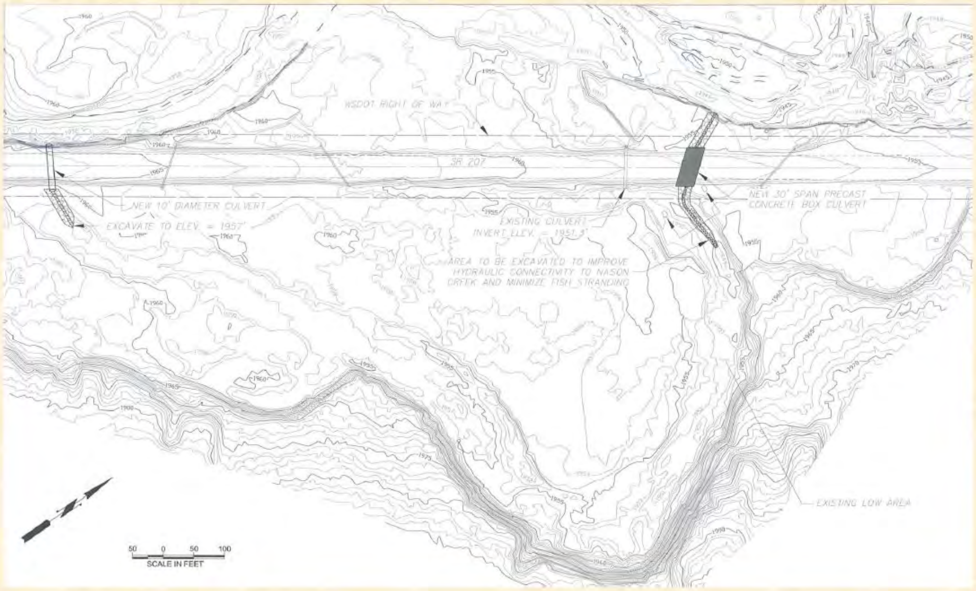
Project History

- 2011 Alternatives Analysis
- 2012 SRFB Funding Fill Removal and oxbow enhancement
- 2013 Trib Com funding
- 2014 Fill removal implemented
- 2016 JARPA submittal

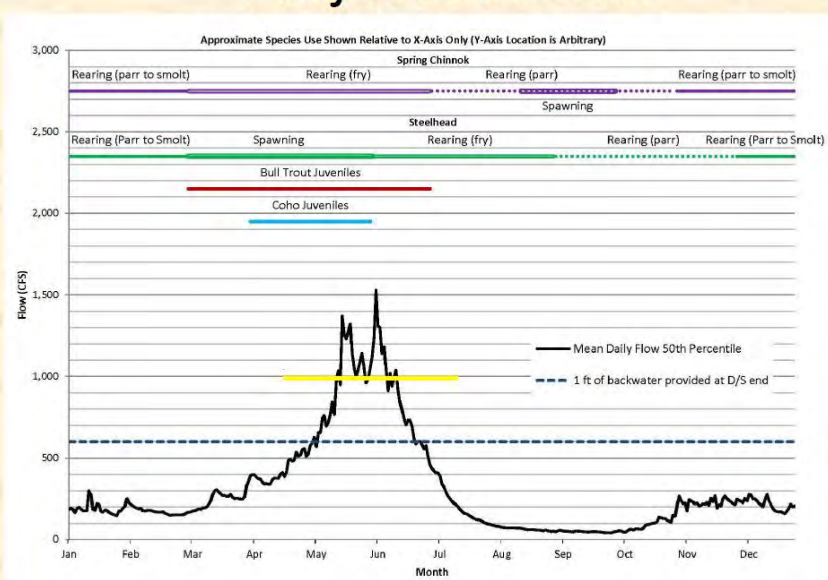


2011 Lower Nason Assessment - USBR

Plan view of proposed project

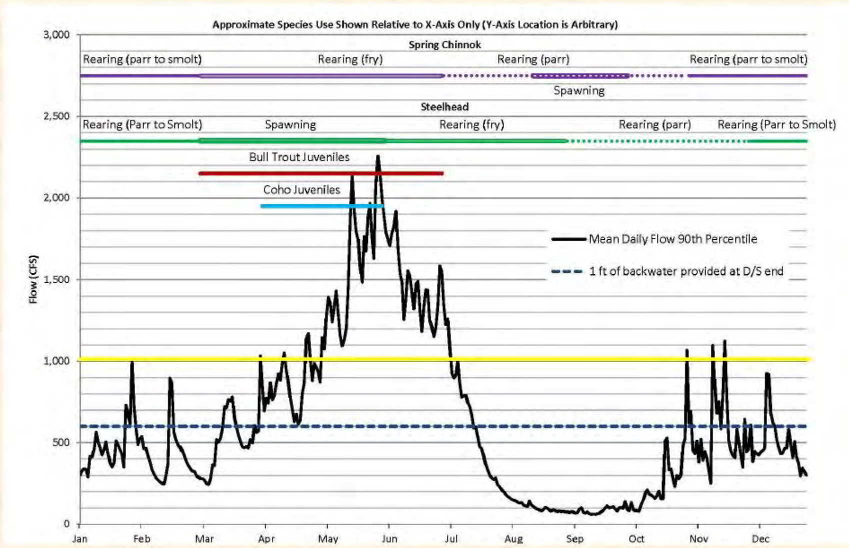


Project Benefits



Typical Flow Year (50^{th} percentile)

Project Benefits

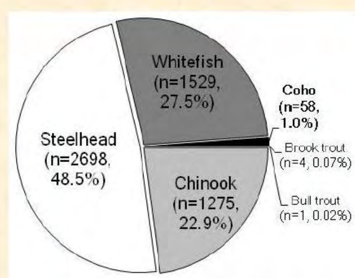


High Flow Year (90th percentile)

Do fish use side channels in Nason Creek?

- Monitoring of the nearby 2007 Oxbow has documented salmonid abundance ranging from 2-16 salmonids/100m2 (Figure 19, page 30 DOE 2011).

2010 survey data



Yakama Nation Juvenile Fish Counts in the 2007 Oxbow

Date	Nason cfs	Chinook	Steelhead
Summer 2012		165	1438
March 2013		131	426
Summer 2013		601	1040
3/20/14	404	171	301
8/27/14	66.5	421	395
3/25/15	733	28	178
8/6/15	33.7	96	372
3/8/16	542	11	83
8/9/16	69.9	30	437

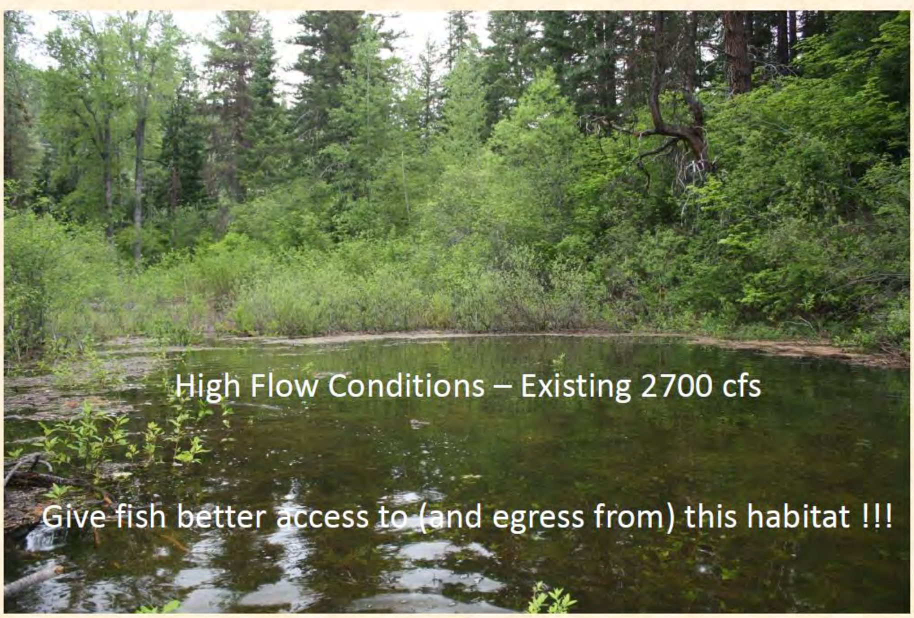
Fish counts in seasonally inundated floodplain side channels,RM 4.6.

Location	Nason discharge (cfs)	Juvenile steelhead	Juvenile Chinook
Floodplain side channel June 2014	734	0	62
Floodplain side channel April 2015	300	0	0
Newly constructed side channel April 2015	300	47	0
Newly constructed side channel March 2016 (pm)	400-750	6	0
Newly constructed side channel May 2016 (CCNRD)	869	0	2

What does the Literature Say?

- Floodplain areas provide better rearing and migration habitat for juvenile chinook salmon than adjacent river channels; salmon increase in size faster in **seasonally** inundated floodplain than in the river, suggesting better growth rates due to bioenergetics and food sources. (Sommer et al 2001)
- Floodplain side channels offer reduced competition for available prey. This study in the Methow river found that side channels are important habitat for juvenile rearing for Chinook salmon and steelhead; Chinook and steelhead rearing in side channels had lower potential exploitative competition for food with other non-target fish (sculpin and whitefish) and as a result, side channels appeared to have a greater capacity to sustain juvenile Chinook and steelhead production relative to the main channel habitat. (Bellmore 2013)

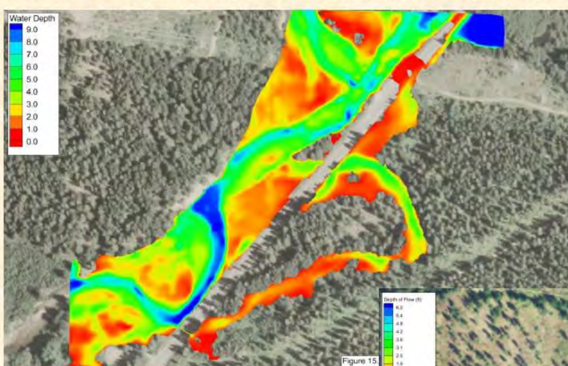
Downstream



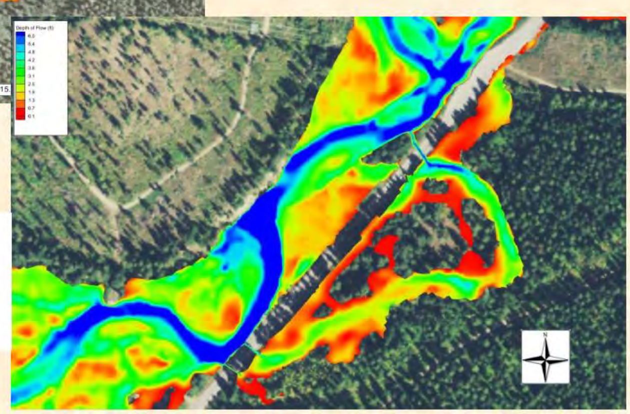
Why Downstream only connection?

1. USFS input
2. WDFW is evaluating the upstream culvert
3. Cost
4. Perhaps limited difference in biological benefit?
5. Phased

1. USFS has concerns about risk involved with upstream culvert

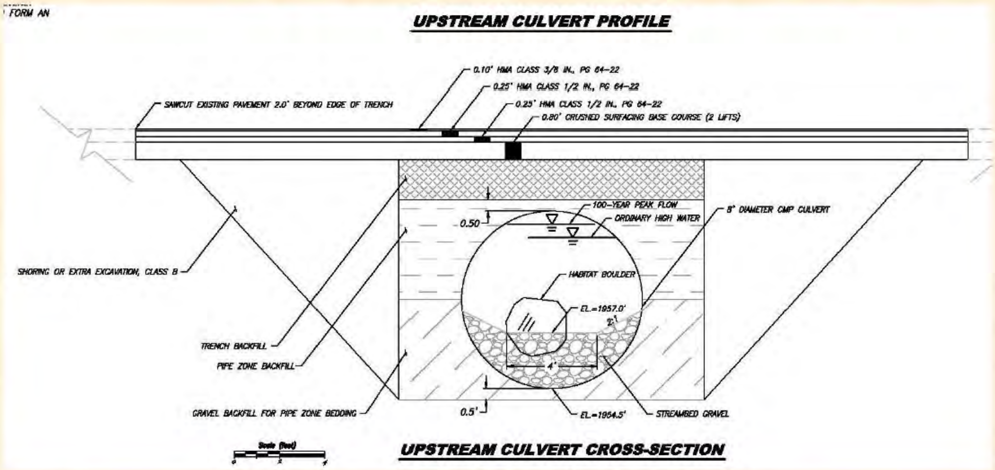


2D model existing conditions (water depth) 100 year (~6,500 cfs) event.



Proposed conditions (water depths) 100 year event.

WDFW evaluating the upstream culvert



Costs

Item	2013 Cost Est.	2016 Cost Estimate	
Construction (2 structures)	$414,530	$571,820	
Construction (1 structure)			$361,853

Project Benefits

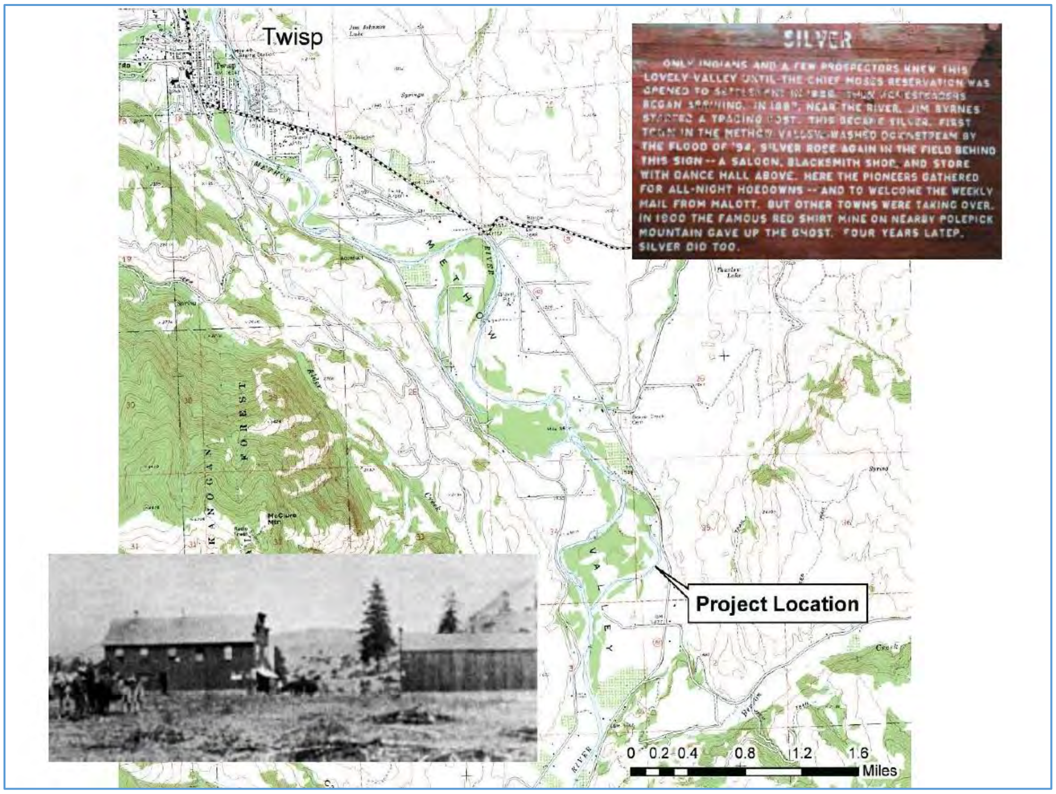
Downstream connection = rearing habitat

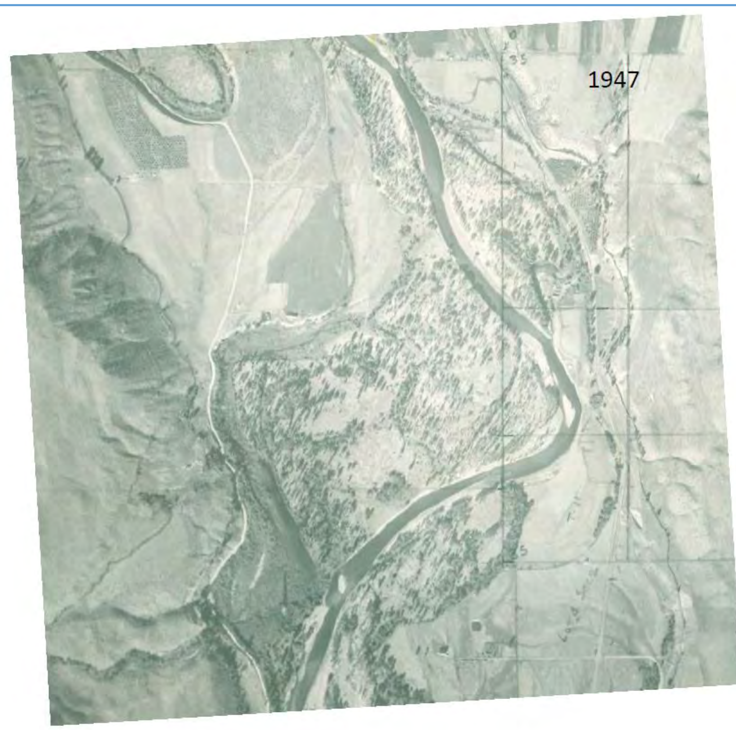
Upstream connection = flushing benefit

Support for downstream only connection?

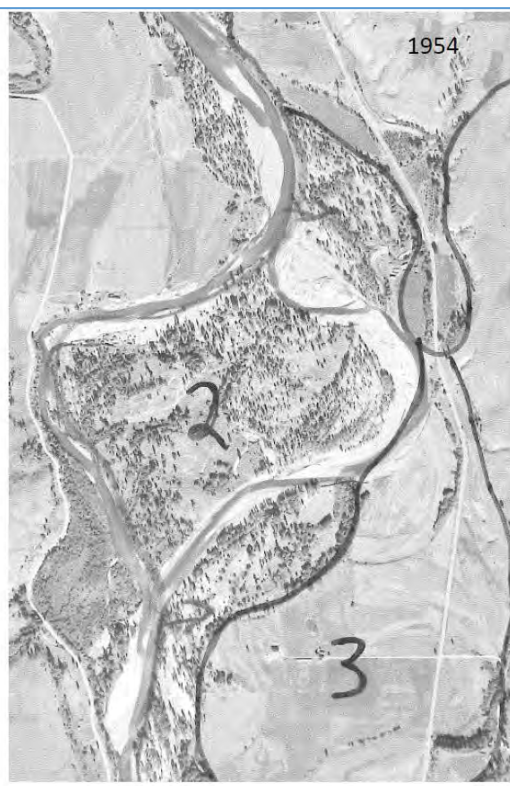
Attachment 3

Presentation by Robes Parrish on Silver Side-Channel Rehabilitation


Twisp
SILVER
ONLY INDIANS AND A FEW PROSPECTORS KNEW THIS
THE FLOOD OF '94, SILVER ROSE AGAIN IN THE FIELD BEHIND
THIS SIGN -- A SALOON, BLACKSMITH SHOP, AND STORE
WITH DANCE HALL ABOVE. HERE THE PIONEERS GATHERED
FOR ALL-NIGHT HOEDOWNS -- AND TO WELCOME THE WEEKLY
MAIL FROM MALOTT. BUT OTHER TOWNS WERE TAKING OVER.
IN 1900 THE FAMOUS RED SHIRT MINE ON NEARBY POLEPICK
SILVER DID TOO.
Project Location
0 0.2 0.4 0.8 1.2 1.6
Miles

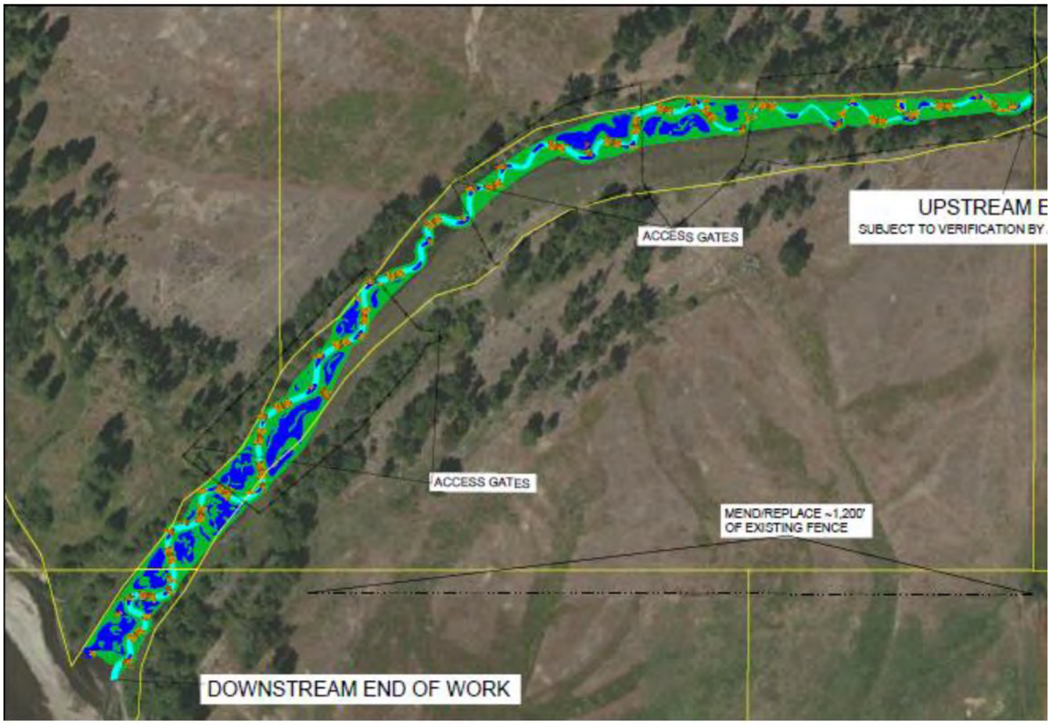

1947

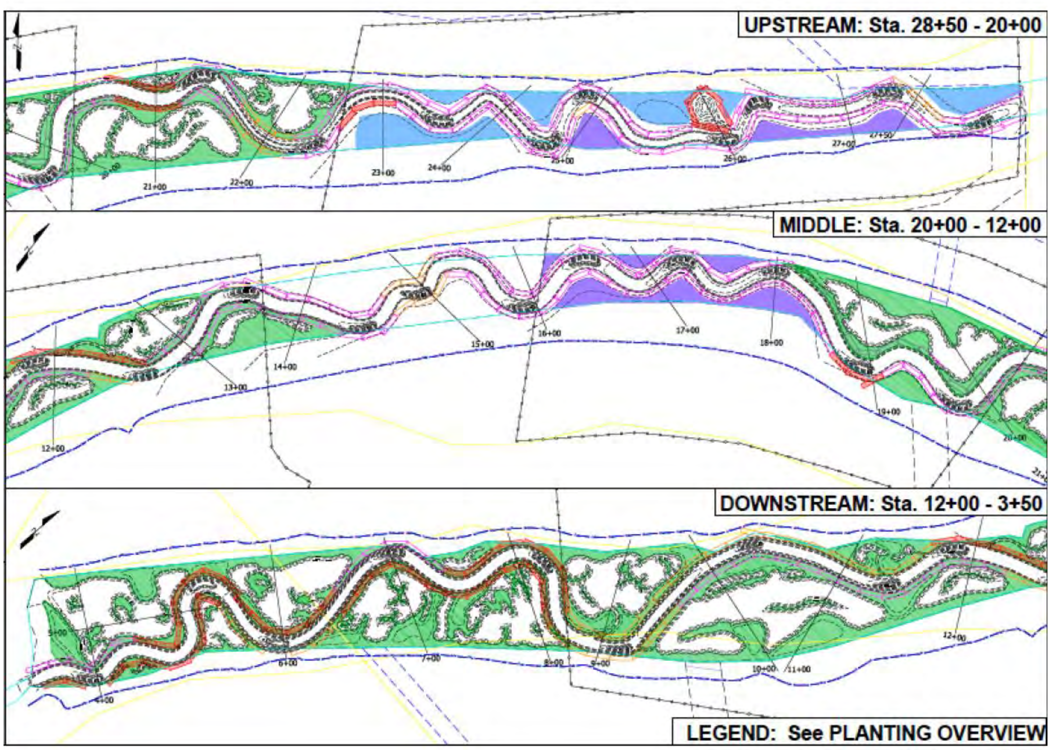

1948
(in flood)


1954
2
3


Human Impacts (fire, diversions, livestock, trespass)


2014
Surface Rd
2016
2018?
Twisp-Carlton Rd
Methow Valley Hwy
© 2016 Google
153
Googl


UPSTREAM E
SUBJECT TO VERIFICATION BY
ACCESS GATES
ACCESS GATES
MEND/REPLACE ~1,200'
OF EXISTING FENCE
DOWNSTREAM END OF WORK


UPSTREAM: Sta. 28+50 - 20+00
MIDDLE: Sta. 20+00 - 12+00
DOWNSTREAM: Sta. 12+00 - 3+50
LEGEND: See PLANTING OVERVIEW


Defishing, Day 1 of 10


Emergent chara choking channel


Dewatering and turbid water collection


Clear water bypass


Turbid water discharge (settling basin)

Channel excavation and fill delivery


Prior to finishing with topsoil


CAT
MWD Placement


FWD Matrix

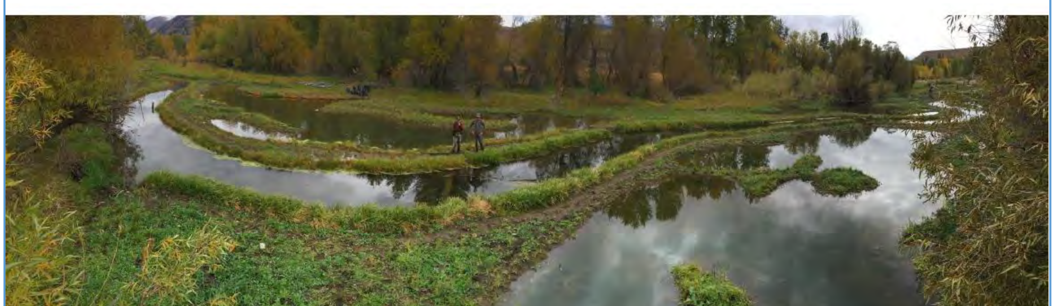

Wetland sod placement

Completed sod and irrigation installation

Wetland plugs and hemi-marshes

Panorama (lower) during construction

Panorama (lower) post-construction



Panorama (lower) post-construction

Panorama (lower) post-construction

Panorama (middle) post-construction

Panorama (middle) post-construction

Panorama (middle) post-construction

Panorama (upper) post-construction

Panorama (upper) post-construction


PP 01.DS.B


PP 01.DS.A


PP 02.US.B


PP 02.US.A


PP 04.US.B


PP 04.US.A


PP 05.US.B


PP 05.US.A


PP ##.US.B


PP ##.US.A

Wells, Rocky Reach, and Rock Island HCP Tributary Committees Notes 9 March 2017

Members Present: Lee Carlson (Yakama Nation), Jeremy Cram (WDFW), Chris Fisher (Colville Tribes), Steve Hays (Chelan PUD), Kate Terrell (USFWS), Justin Yeager (NOAA Fisheries), and Tracy Hillman (Committees Chair).

Members Absent: Tom Kahler (Douglas PUD)[1]

Others Present: Becky Gallaher (Tributary Project Coordinator). Steve Kolk (Bureau of Reclamation), Deanne Pavlik-Kunkel (Grant PUD), and Denny Rohr (PRCC Habitat Subcommittee Chair) attended the meeting for the Middle Entiat Project presentation.

The Wells, Rocky Reach, and Rock Island Hydroelectric Projects Habitat Conservation Plans Tributary Committees met at Grant PUD in Wenatchee, Washington, on Thursday, 9 March 2017 from 9:00 am to 12:00 pm.

I. Review and Adopt Agenda

Tracy Hillman welcomed everyone to the meeting and the Committees adopted the proposed agenda.

II. Review and Approval of Meeting Minutes

The Committees reviewed and approved the 12 January 2017 meeting notes.

III. Monthly Update on Ongoing Projects

Becky Gallaher gave an update on funded projects. Most are progressing well or had no salient activity in the past month.

- MVID Instream Flow Improvement Project – The project sponsor (Trout Unlimited; TU) did not provide an update on this project.
- Twisp-to-Carlton Reach Assessment Project – This project is complete. The sponsor (Cascade Columbia Fisheries Enhancement Group; CCFEG) submitted a final report, which was uploaded to the Extranet site.
- Entiat Stillwaters Gray Reach Acquisition – The sponsor (Chelan-Douglas Land Trust; CDLT) did not provide an update on this project.
- Clear Creek Fish Passage and Instream Flow Project – The sponsor (TU) did not provide an update on this project.
- Barkley Irrigation – Under Pressure Project – The sponsor (TU) did not provide an update on this project.

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[1] Tom provided his votes on decision items following the meeting.

- Methow Watershed Beaver Reintroduction Project – The sponsor (Methow Salmon Recovery Foundation; MSRF) reported that there was no new activity on this project. The final report will be submitted in March 2017.
- Similkameen RM 3.8 Project – Chris Fisher reported that the parties held a conference call to divide the labor among the different entities. In addition, they selected a preferred design, which was approved by the Tributary Committees last year. Permit applications will be completed by the end of March.
- White River Floodplain (RM 3.4) Connection Project – The sponsor (CCFEG) reported that they are continuing discussions with WDFW to finalize the Right of Entry (ROE) permit, which is the final permit needed to begin the project. Once the ROE permit is finalized, the sponsor will schedule work with the contractor.
- Icicle Boulder Field Project – The sponsor (TU) did not provide an update on this project.
- Peshastin Creek RM 10.5 PIT-Tag Detection Site Project – The sponsor (WDFW) reported that the project is complete. The second-year monitoring report is due on 31 December 2017.
- Permitting Nutrient Enhancement Project – The sponsor (CCFEG) reported that they continue to work with the Forest Service to assess interest and willingness to implement the project. They are also working on the project summary and monitoring proposal that will be submitted to the Forest Service in March.
- Burns-Garrity Design Project – The sponsor (CCFEG) reported that Rio Applied Science and Engineering (the contractor on the project) received the 2-D hydraulic model from the Bureau of Reclamation. Rio is now modeling several alternative concepts and they will present those to stakeholders in April. They will then select a preferred concept.
- Beaver Fever Project – The sponsor (TU) did not provide an update on this project.

IV. Budget Amendments and Time Extensions

MVID Instream Flow Improvement Project

The Tributary Committees received a time extension request from Trout Unlimited on the *MVID Instream Flow Improvement Project*. The sponsor asked the Rock Island and Wells Committees to extend the period of their contracts from 30 September 2016 to 30 November 2017 and the Rocky Reach Committee to extend the period of their contract from 31 March 2017 to 30 November 2017. After review and discussion, ***the Committees agreed to extend their respective contracts to 30 November 2017***.

Entiat Stillwaters Gray Reach Acquisition

The Rocky Reach Tributary Committee received a time extension and amendment request from Chelan-Douglas Land Trust on the *Entiat Stillwaters Gray Reach Acquisition Project*. The sponsor asked the Committee if CDLT could use some of the remaining balance of the Entiat Stillwaters Gray Reach Acquisition Project to help cover expenses associated with lot sales and the Beutler and Scoville acquisitions, and help purchase the Coutcher and Phipps properties. To complete the transactions, the sponsor asked to extend the period of the contract from 31 March 2017 to 31 December 2018.

Because the amendment represents a significant departure in the scope of the original project, ***the Rocky Reach Tributary Committee denied the amendment and time extension***. The Committee invited the sponsor to submit a new proposal seeking funds to cover expenses associated with the Beutler and Scoville acquisitions and to help purchase the Coutcher and Phipps properties.

Similkameen RM 3.8 Rehabilitation Project

The Rocky Reach Tributary Committee received a budget amendment request from Okanogan Conservation District on the *Similkameen RM 3.8 Rehabilitation Project*. The sponsor asked the Rocky Reach Committee to add $24,851.27 to their budget in order to complete the project. The additional funds will increase "Salaries/Benefits" from $2,446.50 to $6,364.02, "Professional Services" from $64,108.00 to $84,650.00, and "Indirect/Overhead/Admin" from $815.50 to $1,207.25. The total amount of the contract will increase from $67,370.00 to $92,221.27. After careful consideration, ***the Rocky Reach Tributary Committee approved the budget amendment***.

Beaver Fever: Restoring Ecosystem Function Project

The Rock Island Tributary Committee received a budget amendment request from Trout Unlimited on the *Beaver Fever: Restoring Ecosystem Function Project*. The sponsor asked the Committee to move $1,997.00 from "Administration/Overhead" to "Salaries and Benefits," $2,294.94 from "Administration/Overhead" to "Professional Services," and $7,028.75 from "Administration/Overhead" to "Project Materials." After consideration, ***the Rock Island Tributary Committee approved the budget amendment***. The total budget amount of $108,225.94 will not change as a result of this amendment.

V. General Salmon Habitat Program Proposal

Derby Creek Fish Passage – Collins Project

Cascade Columbia Fisheries Enhancement Group is the sponsor of the *Debry Creek Fish Passage – Collins Project*. The purpose of this project is to remove the lowermost fish passage barrier culvert (RM 0.3) on Derby Creek, a tributary to the Wenatchee River. Removal of the lowermost barrier will open about 10 miles of habitat for steelhead spawning and rearing. The total cost of the project is $190,000. The sponsor requested $90,000 from HCP Tributary Funds. The Committees were unable to make a funding decision and requested additional information from the sponsor.

The Committees asked the sponsor to respond to the following questions/comments:

1. Describe the status of fish passage at the obstacles downstream from the proposed passage barrier. For example, there is one obstacle that is highlighted "unknown passability." Is this at the road or railroad crossing and is there evidence that it is passable?
2. Indicate the location of the PIT-tag array on the map prepared by Chris Dwight.
3. Does Derby Creek dewater at any time of year, and, if so, where?
4. The proposal indicates that CCFEG has removed one total barrier and received funding for removal of two additional barriers. Please show on the map prepared by Chris Dwight the location of these barriers.
5. Has NRCS confirmed that they will fund the cost share?
6. Did you consider replacing the barriers with small bridges similar to those used on Frazer Creek in the Methow River basin (e.g., see: http://methowsalmon.org/currentprojects.html)? If so, why are they not the preferred alternative?

Once the Committees receive the additional information, they will reevaluate the proposal.

VI. Review of Draft Wells HCP Tributary Committee Action Plan

Douglas PUD provided the Committees with the Draft Wells HCP Tributary Committee Action Plan for 2017. The 2017 Draft Action Plan for the Wells Tributary Committee is as follows:

Plan Species Account Annual Contribution

- $176,178 in 1998 dollars: January 2017

Annual Report – Plan Species Account Status

- Draft to Tributary Committee (TC): February 2017
- Integration into HCP Annual Report: February 2017

General Salmon Habitat Program

- Project Review and Funding Decision January – December 2017

Small Projects Program

- Project Review and Funding Decision January – December 2017

The Wells Tributary Committee approved the Tributary Section of the Wells Action Plan for 2017.

VII. Review of Draft Rock Island and Rocky Reach HCP Tributary Committees Action Plans

Chelan PUD provided the Committees with the Draft Rocky Reach and Rock Island HCP Tributary Committees Action Plans for 2017. The 2017 Action Plans for both Rocky Reach and Rock Island Tributary Committees are as follows:

- Plan Species Account Deposits: January 2017
- GSHP Project Review and Approval: Ongoing
- GSHP Project Implementation: Ongoing
- Small Project Review and Approval: Ongoing
- Small Project Implementation: Ongoing

The Rocky Reach and Rock Island Tributary Committees approved the Tributary Sections of the Rocky Reach and Rock Island Action Plans for 2017.

VIII. Review of Tributary Committees' Policies and Procedures

Policies and Procedures for Funding Projects

The Committees reviewed their Policies and Procedures document and added the following language to the beginning of Section 6.3 (Timelines and Extensions).

> *Project Sponsors must have a signed contract with the Committees within one (1) year from the date when the Committees approved the project. In the event the Project Sponsor does not have a signed contract because of a lack of additional funds (cost share), a lack of landowner support, or any other reason, the Committees may cancel funding for the project. After the one-year period, the Project Sponsor will need to resubmit a new proposal seeking funding for a canceled project.*

Following the meeting, there was discussion about the use of the word "may" in the sentence stating "…the Committees may cancel funding for the project." It was pointed out that this statement is not consistent with the first sentence of the paragraph stating that "Project Sponsors must have a signed contract…" In short, the consequence does not fit the rule. The Committees will revisit the language added to Section 6.3 during their next meeting.

The Committees also rearranged statements in Section 3.8 (Management Guidelines for Conservation Easements/Acquired Lands). They placed the statement, "Allow public access[2] except under

[2] Public access is restricted to foot access and will be provided at all times. There shall be no impediments to foot access (e.g., fences) and the access cannot devalue the habitat being protected. The Committees do not require the easement or property-title holder to provide any improvements to facilitate access or to accommodate ADA standards.

extraordinary circumstances" at the front of the list. Finally, they rearranged sub-sections under Section 3 (General Policies) to reflect a more logical order.

Tributary Committee Operating Procedures

Tracy Hillman asked if the Committees had any changes or edits to the Tributary Committee Operating Procedures document. Members had no changes to the Operating Procedures.

IX. Information Updates

The following information updates were provided during the meeting.

1. Approved Payment Requests in February and March:

   Rock Island Plan Species Account:

   - $140.00 to Clifton Larson Allen for Rock Island financial administration in January 2017.
   - $1,578.50 to Trout Unlimited for work on the MVID Instream Flow Improvement Project.
   - $767.75 to Cascade Columbia Fisheries Enhancement Group for work on the Twisp-to-Carlton Reach Assessment (final payment).
   - $102.00 to Clifton Larson Allen for Rocky Island financial administration in February 2017.
   - $2,208.14 to Cascade Columbia Fisheries Enhancement Group for work on Permitting Nutrient Enhancement in the Chiwawa River Basin.

   Rocky Reach Plan Species Account:

   - $140.00 to Clifton Larson Allen for Rocky Reach financial administration in January 2017.
   - $966.78 to Okanogan Conservation District for work in November and December on the Similkameen RM 3.8 Rehabilitation Project.
   - $380.40 to Okanogan Conservation District for work in January on the Similkameen RM 3.8 Rehabilitation Project.
   - $102.00 to Clifton Larson Allen for Rocky Reach financial administration in February 2017.
   - $939.04 to Cascade Columbia Fisheries Enhancement Group for work on the Burns-Garrity Restoration Design Project.

   Wells Plan Species Account:

   - $1,178.28 to the Methow Salmon Recovery Foundation for work on the Methow Watershed Beaver Reintroduction Project.
   - $4,319.10 to Trout Unlimited for work during January on the MVID Instream Flow Improvement Project.
   - $3,868.63 to Trout Unlimited for work during February on the MVID Instream Flow Improvement Project.

2. Becky Gallaher reported that the PUDs deposited funds into each of the Plan Species Accounts at the end of January 2017. Chelan PUD deposited $737,452 into the Rock Island Account and $349,271 into the Rocky Reach Account. Douglas PUD deposited $267,771 into the Wells Account. As of March 2017, the unallocated balances within each account were $5,559,653 in the Rock Island Account, $2,378,263 in the Rocky Reach Account, and $1,331,318 in the Wells Account. Thus, among the three accounts, there is about $8,269,234 available.
3. Becky Gallaher stated that the Methow Salmon Recovery Foundation would like to provide a personal showing of their Methow Watershed Beaver Reintroduction Project film. The film is about 25-minutes long. The Committees appreciated the offer, but declined a personal showing of the film. The Committees will view the film on their own.
4. Tracy Hillman reported that he and Becky Gallaher completed Section 2.3 (Tributary Committees and Plan Species Accounts) for the Annual Report of Activities under the Anadromous Fish Agreement and Habitat Conservation Plan for each hydroelectric project. Tracy said he sent the draft reports to Anchor QEA, who is compiling the draft annual reports. The draft reports were sent to the HCP Coordinating Committees for review. The PUDs will submit the final reports to the Federal Energy Regulatory Commission in April.
5. During the September 2016 meeting, members of the Committees identified possible funded projects they would like to visit in 2017 (see Item #2 on page 4 of the September 2016 meeting notes). Given the long list of possible projects, Tracy Hillman asked the Committees if they would like to refine the list so the tour would take no more than two days (one day for Okanogan/Methow projects and one day for Entiat/Wenatchee projects). In November 2016, Chris Fisher recommended each member identify five projects they would like to visit. During the March 2017 meeting, members agreed to wait until the April 2017 meeting to identify their top projects for a field visit.
6. Tracy Hillman reported that the Northwest Power and Conservation Council (NPCC) sent a letter (memo) asking the Independent Scientific Advisory Board (ISAB) to review Upper Columbia River Spring Chinook recovery analyses and strategies. If the ISAB accepts the request, they will likely ask for a workshop in which groups such as the HCP Tributary Committees describe their approach to selecting tributary habitat actions to protect and restore habitat conditions for spring Chinook. The ISAB has not yet accepted the request. Tracy will share the NPCC memo with the Committees.

X. Middle Entiat Project Presentation

Steve Kolk (BOR) gave a presentation on the status of the Middle Entiat Restoration Project (see Attachment 1). He described the primary objectives and scope of the project, the current landowner-project sponsor relationship, acquisition of permits, and project funding. Regarding the latter, Steve noted that BOR will be funding a large portion of the project; however, they will fall short by about $1-1.5 million to complete the project. Thus, he asked if the Tributary Committees and/or the PRCC Habitat Subcommittee would be interested in funding specific components of the restoration project.

Members of the Committees asked the following questions:

Q: When does BOR need a commitment from other funding entities?
A: Construction is scheduled to being in 2019, so a funding commitment would be needed in 2018.

Q: What is the status of the restoration design?
A: The design is at a point of delegation.

Q: How long will the restoration structures be evaluated?
A: As long as BOR is in the valley.

Q: What agreement has the County established with the landowner (CDLT)?
A: The County will take ownership of all structures on CDLT properties. DNR will own structures up to the high-water mark.

Q: Will the BOR contribute $1 million per year or $1.5 million per year?
A: If the BOR has additional money available, they will likely contribute up to $1.5 million per year.

Q: Are project sponsors planning to submit proposals through the SRFB process?
A: There are no plans to seek funding through the SRFB process this year.

Q: What is the sequence for implementing restoration actions?
A: Sections B and E will be enhanced first; F will be last.

Following questions, members urged BOR to encourage their project sponsors to submit proposals through the SRFB process. Specific projects such as levee removal and reconnecting side channels should score high in the SRFB process.

Members will further discuss the Middle Entiat Project during their April meeting.

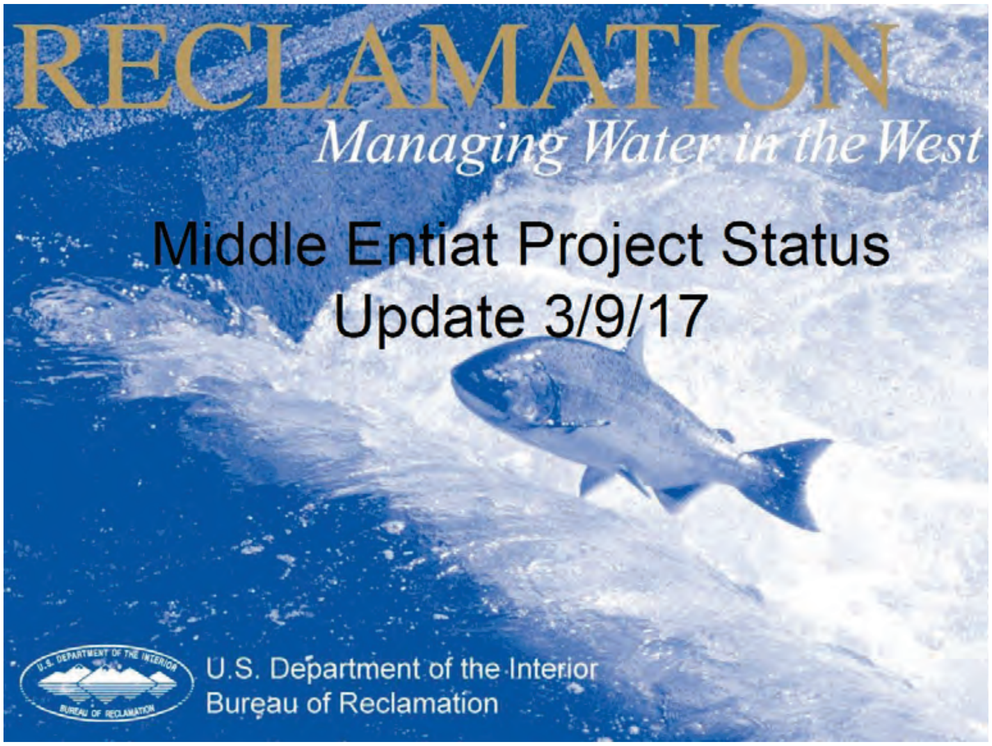
XI. Next Steps

The next meeting of the Tributary Committees will be on Thursday, 13 April 2017 at Grant PUD in Wenatchee.

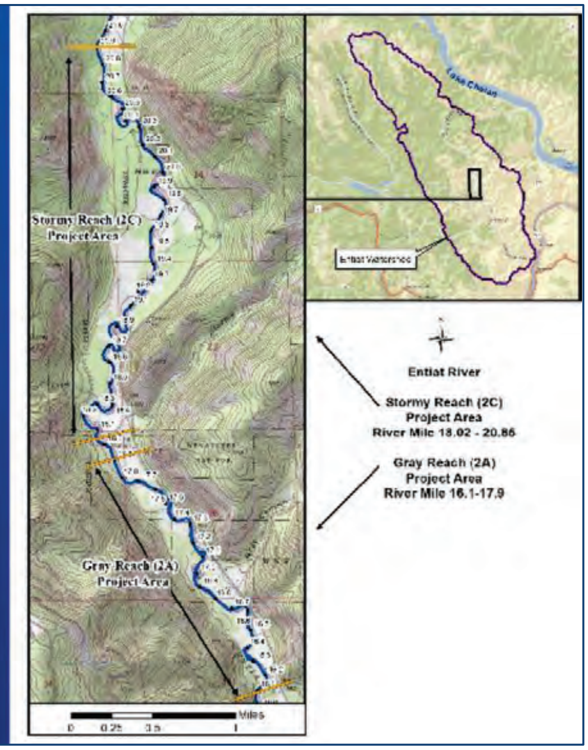
Meeting notes submitted by Tracy Hillman (tracy.hillman@bioanalysts.net).

Attachment 1

Presentation by Steve Kolk on the Status of the Middle Entiat Restoration Project



Vicinity Map

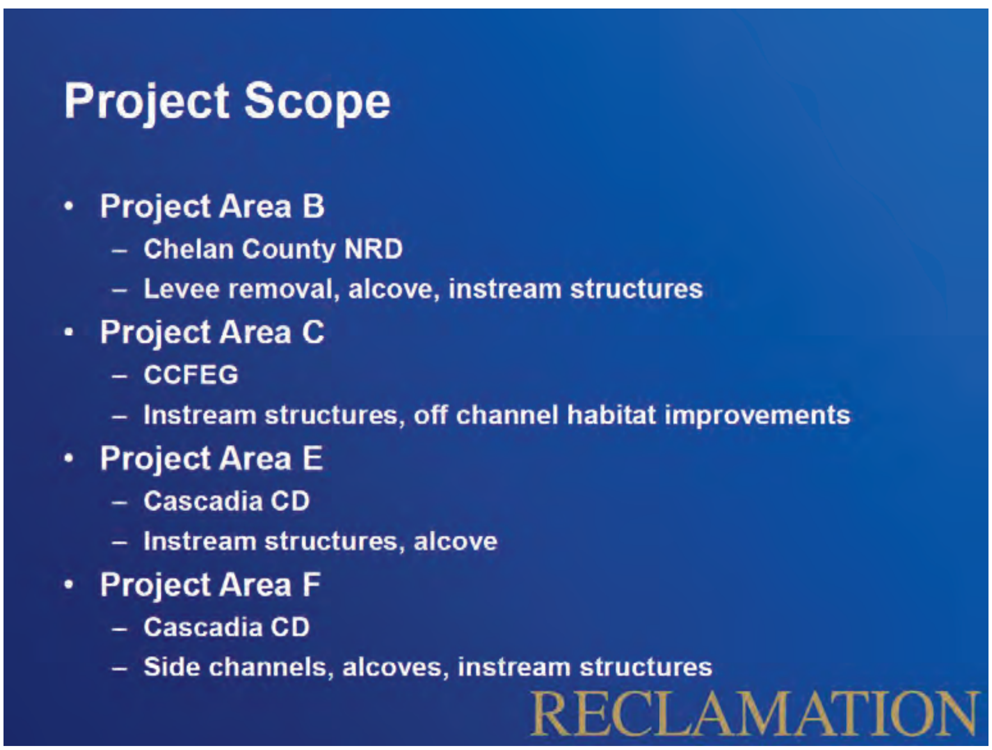


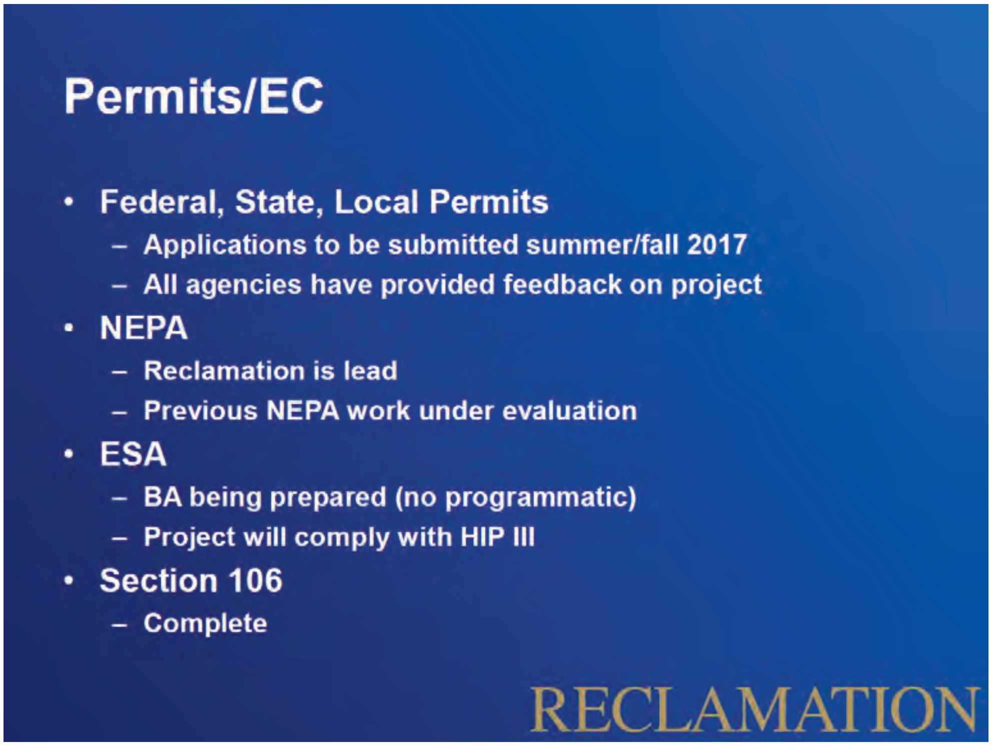
Primary Project Objectives

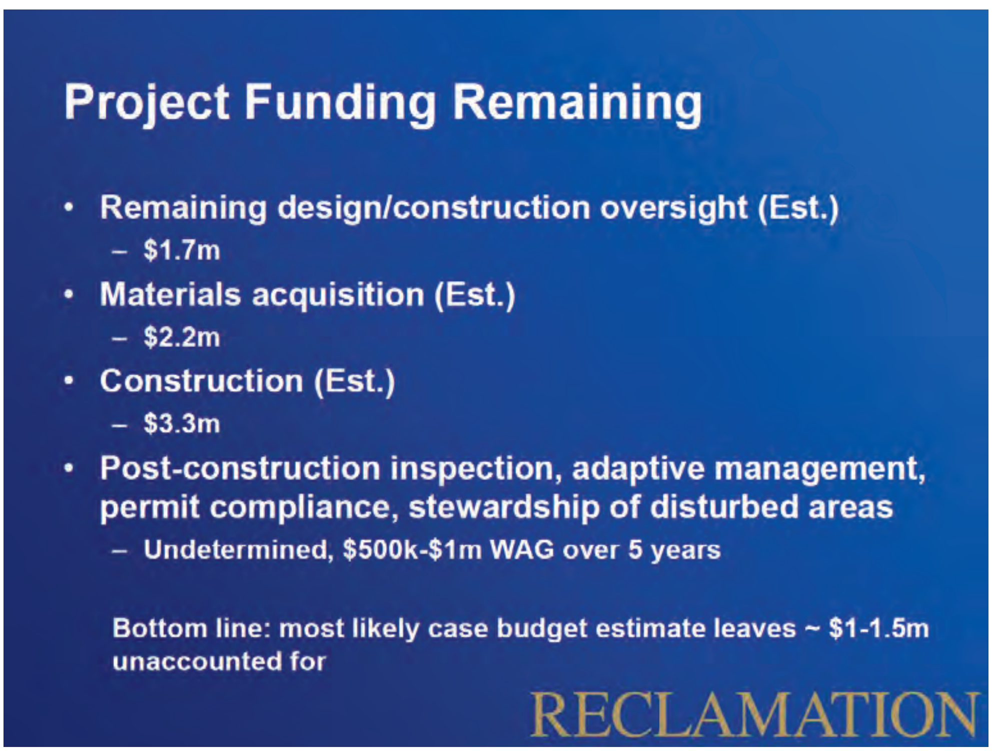
1. Improve off-channel habitat availability and quality
2. Improve habitat complexity
   a. Pool habitat frequency and quality within the main channel
   b. Edge habitat
   c. Alcove habitat
3. Re-engage channel forming processes (promote lateral channel migration)
4. Improve floodplain connectivity (reverse incision)

RECLAMATION


Landowner/Sponsor Considerations
1. Minimize impacts to existing habitat
a. Helicopter staging, structure assembly
2. Consider visual impacts
3. Minimize/eliminate ferrous anchoring
4. Adhere to WA HB 1194 (2013)
5. Follow BOR's Risk Based Design Guidelines
6. Rigorous inspection/adaptive management program following construction
RECLAMATION


Project Scope
• Project Area B
– Chelan County NRD
– Levee removal, alcove, instream structures
• Project Area C
– CCFEG
– Instream structures, off channel habitat improvements
• Project Area E
– Cascadia CD
– Instream structures, alcove
• Project Area F
– Cascadia CD
– Side channels, alcoves, instream structures
RECLAMATION


Permits/EC
• Federal, State, Local Permits
– Applications to be submitted summer/fall 2017
– All agencies have provided feedback on project
• NEPA
– Reclamation is lead
– Previous NEPA work under evaluation
• ESA
– BA being prepared (no programmatic)
– Project will comply with HIP III
• Section 106
– Complete
RECLAMATION


Project Funding Remaining
• Remaining design/construction oversight (Est.)
– $1.7m
• Materials acquisition (Est.)
– $2.2m
• Construction (Est.)
– $3.3m
• Post-construction inspection, adaptive management, permit compliance, stewardship of disturbed areas
– Undetermined, $500k-$1m WAG over 5 years
Bottom line: most likely case budget estimate leaves ~ $1-1.5m unaccounted for
RECLAMATION


Questions?
RECLAMATION

Wells, Rocky Reach, and Rock Island HCP Tributary Committees Notes 13 April 2017

Members Present: Lee Carlson (Yakama Nation), Jeremy Cram (WDFW), Chris Fisher (Colville Tribes), Steve Hays (Chelan PUD), Tom Kahler (Douglas PUD), Kate Terrell (USFWS), Justin Yeager (NOAA Fisheries), and Tracy Hillman (Committees Chair).

Others Present: Becky Gallaher (Tributary Project Coordinator). Cody Gillin (Trout Unlimited) and Robes Parrish (USFWS) attended the meeting for the Beaver Fever discussion.

The Wells, Rocky Reach, and Rock Island Hydroelectric Projects Habitat Conservation Plans Tributary Committees met at Grant PUD in Wenatchee, Washington, on Thursday, 13 April 2017 from 9:00 am to 12:30 pm.

I. Review and Adopt Agenda

Tracy Hillman welcomed everyone to the meeting and the Committees adopted the proposed agenda with revisions. Because of time constraints, they elected to drop discussions on the Middle Entiat Restoration Project and the Methow Beaver Project film. They will add these items on a future agenda.

II. Review and Approval of Meeting Minutes

The Committees reviewed and approved the 9 March 2017 meeting notes.

III. Monthly Update on Ongoing Projects

Becky Gallaher gave an update on funded projects. Most are progressing well or had no salient activity in the past month.

- MVID Instream Flow Improvement Project – The project sponsor (Trout Unlimited; TU) reported that as-builts have been completed. The remaining punch list items should be completed by 30 June 2017.
- Entiat Stillwaters Gray Reach Acquisition – The sponsor (Chelan-Douglas Land Trust; CDLT) reported that the Crone property is ready for closing.
- Clear Creek Fish Passage and Instream Flow Project – The sponsor (TU) reported that they are focused on permitting, engineering, and construction planning. They also worked on the water-right change process and completed another draft ROE, which was approved by the Chelan County Water Conservancy Board and is now being reviewed by Ecology.
- Barkley Irrigation – Under Pressure Project – The sponsor (TU) reported they have been working with Barkley Irrigation Company on pump site planning and coordination. They are evaluating three sites to determine the most affordable site for the pump station. They expect to have a site selected by late April.

- Methow Watershed Beaver Reintroduction Project – This project is complete. The final report and 2016 annual report were uploaded to the Extranet site.
- Similkameen RM 3.8 Project – The sponsor (Okanogan Conservation District; OCD) reported that Cardno has completed the design and cost estimate.
- White River Floodplain (RM 3.4) Connection Project – The sponsor (CCFEG) reported they have contracted with Dickenson Construction for the excavation phase of the project. The sponsor received an updated HPA that will allow for excavation during low flow this summer. The sponsor has submitted all materials to WDFW in order to receive the Right of Entry permit, which is the last permit needed for implementation.
- Icicle Boulder Field Project – The sponsor (TU) reported that they are procuring engineering services for the City of Leavenworth waterline. They also spent time working through project challenges, which seem to be political.
- Peshastin Creek RM 10.5 PIT-Tag Detection Site Project – The sponsor (WDFW) reported that the project is complete. The second-year monitoring report is due on 31 December 2017.
- Permitting Nutrient Enhancement Project – The sponsor (CCFEG) reported they will be presenting the project summary and monitoring proposal to the Forest Service in April. PACE Engineering is working on updating the QAPP to reflect Ecology's most recent concern about using analogs that may have PCBs and mercury. Last year CCFEG tested analogs from two sources and detected no toxics.
- Burns-Garrity Design Project – The sponsor (CCFEG) did not provide an update on this project.
- Beaver Fever Project – The sponsor (TU) reported that they and their restoration partners have narrowed the list of suitable sites for restoration to a few in each of the Wenatchee and Entiat basins. Additionally, they continue to consider an appropriate monitoring strategy.
- Wenatchee Sleepy Hollow Floodplain Acquisition Project – The sponsor (CDLT) did not provide an update on this project.
- Ecommunity Place Locatee Land Acquisition Project – The sponsor (Okanagan Nation Alliance; ONA) reported that the property is ready for closing. The final report has been received and will be uploaded to the Extranet site.

IV. Time Extensions

Clear Creek Fish Passage and Instream Flow Enhancement Project

The Rocky Reach Tributary Committee received a time extension request from Trout Unlimited on the *Clear Creek Fish Passage and Instream Flow Enhancement Project*. The sponsor asked the Committee to extend the period of the contract from 31 May 2017 to 30 September 2018. After review and discussion, ***the Rocky Reach Tributary Committee agreed to extend the contract to 30 September 2018***.

White River Floodplain Connection (RM 3.4) Project

The Rock Island Tributary Committee received a time extension request from CCFEG on the *White River Floodplain Connection (RM 3.4) Project*. The sponsor asked the Committee to extend the period of the contract from 30 September 2017 to 30 December 2017. After review and discussion, ***the Rock Island Tributary Committee agreed to extend the contract to 30 December 2017***.

V. General Salmon Habitat Program Proposal

Derby Creek Fish Passage – Collins Project

Last month, CCFEG submitted the *Debry Creek Fish Passage – Collins Project* proposal to the Tributary Committees. The purpose of this project is to remove the lowermost fish passage barrier culvert (RM 0.3) on Derby Creek, a tributary to the Wenatchee River. Removal of the lowermost barrier will open about 10 miles of habitat for steelhead spawning and rearing. The total cost of the project is $190,000. The sponsor requested $90,000 from HCP Tributary Funds. The Committees were unable to make a funding decision and requested additional information from the sponsor. Specifically, the Committees asked the sponsor to respond to the following questions/comments:

1. Describe the status of fish passage at the obstacles downstream from the proposed passage barrier. For example, there is one obstacle that is highlighted "unknown passability." Is this at the road or railroad crossing and is there evidence that it is passable?
2. Indicate the location of the PIT-tag array on the map prepared by Chris Dwight.
3. Does Derby Creek dewater at any time of year, and, if so, where?
4. The proposal indicates that CCFEG has removed one total barrier and received funding for removal of two additional barriers. Please show on the map prepared by Chris Dwight the location of these barriers.
5. Has NRCS confirmed that they will fund the cost share?
6. Did you consider replacing the barriers with small bridges similar to those used on Frazer Creek in the Methow River basin (e.g., see: http://methowsalmon.org/currentprojects.html)? If so, why are they not the preferred alternative?

In late March CCFEG provided responses to the Committees' questions. The sponsor also indicated that they revised the budget for the project. This is largely because they now intend to use a steel-bridge deck rather than a concrete-bridge deck. Using a steel-bridge deck reduced the estimated cost of the project by about $30,000. The revised total cost of the project is $155,000. They requested $65,000 from HCP Tributary Funds (aka Plan Species Account Funds). The Committees evaluated and discussed the responses from the sponsor and the ***Rock Island Tributary Committee elected to contribute $65,000 to the project***.

The Committee noted that if the sponsor intends to seek additional funds from the Committees to address other passage issues in Derby Creek, the sponsor will need to conduct a habitat assessment to determine the quality and quantity of habitat within the stream and also to demonstrate that steelhead and/or Chinook salmon use the stream for spawning and rearing. This will help the Committee determine if the biological benefit of enhancing fish passage justifies the cost.

VI. Review of Tributary Committees' Policies and Procedures

Policies and Procedures for Funding Projects

The Committees completed their review of the Policies and Procedures document and added the following language to the beginning of Section 6.3 (Timelines and Extensions).

> *Project Sponsors must have a signed contract with the Committees within one (1) year from the date when the Committees approved the project. In the event the Project Sponsor does not have a signed contract because of a lack of additional funds (cost share), a lack of landowner support, or any other reason, the Committees may cancel funding for the project. After the one-year period, the Project Sponsor may need to resubmit a new proposal seeking funding for a canceled project.*

Tributary Committee Operating Procedures

The Committees reviewed their Operating Procedures and elected to remove the following statement from Section IX (Plan Species Account):

> *The Committees will provide financial reports to the District no less than on a quarterly basis.*

The Committees provide annual reports and believe there is no need to provide quarterly reports.

VII. Information Updates

The following information updates were provided during the meeting.

1. Approved Payment Requests in March and April:

   Rock Island Plan Species Account:

   - $80.00 to Clifton Larson Allen for Rock Island financial administration in March 2017.
   - $44,484.53 to Okanagan Nation Alliance for the Ecommunity Place Locatee Land Acquisition.

   Rocky Reach Plan Species Account:

   - $80.00 to Clifton Larson Allen for Rocky Reach financial administration in March 2017.
   - $309.55 to Okanogan Conservation District for work in February on the Similkameen RM 3.8 Rehabilitation Project.
   - $9,000.00 to North Meridian Title for the Entiat Stillwaters Gray Reach Acquisition (Crone Property).
   - $14,500 to Chelan-Douglas Land Trust for the Entiat Stillwaters Gray Reach Acquisition (Cone Property Stewardship Plan).

   Wells Plan Species Account:

   - $833.00 to the Methow Salmon Recovery Foundation for work on the Methow Watershed Beaver Reintroduction Project (final payment).
   - $4,843.09 to Trout Unlimited for work during March on the MVID Instream Flow Improvement Project.
   - $456.64 to Chelan PUD for project coordination and administration during the first quarter of 2017.

2. Tracy Hillman shared the Salmon Recovery Funding Board (SRFB) and Tributary Committees Funding Schedule with the Committees (see Attachment 1). He said draft proposals are due on Friday, 14 April. Project tours will be on 10 May (Wenatchee), 11 May (Entiat), and 18 May (Methow). The Committees will evaluate the draft proposals on Thursday, 8 June and decide which projects should be submitted as final proposals. Final proposals are due on Friday, 30 June. The Committees will evaluate final proposals and make funding decisions on Thursday, 13 July.

3. During the September 2016 meeting, members of the Committees identified possible funded projects they would like to visit in 2017 (see Item #2 on page 4 of the September 2016 meeting notes). Given the long list of possible projects, Tracy Hillman asked the Committees if they would like to refine the list so the tour would take no more than two days (one day for Okanogan/Methow projects and one day for Entiat/Wenatchee projects). In November 2016, Chris Fisher recommended each member identify five projects they would like to visit. During

the April 2017 meeting, members agreed to wait until the May 2017 meeting to identify their top projects for a field visit.

4. Tracy Hillman reported that the Northwest Power and Conservation Council (NPCC) staff and Bonneville Power Administration (BPA) staff have scheduled a meeting with various Upper Columbia entities including tribes, state agencies, project sponsors, monitoring groups, etc. to discuss insights and experiences related to habitat actions and monitoring in the basin. Specifically, NPCC and BPA want to better understand how different entities are using data or products from the Integrated Status and Effectiveness Monitoring Program (ISEMP), Columbia Habitat Monitoring Program (CHaMP), and BPA's Action Effectiveness Monitoring (AEM) Program. The meeting will be held on Wednesday, 19 April at the Upper Columbia Salmon Recovery Board Office. Tracy said he was asked to participate in the meeting and share Regional Technical Team perspectives.

VIII. Beaver Fever Project Presentation and Discussion

Cody Gillin (TU) and Robes Parrish (USFWS) gave a presentation on the status of the Beaver Fever Project (see Attachment 2). This was the second time the project sponsors met with the Tributary Committees. The purpose of the first meeting was to get feedback from the Committees on where to focus BDA work and what metrics should be monitored to assess BDA effectiveness (see January meeting notes). During this meeting, Cody and Robes described results from their recent modeling work, which included both primary and secondary ranking criteria. Primary criteria included gradient and site accessibility. Secondary criteria included fish distribution data, temperature data, ecological concerns (limiting factors), stream flows, consideration of social-recreation-land use, and opportunities for robust monitoring. Within the Wenatchee River basin, 46 of the 78 streams ranked high according to the primary criteria, while only three streams ranked high using both the primary and secondary criteria. Those included the White River, Icicle Creek historical channel, and Icicle Leavenworth National Fish Hatchery canal. Within the Entiat River basin, five of 22 streams ranked high according to the primary criteria; two ranked high using both the primary and secondary criteria. Those were Roaring Creek and Potato Creek. Cody and Robes provided reasons why Potato and Roaring creeks are the most appropriate for BDA work. They then compared the effects of beavers and BDAs on biological, hydrologic/geomorphic, chemical parameters. They also described the potential positive and negative effects of beaver modifications on fish. They concluded their presentation by describing possible parameters to be monitored at BDA sites.

The Committees supported BDA work in both Roaring and Potato creeks and recommended that in one stream BDAs be clustered and in the other BDAs be more widely spaced. This will provide information on the effects of spatial arrangement of BDAs on fish and habitat. The Committees also recommended that the monitoring work focus on effects of BDAs on stream flows, water temperatures, other habitat conditions (metrics identified on the last slide of the presentation), and fish. The Committees had a lengthy discussion on fish monitoring. They ended by recommending the sponsor monitor abundance and distribution of different fish species seasonally before and after implementation of BDAs. They also suggested the need to monitor fish abundance and distribution in control areas (i.e., BACI monitoring design). Fish data could be collected using snorkel or electrofishing surveys. The Committees also advised the sponsor to work with WDFW on the possibility of using mark-recapture methods to estimate abundance and fish movement.

IX. Next Steps

The next meeting of the Tributary Committees will be on Thursday, 8 June 2017 at Grant PUD in Wenatchee. The Committees will tour proposed projects in May.

Meeting notes submitted by Tracy Hillman (tracy.hillman@bioanalysts.net).

Attachment 1

UPPER COLUMBIA SRFB/TRIB 2017 FUNDING SCHEDULE				
DATE	**ACTIVITY/MILESTONE**	**PARTICIPANTS**	**LOCATION**	**FACILITATOR/ COORDINATOR**
MARCH				
March 8	Meeting/Webinar *Optional*: Salmon Recovery Grants Workshop	Sponsors, RCO	Online Webinar	RCO
March 8	Meeting *Optional*: Project preview RTT regular March meeting	Sponsors, RTT, TRIB	Wenatchee, TBD	RTT Chair
March 14	Meeting: SRFB/TRIB/BPA Kick-Off Meeting	LE, RTT, TRIB, Sponsors, RCO	Chelan, WA. Fire District	LE/RCO
March 31	**Deadline:** One paragraph project abstracts submitted to Lead Entity	Sponsors	Email	LE
APRIL				
April 14	**Deadline:** Draft proposals due	Sponsors, LE, RCO, SRP, RTT, CAC, TRIB	PRISM	LE
MAY				
May 10 & 11	Tours: SRFB/TRIB Project Tours Wenatchee (Wed) Entiat (Thur)	Sponsors, LE, RTT, TRIB, SRFB SRP, CAC	TBD	LE
May 15	Deadline: Monitoring Letter of Intent	Sponsors, UCSRB Staff	GSRO	UCSRB
May 18	Tours: SRFB/TRIB Project Tours Methow (Thur) No projects in Okanogan	Sponsors, LE, RTT, TRIB, SRFB SRP, CAC	TBD	LE

UPPER COLUMBIA SRFB/TRIB 2017 FUNDING SCHEDULE				
DATE	**ACTIVITY/MILESTONE**	**PARTICIPANTS**	**LOCATION**	**FACILITATOR/ COORDINATOR**
JUNE				
June 14	Sponsor Presentations	RTT, TRIB, SRP	TBD	LE
June TBD	Action: SRP provides comments	SRP	Email via LE	RCO/SRP
June 8	Action: TRIB reviews draft proposals	TRIB	TRIB	TRIB Chair
June 15	Action: TRIB provide comments	TRIB	Emails	TRIB Chair
June 30	**DEADLINE:** Final proposals due for Regional scoring and ranking	Sponsors, LE, RTT, CAC, TRIB	PRISM	LE
JULY				
July 12	Action: RTT technical scoring	RTT, CAC, LE, BOR	RTT Meeting	RTT
July 13	Action: TRIB reviews final proposals	TRIB	TRIB Meeting	TRIB Chair
July 20	Action: TRIB Decisions	TRIB	Email/Letter	TRIB Chair
July 18/20 tbd	Presentations to Citizens: Okanogan/Chelan CAC's	Sponsors, CAC's, RTT, LE	Twisp River Bank/Wenatchee Reclamation Office	LE
July 27	CAC Project Rankings Chelan/Okanogan CAC's	CAC's, LE	Chelan Fire Hall	LE
AUGUST				

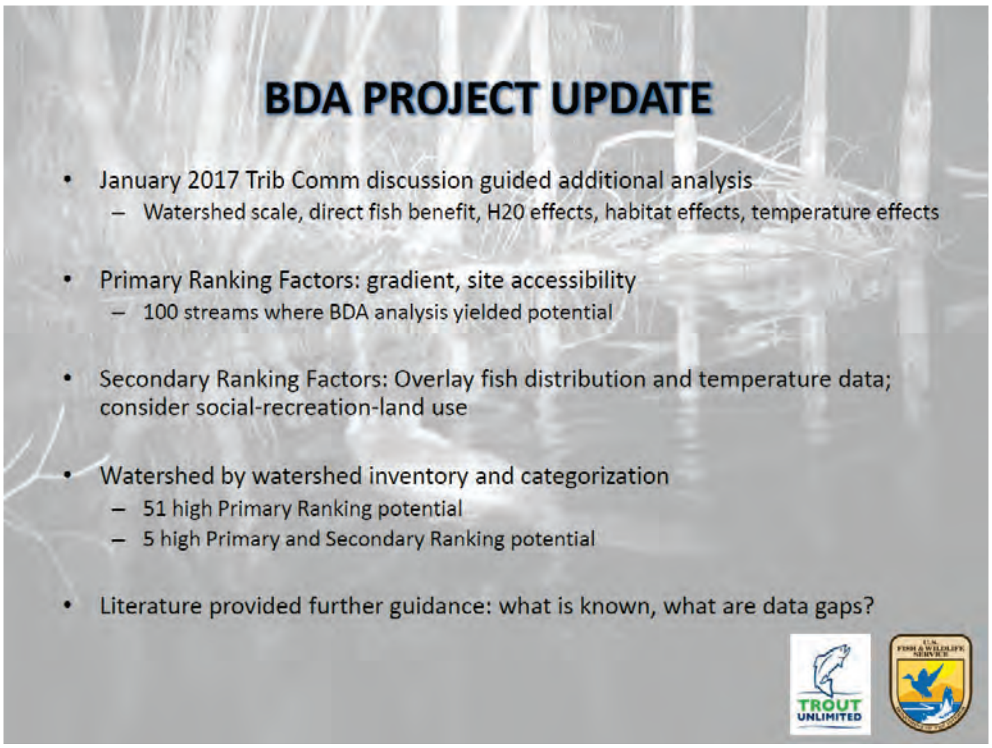
Upper Columbia SRFB/TRIB 2017 Funding Schedule				
DATE	**ACTIVITY/MILESTONE**	**PARTICIPANTS**	**LOCATION**	**FACILITATOR/ COORDINATOR**
August 10	Deadline: Sponsors PRISM upload	Sponsors, LE	PRISM	LE
August 14	Deadline: Submit Regional List	LE	PRISM	LE/RCO
SEPTEMBER				
Sept 6	Deadline: Regional Submittal	LE	Email	LE
Sept 8	Monitoring Review Panel Provides Comments	Monitoring Review Panel	Email via UCSRB	UCSRB
Sept 22	Deadline: Response to comments from Monitoring Review Panel	Sponsors, UCSRB	Email via UCSRB	UCSRB
Sept 29	Action: SRP provides comments	SRP	Email via LE	SRP
OCTOBER				
Oct 12	Deadline: Response to comments from project sponsors to SRP	Sponsors, LE	Email via LE	LE
Oct 23-25	Presentations: Sponsors present projects to SRP (*only projects identified*)	Select Sponsors, LE	Olympia, Washington or via phone	RCO
NOVEMBER				
Nov 1	Action: SRP finalizes comments	SRP	Email via LE	SRP
Nov 7	Deadline: Submit Final Regional List	LE/UCSRB	PRISM	LE/UCSRB
Nov 16	Final report by SRP to SRFB	RCO		RCO
DECEMBER				
Dec 6-7	Action: SRFB Decisions	SRFB	Olympia, WA	RCO

Acronyms
CAC- Citizen's Advisory Committee
BPA- Bonneville Power Administration
LE- Lead Entity Coordinator/Program
RCO- Recreation and Conservation Office
RTT- Upper Columbia Regional Technical Team
SRP- State Review Panel
SRFB- Salmon Recovery Funding Board
TRIB- Tributary Committees
UC- Upper Columbia Region
UCSRB- Upper Columbia Salmon Recovery Board

Timeline Legend	
Meetings	Blue
Deadlines	Red
Actions	Black

Attachment 2

Presentation by Cody Gillin and Robes Parrish on the Status of the Beaver Fever Project



CRITERIA TO ACHIEVE HIGH PRIMARY RANKING FACTOR POTENTIAL

- Many dots or dot clusters in the first run BDA suitability analysis
  - < 2% slope, within 200 feet of a road

High Primary Ranking Potential

Low Primary Ranking Potential

CRITERIA TO ACHIEVE HIGH SECONDARY RANKING POTENTIAL

- ESA and other salmonid species use (UCSRB, SWIFD)
- Addressing top Ecological Concerns in the Assessment Unit
- Perennial or near perennial flow (but not too much discharge)
- No social-recreation-land use challenges
- Watershed-scale implementation potential AND/OR opportunity for significant physical and hydrological improvements
- Validation of Primary Ranking Factors geospatial analysis
- Opportunities for robust monitoring and data gathering
- Considered historic / predicted stream temperatures
- Some objective, some based on knowledge / experience

+ access, ECs, species, flow, scale
- recreation conflict, monitoring, feasibility

+ access, ECs, species, flow, scale
monitoring, feasibility

Wenatchee River Basin Primary-Secondary Ranking Factor Results

HIGH-HIGH	HIGH-MEDIUM	HIGH-LOW
~~Icicle Historic Channel~~	Skinney Creek	Mainstem Wenatchee River
~~Icicle LNFH Canal~~	Beaver Creek	Chumstick Creek
WDFW-PUD-CDLT White River	Tronsen Creek	Mainstem Upper Icicle Creek
?	Peshastin Creek (above Ingalls)	Mainstem White River
	Lower White unnamed roadside tribs	Gill Creek
	Lower Wenatchee CDLT side channel	Fish Lake Run (outlet)
	Derby Creek	Scotty Creek
	Eagle Creek	Peshastin Creek (below Ingalls)
	Van Creek	Mainstem Mission Creek
	Sunitsch Creek	Sand Creek
	Railroad Canyon Creek	Tripp Creek
	Deep Creek	Brender Creek
	unnamed trib across from Deep Creek	Yaksum Creek
	Brush Creek	unnamed Sunnyslope trib
		Warm Springs Creek
		Fairview Canyon Creek
		Warner Canyon Creek
		Nahahum Canyon Creek
		Hay Canyon Creek
		Williams Canyon Creek
		Spromberg Canyon Creek
		Longview Canyon Creek
		Clark Canyon Creek
		Little Chumstick Creek
		Mainstem Chiwawa River
		Chikamin Creek
		Rock Creek
		Clear Creek
		Big Meadow Creek

46 of 78 Wenatchee streams with high Primary Ranking
3 with high Primary and Secondary Ranking

Entiat River Basin Primary-Secondary Ranking Factor Results

HIGH-HIGH	HIGH-MEDIUM	HIGH-LOW
Roaring Creek Potato Creek		Mud Creek Mainstem Entiat River Mainstem Mad River

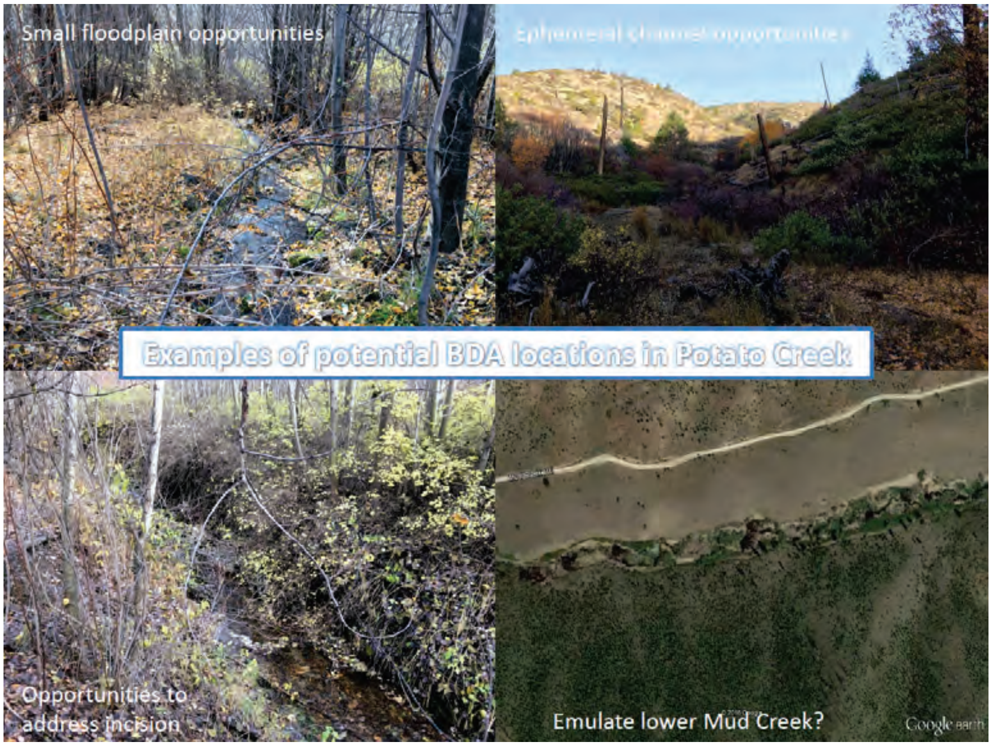
5 of 22 Entiat streams with high Primary Ranking
2 with high Primary and Secondary Ranking

THE CASE FOR ROARING AND POTATO

- ESA species
  - Roaring known Entiat STHD stronghold
  - STHD and Chinook in Potato (relative abundance unknown)

Last Antenna Group Name	Release Date MMDDYYYY	Species Code	Species Name	Run Code	Run Name	Rear Type Code	Rear Type Name	Release Site Name
DSM BYPASS SURFACE COLLECTOR	7/13/2011	3	Steelhead	2	Summer	W	Wild Fish or Natural Production	POTATC - Potato Creek, tributary to Entiat River

- Flow: Perennial / near perennial, some large substrate
- Social constraints: None to our knowledge, single to few landowners
- Scale: Multi-reach (Lower Roaring Ck.) to watershed (Potato Ck.) potential
- Validation of Primary Ranking: So far, yes, more work needed


Small floodplain opportunities
Ephemeral channel opportunities
Examples of potential BDA locations in Potato Creek
Opportunities to
address incision
Emulate lower Mud Creek?
Google earth


Side channel and floodplain
opportunities
Diversion rehabilitation opportunities
Examples of potential BDA locations in Roaring Creek
Pool development opportunities

	Beavers	BDAs	Notes
Biological Effects			
Increased fish density	●	◓	Shown for many species; higher linear and areal densities in BC
Increased fish survival	●	◓	Shown for STHD, Chinook, coho. +52% in Bridge Cr. BDA sthd.
Increased fish growth	○	○	Decreased growth in Bridge Cr. study
Fish Productivity	●	◓	+175% juv. STHD in BC after 4yrs (density, growth, survival)
Overwinter refuge	◓	(?)	-86% in Stillaguamish coho ovw capacity; freezing (eg, Wilson)?
Invertebrates	◓	(?)	>diversity but largely changes from lotic to lentic taxa
Fish barriers	○	○	Highly speculative, variable., no effect in Bridge Cr. w/236 dams for adult or juvenile upstream or downstream
Hydrologic-Geomorphic Effects			
Change Flow Regime	●	(?)	Shown under both removal and addition of dams
Aggradation/Incision	●	◓	1" to > 0.5m; more lit. on natural dams than BDAs
Groundwater storage	●	◓	Shown for small check structures and BDAs
Peak flow amelioration	●	(?)	Up to 5%. Recent paper shows not dependent on confinement
Temperature reduction	◓	◓	Positive with >depth and GW exchange. -1.5C in BC. Less flux
Channel complexity	●	◓	Most of BDA results from Bouwes 2016.
Riparian expansion	◓	(?)	Can be expansive; change in veg. types/mosaic; No lit. on BDAs
Sediment storage	●	(?)	Can be large effect: varies by age, vegetation, u/s dam failure
Heterogeneity	●	●	Incr. depths, 3x side channels, deeper pools, inundation area

	Beavers	BDAs	Notes
Chemical Effects			
Biogeochemical cycling	◓	(?)	Ponds trap WM and beaver caches store organic material
Deposition/Retention	◓	(?)	See above; Naimain 1994 constitutes much of published work
Nutrient amelioration	●	◓	Easily bound with sediment but also released upon dam failure; some European studies show retention times of 6-8 days is sufficient to remove excess nitorgen, phosphorus, and herbicides; small check dams store sediment

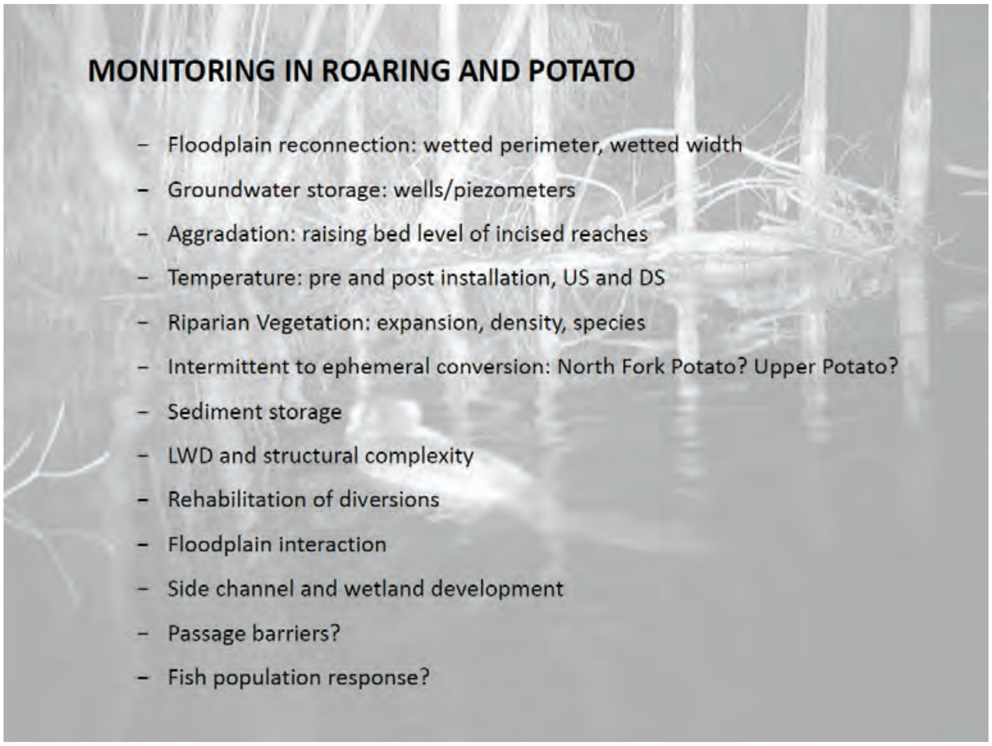
Kemp et al. (2012) meta analysis

Potential Impacts of Beaver Modifications on Fish Species

Potential Positive Impacts
- Increased fish productivity/abundance
- Increased habitat and habitat heterogeneity
- Increased rearing and overwintering habitat
- Enhanced growth rates
- Providing flow refuge
- Improved production of invertebrates

Potential Negative Impacts
- Barriers to fish movement
- Siltation of spawning habitat
- Low oxygen levels in beaver ponds
- Altered temperature regime

Kemp et al. noted that many of the positive effects cited (51.5 percent) were supported by data, while many more of the negative impacts (71.4 percent) were speculative and not supported by data collected in the field. Furthermore, the most commonly cited negative impact of beaver dams—as barriers to fish movement—was highly speculative, as 78.4 percent of the studies did not support this claim with data.


MONITORING IN ROARING AND POTATO
– Floodplain reconnection: wetted perimeter, wetted width
– Groundwater storage: wells/piezometers
– Aggradation: raising bed level of incised reaches
– Temperature: pre and post installation, US and DS
– Riparian Vegetation: expansion, density, species
– Intermittent to ephemeral conversion: North Fork Potato? Upper Potato?
– Sediment storage
– LWD and structural complexity
– Rehabilitation of diversions
– Floodplain interaction
– Side channel and wetland development
– Passage barriers?
– Fish population response?

Wells, Rocky Reach, and Rock Island HCP Tributary Committees Notes 8 June 2017

Members Present: Lee Carlson (Yakama Nation), Jeremy Cram (WDFW), Chris Fisher (Colville Tribes), Steve Hays (Chelan PUD), Tom Kahler (Douglas PUD), Kate Terrell (USFWS), Justin Yeager (NOAA Fisheries), and Tracy Hillman (Committees Chair).

Others Present: Becky Gallaher (Tributary Project Coordinator).

The Wells, Rocky Reach, and Rock Island Hydroelectric Projects Habitat Conservation Plans Tributary Committees met at Grant PUD in Wenatchee, Washington, on Thursday, 8 June 2017 from 9:30 am to 12:30 pm.

I. Review and Adopt Agenda

Tracy Hillman welcomed everyone to the meeting and the Committees adopted the proposed agenda with revisions. Two budget amendments and an update on the Beaver Creek road damage were added to the agenda.

II. Review and Approval of Meeting Minutes

The Committees reviewed and approved the 13 April 2017 meeting notes.

III. Monthly Update on Ongoing Projects

Becky Gallaher gave an update on funded projects. Most are progressing well or had no salient activity in the past month.

- MVID Instream Flow Improvement Project – The project sponsor (Trout Unlimited; TU) reported that they are completing the final punch list items.
- Clear Creek Fish Passage and Instream Flow Project – The sponsor (TU) reported that they completed the installation of two, 6-inch pipes that will provide a conduit for the electrical and water lines. This system will connect the new treatment plant to the water-storage cistern. Ecology recently approved the water-right change application. The Source Approval Package was compiled and submitted to the Department of Health. Finally, the sponsor initiated the bid package development process and began compiling bid and contract documents.
- Barkley Irrigation – Under Pressure Project – The sponsor (TU) reported they have been working with Barkley Irrigation Company on pump site planning and project coordination. They also spent time coordinating the Barkley and MVID ditches and continue to work through the water-right change process. They are nearing completion of the Righty of Entry.
- Similkameen RM 3.8 Project – The sponsor (Okanogan Conservation District; OCD) reported that permits, based on the updated design, have been submitted to DNR and WDFW. A paper copy will be sent to the Corps of Engineers. A Request for Proposals will be prepared and distributed in early June.

- White River Floodplain (RM 3.4) Connection Project – The sponsor (CCFEG) reported they will be coordinating with WDFW to select an appropriate time for construction. The sponsor ordered 100 cedar trees and riparian plants for revegetation work along a portion of the project.
- Icicle Boulder Field Project – The sponsor (TU) reported they have been working with their consultants to set up the scope of work for the City of Leavenworth waterline and Geotech work. Fieldwork this summer will focus on geotech work. In addition, the sponsor continues to work on permitting and they are preparing the JARPA for geotech and project implementation.
- Peshastin Creek RM 10.5 PIT-Tag Detection Site Project – The sponsor (WDFW) will submit the second-year monitoring report on 31 December 2017.
- Permitting Nutrient Enhancement Project – The sponsor (CCFEG) reported they have finalized the proposal for implementation and monitoring and sent it to the Forest Service and other project partners. They will hold a meeting with project partners on Friday, 9 June, to discuss project feasibility and next steps.
- Burns-Garrity Design Project – The sponsor (CCFEG) reported that selection of a restoration concept was put on hold when a landowner listed his property for sale. The sponsor continues to do landowner outreach, delineate wetlands, and discuss potential effects of restoration alternatives.
- Beaver Fever Project – The sponsor (TU) reported that they initiated site-specific research and are developing a permitting strategy. Because BDA projects have not been implemented on Okanogan-Wenatchee forest lands, the sponsor and the USFWS are reaching out to BDA implementers to learn how to permit these projects on Forest Service lands.
- Wenatchee Sleepy Hollow Floodplain Acquisition Project – The sponsor (CDLT) reported they are still waiting for funding approval from Washington Wildlife and Recreation. The legislature failed to pass a budget in the regular session or first special session. As soon as the capital budget is passed, the sponsor will prepare the boundary line adjustment to separate the house from the rest of the property. The property will then be reappraised.

IV. Budget Amendments

Clear Creek Fish Passage Project

In May, the Rocky Reach Tributary Committee received a budget amendment request from Trout Unlimited on the *Clear Creek Fish Passage Project*. The sponsor asked to move $2,000 from "Project Materials and Supplies" to Professional Services and Permitting." Via email, ***the Rocky Reach Tributary Committee approved the budget amendment***. The amendment will not change the total budget amount.

Permitting Nutrient Enhancement in the Chiwawa River Basin Project

The Rock Island Tributary Committee received a budget amendment request from CCFEG on the *Permitting Nutrient Enhancement in the Chiwawa River Basin Project*. The sponsor asked to move $1,028 from "Professional Services" and "Indirect/Admin/Overhead" to "Sponsor Salaries and Benefits." ***The budget amendment was approved.*** The amendment will not change the total budget amount.

White River Floodplain Connection (RM 3.4) Project

The Rock Island Tributary Committee received a budget amendment request from CCFEG on the *White River Floodplain Connection (RM 3.4) Project*. The sponsor asked to take all the available funds in "Excavation and Heavy Equipment" ($5,000) and "Project Materials and Equipment" ($500) and move those into "Salaries and Benefits," "Overhead and Administration," and "Permit Fees." According to the request, this amendment will leave no money for excavation and haul. The Committee questioned how the project will be completed if there is no money available to conduct excavation and heavy equipment work. As a result, ***the Rock Island Tributary Committee denied the request until the sponsor can describe how the project will be completed without excavation and haul***.

V. Time Extension

Barkley Irrigation Project

In May, the Rock Island Tributary Committee received a time extension request from Trout Unlimited on the *Barkley Irrigation Project*. Because construction on the project is unlikely to begin until this fall, the sponsor asked to extend the project from 31 May 2017 to 31 December 2018. Via email, ***the Rock Island Tributary Committee approved the time extension***.

VI. General Salmon Habitat Program Draft Proposals

The Committees received nine General Salmon Habitat Program draft proposals. The Committees reviewed each draft proposal and selected those that they believe warranted a final proposal. Projects that the Committees dismissed were either inconsistent with the intent of the Tributary Fund, did not have strong technical merit, or had low benefits per cost. The Committees assigned draft proposals to one of two categories: Fundable and Not Fundable. It is important to note that these are ratings of draft proposals and do not reflect ratings of final proposals. The Committees directed Tracy Hillman to notify sponsors with appropriate projects to submit a final proposal, with a discussion of the questions/comments identified for each draft proposal listed below. Tracy will also notify sponsors with projects that have no chance or a low likelihood of receiving funding from the Tributary Committees.

Stormy Preserve – Restore Wood Recruitment Project (Not Fundable)

The Committees recommend that this project, sponsored by Cascade Columbia Fisheries Enhancement Group, should not be submitted as a full proposal to the Tributary Committees for the following reason:

- At this time, the Committees are not interested in funding the construction of large wood structures in the Stormy Preserve. However, they would accept applications that address levee removal and floodplain reconnection projects.

Icicle RM 0.3-1.1 Habitat Design Project (Not Fundable)

The Committees recommend that this project, sponsored by Chelan County Natural Resources Department, should not be submitted as a full proposal to the Tributary Committees for the following reason:

- The Committees believe the project is too expensive for a conceptual design and they recommend that the sponsor spend time discussing the project with the landowner to find out what level of restoration the landowner will allow on their property. For example, riparian vegetation along the meander bend will need to be widened to allow for meaningful process-based restoration. It is unknown if the landowner is willing to allow widening of the riparian area at this site.

M2 WDFW Flow Connection Project (Fundable)

The Committees recommend that the project sponsor (Methow Salmon Recovery Foundation) address the following comment/suggestion as they develop the full proposal:

- The sponsor needs to describe what type of fence will be installed and who will be responsible for maintaining the fence.

M2 Mid-Sugar Acquisition Project (Fundable)

The Committees recommend that the project sponsor (Methow Salmon Recovery Foundation) address the following comment/suggestion as they develop the full proposal:

- For accounting purposes, the sponsor should include the Tributary Committees' match ($43,690) in the land purchase cost, not in the other line items.

Wenatchee LiDAR Acquisition Watershed Assessment Project (Not Fundable)

The Committees recommend that this project, sponsored by Chelan County Natural Resources Department, should not be submitted as a full proposal to the Tributary Committees for the following reasons:

- It is not clear what the project will provide in terms of restoration and protection that does not already exist. For example, roads that are likely to contribute significant amounts of fine sediments to streams have been identified or can be identified during road surveys and/or aerial photography.
- The proposal did not describe how LiDAR data combined with temperature data will be used to map the distribution of invasive species.
- A better approach would be to use Green LiDAR, at least within the floodplains.

Piscine Passage Design for Brush and Minnow Creeks Project (Fundable)

The Committees recommend that the project sponsor (Cascade Columbia Fisheries Enhancement Group) address the following comments/suggestions as they develop the full proposal:

- Because this is a design project, the sponsor needs to consider ways to reduce the cost of the project. The Committees believe the project is too expensive.
- The sponsor needs to provide information on the status of the roads. For example, will the roads, especially the one crossing Brush Creek be removed or abandoned.

Sleepy Hollow Side Channel Feasibility Study Project (Not Fundable)

The Committees recommend that this project, sponsored by Chelan County Natural Resources Department, should not be submitted as a full proposal to the Tributary Committees for the following reason:

- The Committees believe the side channel and floodplain are currently functioning to the benefit of salmonids. Indeed, the goal of the acquisition was to protect the existing habitat.

Tillicum Creek Culvert Replacement Project (Not Fundable)

The Committees recommend that this project, sponsored by Chelan County Natural Resources Department, should not be submitted as a full proposal to the Tributary Committees for the following reasons:

- The Committees believe there is limited usable habitat upstream from the culvert (there appears to be a total or partial fish passage barrier just upstream from the old road crossing).
- The channel upstream and downstream from the culvert is a confined, relatively steep channel that provides limited fish benefit. Thus, the potential benefits of the project do not justify the cost of the project.

Methow Basin Barrier and Diversion Assessment Project (Fundable)

The Committees recommend that the project sponsor (Cascade Columbia Fisheries Enhancement Group) address the following comments/suggestions as they develop the full proposal:

- Given the extensive spawning surveys conducted in the Methow River basin, the sponsor needs to describe how much more information this project will provide beyond what is currently known.
- The sponsor needs to provide a summary of what was learned from implementing a similar

project in the Wenatchee River basin.

- The sponsor should consider focusing their efforts in a few high-priority watersheds. This will reduce the need to repeat the surveys in the future.

VII. Small Projects Program Application

Poison Canyon Restoration Project

The Committees reviewed a Small Projects Program application from Chelan County Natural Resources Department titled, *Poison Canyon Restoration*. The purpose of the project is to aggrade incised reaches within Poison Canyon, a tributary to Sand Creek, which is a tributary to Mission Creek, by installing about 20 wood jams using onsite wood and hand tools. Aggrading the channel should improve instream flows and water quality in Mission Creek. The total cost of the project is $73,330. The sponsor requested $38,160 from HCP Tributary Funds. After careful consideration, ***the Committees declined the opportunity to fund the project***. The Committees believe the project is overly engineered and too expensive. Based on implementation of similar projects, the Committees believe that two or more structures can be constructed per day. In addition, they see no need for highly engineered structures in this stream. Rather, simply adding appropriately sized wood to the channel should be appropriate. This will also reduce the cost of the project. Finally, they see no need to monitor the project with game cameras or piezometers. The Committees noted that if the sponsor addresses these concerns, the sponsor is welcome to submit a revised proposal for the Committees' consideration.

VIII. Methow Beaver Project Film

Because of time constraints, the Committees were unable to watch the film, "One Stick at a Time." Members asked for the link to the film so they can watch it on their own time. Below is the link.

https://youtu.be/EQNK7W-P-_0

IX. Information Updates

The following information updates were provided during the meeting.

1. Approved Payment Requests in May and June:

   Rock Island Plan Species Account:

   - $102.50 to Clifton Larson Allen for Rock Island financial administration in April 2017.
   - $40.00 to Clifton Larson Allen for Rock Island financial administration in May 2017.
   - $2,618.83 to Cascade Columbia Fisheries Enhancement Group for the White River Floodplain Connection Project.
   - $1,665.57 to Cascade Columbia Fisheries Enhancement Group for the Permitting Nutrient Enhancement in the Chiwawa River Project.

   Rocky Reach Plan Species Account:

   - $102.50 to Clifton Larson Allen for Rocky Reach financial administration in April 2017.
   - $40.00 to Clifton Larson Allen for Rocky Reach financial administration in May 2017.

- $17,110.26 to Okanogan Conservation District for work on the Similkameen RM 3.8 Rehabilitation Project.

Wells Plan Species Account:

- $10,005.01 to Trout Unlimited for work on the MVID Instream Flow Improvement Project.

2. Tracy Hillman reported that project sponsors will give presentations to the Upper Columbia Regional Technical Team and the Tributary Committees on Wednesday, 14 June at the Sunnyslope Fire District on Easy Street. Tracy said final proposals are due on Friday, 30 June. The Committees will evaluate final proposals and make funding decisions on Thursday, 13 July.
3. Tracy Hillman said the Independent Scientific Advisory Board (ISAB) will be in Wenatchee on 19-21 July for presentations and site visits as part of their evaluation of Upper Columbia Spring Chinook. An agenda for their visit has not yet been prepared, but it is likely the ISAB will want information and maybe presentations from the Tributary Committees. Tracy said he will share more information as it becomes available.
4. Tracy Hillman and Becky Gallaher shared with the Committees possible logos for the Tributary Committees. The Committees identified one logo that with some modifications may work for the Committees. Tracy will work with the designer and present an updated version to the Committees in July.
5. Chris Fisher shared with the Committees that a rain event in early May damaged a portion of the Upper Beaver Creek road. Chris said he met on site with County Commissioners, Methow Salmon Recovery Foundation, Bonneville Power Administration, Salmon Recovery Funding Board, and others to discuss the problem. The meeting started off with Commissioners blaming fish enhancement work in Beaver Creek for causing the road damage. Chris said the engineer of the enhancement work (Tracy Drury with Anchor QEA) indicated that the road would have been damaged regardless of the habitat enhancement work. Chris said by the end of the site visit, the parties involved expressed an interest in finding common ground and moving forward in some undefined way to make the existing road safe and passable, and identify changes, repairs, and improvements that would improve both the resilience of the road and the function of the floodplain.

   Tracy Hillman noted that he received an email from Chris Johnson, Methow Salmon Recovery Foundation, asking if the Tributary Committees would support the idea of a cooperative action to help demonstrate a commitment to fish projects implemented in Beaver Creek. After a long discussion, the Committees agreed to continue to support the enhancement of fish habitat within Beaver Creek. However, they will not support the rebuilding of the road in its current location. They believe the road would have been damaged regardless of enhancement work in the stream. Thus, if the County is looking for support from the Tributary Committees to restore the existing road, the Committees are not interested. On the other hand, the Committees may support the relocation of the road, allowing Beaver Creek to use a larger portion of its floodplain. Relocating the road will make the road more resilient to future flood events and will improve the ability of Beaver Creek to sustain fish habitat. The sustainability of fish habitat is the common ground that the Committees would find compatible with a funding decision. The Committees directed Tracy to relay this information to Chris Johnson.

X. Next Steps

The next meeting of the Tributary Committees will be on Thursday, 13 July 2017 at Grant PUD in Wenatchee. At that time, the Committees will review final proposals.

Meeting notes submitted by Tracy Hillman (tracy.hillman@bioanalysts.net).

Wells, Rocky Reach, and Rock Island HCP Tributary Committees Notes 13 July 2017

Members Present: Lee Carlson (Yakama Nation)[1], Jeremy Cram (WDFW), Chris Fisher (Colville Tribes), Steve Hays (Chelan PUD), Tom Kahler (Douglas PUD), Kate Terrell (USFWS), Justin Yeager (NOAA Fisheries), and Tracy Hillman (Committees Chair).

Others Present: Becky Gallaher (Tributary Project Coordinator).

The Wells, Rocky Reach, and Rock Island Hydroelectric Projects Habitat Conservation Plans Tributary Committees met at Grant PUD in Wenatchee, Washington, on Thursday, 13 July 2017 from 10:00 am to 12:15 pm.

I. Review and Adopt Agenda

Tracy Hillman welcomed everyone to the meeting and the Committees adopted the proposed agenda.

II. Review and Approval of Meeting Minutes

The Committees reviewed and approved the 8 June 2017 meeting notes.

III. Monthly Update on Ongoing Projects

Becky Gallaher gave an update on funded projects. Most are progressing well or had no salient activity in the past month.

- MVID Instream Flow Improvement Project – The project sponsor (Trout Unlimited; TU) reported that they are completing the final punch list items. They are also working with MVID and the Bureau of Reclamation (BOR) on a drainage issue near Wright Road, east of Twisp. Fires upslope from the pipeline have increased surface runoff in a small canyon. The ditch that used to capture the water is now a buried pipe. BOR is working on a conceptual design and cost analysis for piping the surface-water runoff to the Methow River.
- Clear Creek Fish Passage and Instream Flow Project – The sponsor (TU) reported they are preparing bid and contract documents for the construction bid package. They are currently planning construction in late summer or early fall. They also started planning for diversion dam removal, which will occur 1-2 years after the new water system is installed.
- Barkley Irrigation – Under Pressure Project – The sponsor (TU) reported they have an executed agreement with MVID and have finalized the pump site location. With both MVID and Barkley agreements signed, they now need to secure the relationship agreement between the two parties. The sponsor started working on the headworks design and held several meetings with Barkley

[1] Lee joined via phone.

Irrigation Company and MVID to review engineer alternatives. The sponsor is still working on changing the water rights from Barkley to MVID's diversion.

- Similkameen RM 3.8 Project – The sponsor (Okanogan Conservation District; OCD) and the Colville Tribes reported that BPA reviewed the updated plan and decided not to support the project. The sponsor is working on next steps.
- White River Floodplain (RM 3.4) Connection Project – The sponsor (Cascade Columbia Fisheries Enhancement Group; CCFEG) did not provide a project update.
- Icicle Boulder Field Project – The sponsor (TU) reported they are working on the JARPA permit for geotech explorations. They intend to file permits for the project this fall in anticipation for fall 2018 construction.
- Peshastin Creek RM 10.5 PIT-Tag Detection Site Project – The sponsor (WDFW) will submit the second-year monitoring report on 31 December 2017.
- Permitting Nutrient Enhancement Project – The sponsor (CCFEG) did not provide a project update; however, they did provide a draft Quality Assurance Project Plan (QAPP), which is being reviewed by Ecology. The sponsor expects a permit (Administrative Order) from Ecology soon.
- Burns-Garrity Design Project – The sponsor (CCFEG) did not provide a project update.
- Beaver Fever Project – The sponsor (TU) reported they continue project planning and due diligence. The focus has been on permitting, project task sequencing, and consideration of preliminary designs.
- Wenatchee Sleepy Hollow Floodplain Acquisition Project – The sponsor (Chelan-Douglas Land Trust; CDLT) did not provide a project update.

IV. Budget Amendments

White River Floodplain Connection (RM 3.4) Project

In June, the Rock Island Tributary Committee received a budget amendment request from Cascade Columbia Fisheries Enhancement Group on the *White River Floodplain Connection (RM 3.4) Project*. The sponsor asked to take all the available funds in "Excavation and Heavy Equipment" ($5,000) and "Project Materials and Equipment" ($500) and move those into "Salaries and Benefits," "Overhead and Administration," and "Permit Fees." According to the request, this amendment would leave no money for excavation and haul. The Committee questioned how the project will be completed if there is no money available to conduct excavation and heavy equipment work. As a result, the Rock Island Tributary Committee denied the request until the sponsor can describe how the project will be completed without excavation and haul.

Following the meeting, Cascade Columbia Fisheries Enhancement Group provided additional information on the budget amendment. The sponsor noted that they have adequate funding through other sources to complete all excavation and construction work and will not need additional funds to complete the project. Given that, the ***Rock Island Tributary Committee approved the budget amendment***.

Beaver Fever: Restoring Ecosystem Function Project

The Rock Island Tributary Committee received a budget amendment request from Trout Unlimited on the *Beaver Fever: Restoring Ecosystem Function Project*. The sponsor asked if they could use $10,000 under Construction and Permitting to purchase a hydraulic post driver. The driver would be used to install BDAs. This would eliminate the need to rent the equipment and could be used on other projects. After discussion, ***the Rock Island Committee denied the budget amendment***. This is because any equipment purchased by a project sponsor with Plan Species Account funds becomes the property of the Committee.

The Committee is not set up to deal with equipment storage, maintenance, management, and liability, and they do not want to be in a position of lending expensive equipment to project sponsors. Thus, they do not want project sponsors purchasing equipment with Plan Species Account funds.

V. Time Extension

Permitting Nutrient Enhancement in the Chiwawa

The Rock Island Tributary Committee received a time extension request from Cascade Columbia Fisheries Enhancement Group on the *Permitting Nutrient Enhancement in the Chiwawa*. Because of ongoing discussions with the Forest Service, USFWS, and Ecology, the sponsor asked to extend the period of the contract from 30 June 2017 to 30 June 2018. After discussion, ***the Rock Island Committee agreed to the one-year extension***.

VI. Small Projects Program Application

Poison Canyon Restoration Project

In June, the Committees reviewed a Small Projects Program application from Chelan County Natural Resources Department titled, *Poison Canyon Restoration*. The purpose of the project was to aggrade incised reaches within Poison Canyon, a tributary to Sand Creek, which is a tributary to Mission Creek, by installing about 20 wood jams using onsite wood and hand tools. Aggrading the channel should improve instream flows and water quality in Mission Creek. The total cost of the project was $73,330. The sponsor requested $38,160 from HCP Tributary Funds. The Committees declined the opportunity to fund the project because the project was overly engineered and too expensive. The Committees also found no need for game cameras or piezometers. The Committees noted if the sponsor addresses these concerns, the sponsor is welcome to submit a revised proposal for the Committees' consideration.

Chelan County Natural Resources Department resubmitted the Small Projects Program application, which addressed the Committees' concerns. The proposed project will still construct 20 wood structures to aggrade incised reaches within Poison Canyon, but the project will use a less engineered approach and include onsite wood/brush and hand tools. The total cost of the project is $37,918. The sponsor requested $21,600 from HCP Tributary Funds. ***The Rock Island Committee approved funding for this project.*** The Committee appreciated the sponsor's responses to questions and complemented the sponsor on their diligence and desire to implement a cost-effective project.

Cottonwood Bridge Removal Project

The Committees reviewed a Small Projects Program application from Chelan-Douglas Land Trust titled, *Cottonwood Bridge Removal Project*. The purpose of the project is to remove the steel and creosoted railroad ties that make up the Cottonwood Bridge on the Entiat River. Once the bridge is removed, the sponsor can remove the associated road and begin floodplain enhancement on the Cottonwood property. The total cost of the project is $95,000. The sponsor requested $21,000 from HCP Tributary Funds. The Committees declined the opportunity to fund the project because the project did not include the removal of the bridge abutments. The Committees recommended that the sponsor resubmit a larger project the includes the removal of the abutments. The project could be a phased approach if the sponsor includes a timeline showing when each phase of the project will be completed.

Following the meeting, Chelan-Douglas Land Trust provided the following response to the Committees' comments. "*The reason the abutments are not being removed at the same time as the railroad ties and steel is due to 3 interrelated reasons: (1) due to the deterioration of the bridge, it is essential to remove it this summer, before additional high water, ice, freezing and thawing that would result in complete failure, (2) abutment removal would involve in-water work requiring additional permitting and (3) the abutments will be removed as part of a larger project, probably in 2020, to remove the fill for the bridge approaches on both sides, fill added for "streets" within the Cottonwood property, and enhancement of side channels* *through Cottonwood – all of which will involve the appropriate time, equipment and permitting. These factors all led to the conclusion that the goal for this work season should be limited to removal of the ties and steel, and "pulling back" the abutment so that it does not come apart in the river.*" After evaluating the response, ***the Rocky Reach Tributary Committee approved funding for this project***.

VII. General Salmon Habitat Program Proposals

The Committees received four General Salmon Habitat Program proposals. Before reviewing the proposals and consistent with the Committees' Operating Procedures, members of the Committees identified potential conflicts of interest. Kate Terrell recused herself from voting on the *Piscine Passage Design for Brush and Minnow Creeks Project*.

M2 WDFW Flow Connection Project

The Methow Salmon Recovery Foundation is the sponsor of the M2 WDFW Flow Connection Project. The purpose of this project is to reconnect 3.7 acres of floodplain habitat and wetlands by removing a flood levee located at RM 46.8 on the Methow River. The total cost of the project is $78,828. The sponsor requested $11,824 from HCP Tributary Funds. ***The Wells Committee approved funding for this project.***

The Committee noticed in the proposal that the sponsor expects the side channel to connect at flows above 6,000 cfs; however, Figure 1 in the proposal indicates that the channel will be connected at flows near 8,000 cfs. The Committee prefers the channel to connect at flows closer to 6,000 cfs.

M2 Mid-Sugar Acquisition Project

The Methow Salmon Recovery Foundation is the sponsor of the M2 Mid-Sugar Acquisition Project. The purpose of this project is to acquire 17.3 acres of riparian and floodplain habitat including about 1,300 feet of stream bank and 550 feet of side channel near RM 42.2 on the Methow River. The acquisition will allow for future restoration actions including side channel and floodplain reconnection and riparian enhancement. The total cost of the project is $291,268. The sponsor requested $43,690 from HCP Tributary Funds. ***The Wells Committee approved funding for this project.***

Piscine Passage Design for Brush and Minnow Creeks Project

Cascade Columbia Fisheries Enhancement Group is the sponsor of the Piscine Passage Design for Brush and Minnow Creeks Project. The purpose of this project is to produce designs and submit permits for projects that will restore fish passage and connectivity within Minnow and Brush creeks, tributaries to the Chiwawa River. The total cost of the project is $162,500. The sponsor requested $52,500 from HCP Tributary Funds. ***The Tributary Committees elected not to fund this project***.

The Committees are not interested in the Brush Creek project, because of the low biological benefit associated with it. On the other hand, the Committees see more value in restoring connectivity on Minnow Creek. Given the level of funding available from the USFWS and the possibility of receiving funding from SRFB, the Committees believe the project will receive adequate funding without the need for Plan Species Account funds. In the event the Minnow Creek project does not receive adequate funding, the sponsor can resubmit an application to the Committees. The resubmittal must include the status of the roads in Minnow Creek.

Methow Basin Barrier and Diversion Assessment Project

Cascade Columbia Fisheries Enhancement Group is the sponsor of the Methow Basin Barrier and Diversion Assessment Project. The purpose of this project is to complete a comprehensive and standardized fish barrier and diversion inventory in the Methow River basin and to prioritize barrier sites for restoration. The total cost of the project is $206,650. The sponsor requested $40,000 from HCP Tributary Funds. ***The Wells Committee approved funding for this project.***

The Committee understands that the sponsor will use a combination of prioritization methods developed by WDFW and the RTT. As a requirement of the Committee's funding contribution to this project, the Committee will need to review and approve the "final" approach used to prioritize fish passage barriers.

Summary of Review of 2017 General Salmon Habitat Program Projects.

Project Name	Sponsor[1]	Total Cost	Request from T.C.	T.C. Contribution[2]
M2 WDFW Flow Connection	MSRF	$78,828	$11,824	W: $11,824
M2 Mid-Sugar Acquisition	MSRF	$291,268	$43,690	W: $43,690
Piscine Passage Design for Brush and Minnow Creeks	CCFEG	$162,500	$52,500	$0
Methow Basin Barrier and Diversion Assessment	CCFEG	$206,650	$40,000	W: $40,000
Total:		**$739,246**	**$148,014**	**$95,514**

[1] CCFEG = Cascade Columbia Fisheries Enhancement Group; MSRF = Methow Salmon Recovery Foundation.

[2] RI = Rock Island Plan Species Account; RR = Rocky Reach Plan Species Account; W = Wells Plan Species Account.

VIII. Information Updates

The following information updates were provided during the meeting.

1. Approved Payment Requests in June and July:

   Rock Island Plan Species Account:

   - $47.50 to Clifton Larson Allen for Rock Island financial administration in June 2017.
   - $855.94 to Chelan County PUD for project coordination and administration during the first and second quarters of 2017.
   - $11,487.26 to Trout Unlimited for the MVID Instream Flow Project.

   Rocky Reach Plan Species Account:

   - $47.50 to Clifton Larson Allen for Rocky Reach financial administration in June 2017.
   - $911.16 to Chelan County PUD for project coordination and administration during the first and second quarters of 2017.
   - $3,442.78 to Trout Unlimited for work on the Clear Creek Fish Passage and Instream Flow Enhancement Project.

   Wells Plan Species Account:

   - $661.84 to Chelan County PUD for project coordination and administration during the second quarter of 2017.

2. Tracy Hillman said the Independent Scientific Advisory Board (ISAB) will be in Wenatchee on 19-21 July for presentations and site visits as part of their evaluation of Upper Columbia Spring Chinook. The Council has prepared a draft agenda for the ISAB visit.
3. Tracy Hillman and Becky Gallaher shared the updated logos for the Tributary Committees. The Committees approved the following logo:

4. Becky Gallaher reported that she received a request from Cascade Columbia Fisheries Enhancement Group asking the Wells Tributary Committee if CCFEG could use the Committee's piezometers for an assessment project in the Methow River basin. The Wells Committee approved the request, but asked that the sponsor let the Committee know how long they need the piezometers, where exactly they will use them, and for what project. Kate Terrell said she will provide Becky with a release form that is used by the USFWS when they lend equipment to project sponsors.
5. Tracy Hillman asked the Committees if they have decided on which completed project they would like to visit in 2017. Given schedules and interest, it is unlikely members will have time to visit completed projects in 2017. Chris Fisher said by August he will have information on the annual tour of projects in Canada.

IX. Next Steps

If necessary, the next meeting of the Tributary Committees will be on Thursday, 10 August 2017 at Grant PUD in Wenatchee.

Meeting notes submitted by Tracy Hillman (tracy.hillman@bioanalysts.net).

Wells, Rocky Reach, and Rock Island HCP Tributary Committees Notes 9 November 2017

Members Present: Jeremy Cram (WDFW), Chris Fisher (Colville Tribes), Steve Hays (Chelan PUD), Tom Kahler (Douglas PUD), Kate Terrell (USFWS), Justin Yeager (NOAA Fisheries), and Tracy Hillman (Committees Chair).

Members Absent: Lee Carlson (Yakama Nation)[1]

Others Present: Becky Gallaher (Tributary Project Coordinator), Brandon Rogers (Yakama Nation), Jeff Osborn (Chelan PUD), Catherine Willard (Chelan PUD), and Scott Hopkins (Chelan PUD).

The Wells, Rocky Reach, and Rock Island Hydroelectric Projects Habitat Conservation Plans Tributary Committees met at Grant PUD in Wenatchee, Washington, on Thursday, 9 November 2017 from 9:30 am to 12:05 pm.

I. Review and Adopt Agenda

Tracy Hillman welcomed everyone to the meeting and the Committees adopted the proposed agenda with additional agenda items. The Committees reviewed two Small Projects Program applications they received from the Methow Salmon Recovery Foundation.

II. Review and Approval of Meeting Minutes

The Committees reviewed and approved the 13 July 2017 meeting notes.

III. Monthly Update on Ongoing Projects

Becky Gallaher gave an update on funded projects. Most are progressing well or had no salient activity in the past month.

- MVID Instream Flow Improvement Project – The project sponsor (Trout Unlimited; TU) completed the remaining punch-list items and will submit their final report by the end of the month.
- Clear Creek Fish Passage and Instream Flow Project – The sponsor (TU) met with the project engineers to discuss bids and to examine the potential for cost savings through project design modifications. They found little room for cost savings by modifying structural and civil/plumbing plans. Any changes here would result in reduced functionality, quality, lifespan, or overall project value. Electrical modifications are currently being considered. For example, the current design calls for a robust, multi-function operator interface, which offers remote control capability with numerous checks and alarms. Switching to a simple control-panel interface could save several

[1] Lee provided votes on decision items following the meeting.

thousand dollars. The electrical engineer is evaluating cost savings and effort/cost. The sponsor will send the project out for bid later this year or early next.

- Barkley Irrigation – Under Pressure Project – The sponsor (TU) continues to work on the joint diversion redesign and gravity portion of the system. They have also been working on finalizing the water rights change, completing environmental compliance, securing easements, and seeking funding and general coordination with the districts.
- Similkameen RM 3.8 Project – This project is complete. The sponsor (Okanogan Conservation District; OCD) submitted the final report, which was uploaded to the extranet site.
- White River Floodplain (RM 3.4) Connection Project – This project is complete. The sponsor (Cascade Columbia Fisheries Enhancement Group; CCFEG) will submit a final report soon.
- Icicle Boulder Field Project – The sponsor (TU) dug test pits to evaluate subsurface material. The information collected is being evaluated and a report of findings should be available in November. The cultural resource survey was completed in October and that report is expected in November. Tracy Hillman stated that the Committees may receive a proposal asking for funds to install a fish screen in the Icicle Diversion. The irrigation district has stated they may not allow the Icicle Boulder Field Project to move forward unless their diversion is screened.
- Peshastin Creek RM 10.5 PIT-Tag Detection Site Project – The sponsor (WDFW) will submit the second-year monitoring report on 31 December 2017.
- Permitting Nutrient Enhancement Project – The sponsor (CCFEG) reported there was no new activity.
- Burns-Garrity Design Project – The sponsor (CCFEG) met recently with the "new" private landowners. The new landowners support a design for a perennial channel. The sponsor will work with WDFW and the other private landowner to select a preferred concept and then they will move forward with design. *Following the meeting, the sponsor noted that the proposed channel will be a flow-through channel connected upstream and downstream with the river.*
- Beaver Fever Project – The sponsor (TU) is communicating with private landowners and the Forest Service hoping to get interest and insight about the potential for BDA work in lower Potato Creek.
- Wenatchee Sleepy Hollow Floodplain Acquisition Project – The sponsor (Chelan-Douglas Land Trust; CDLT) reported that Larry Rees is scheduled to complete the appraisal by the end of the year.
- Poison Canyon Restoration Project – The sponsor (Chelan County Natural Resources Department; CCNRD) indicated that they awarded the construction contract to Wildfire Home Protection. All but three structures have been built. The sponsor provided photos.
- Cottonwood Bridge Removal Project – This project is complete. The sponsor (CDLT) submitted the final report, which was uploaded to the extranet site.
- M2 Mid-Sugar Acquisition Project – The sponsor (Methow Salmon Recovery Foundation; MSRF) reported that Larry Rees initiated the appraisal on 27 October. Reclamation confirmed that a project budget is being processed for prioritization of project design alternatives for 2018/2019.

IV. Small Projects Program Applications

Frazer Creek – Lazy K Property Appraisal Project

The Committees reviewed a Small Projects Program application from MSRF titled, *Frazer Creek – Lazy K Property Appraisal Project*. The purpose of the project is to appraise the value of a 20-acre parcel along Frazer Creek in the Methow River basin. Acquiring the property would allow stream restoration in a site where the 2017 flood plugged a culvert causing the stream to cut deep gullies through the property. The cost of the project is $1,421.40, which covers coordination with the landowner and appraiser, and billing and administration work. The Committees would pay for the appraiser. After careful consideration, the Committees elected not to fund the appraisal. Most of the property does not boarder the stream and restoring this site would have little biological benefit.

Upper Beaver Creek – Anderson Property Appraisal Project

The Committees reviewed a Small Projects Program application from MSRF titled, *Upper Beaver Creek – Anderson Property Appraisal Project*. The purpose of the project is to appraise the value of a 1.6-acre parcel along Beaver Creek in the Methow River basin. Acquiring the property would allow stream restoration in a site where the 2017 flood avulsed through the Anderson property and damaged the County road. The cost of the project is $1,421.40, which covers coordination with the landowner and appraiser, and billing and administration work. The Committees would pay for the appraiser. The Committees were unable to make a final decision on the project and asked for additional information. They said before they can make a final decision on the appraisal, they would like to know if the County intends to relocate the road away from the channel. They also need information on the status of the channel upstream and downstream from the property, and what measures adjacent landowners are taking, or have taken, to minimize future damage to the Anderson parcel.

Following the meeting, MSRF provided additional information on the proposed project. After carefully reviewing the proposal and the additional information, the Committees elected not to fund the appraisal. The Committees are uncomfortable acquiring the property without a comprehensive review of the vulnerability of the road from the stream.

V. Chelan River Restoration Presentation

Steve Hays gave a presentation on the Chelan River Restoration project, which was funded by Chelan PUD (see Attachment 1). He began by describing riverine conditions before hydro development in the Chelan River, and then talked about the first two Chelan Licenses. He followed that by describing the most recent relicensing process, objectives, and agreement. He then walked through the restoration process, showing the evolution of the river during the restoration process.

With the completion of the restoration work, Steve said Chelan PUD has implemented a robust monitoring program to evaluate the success of the work. He said they conduct spawning surveys for summer/fall Chinook, coho salmon, and steelhead; conduct studies to evaluate powerhouse operations on intragravel dissolved oxygen levels in redds; evaluate egg-emergence success for Chinook and steelhead; conduct snorkel surveys in designated reaches; conduct macroinvertebrate population studies; conduct water temperature monitoring and modeling; and monitor TDG, DO, pH, and turbidity. He provided results from monitoring efforts and concluded that the restoration work is providing high quality habitat for salmonids, including cutthroat trout. He added that riparian vegetation is growing rapidly, and salmonids are spawning successfully within the habitat channel and tailrace. He ended by stating, "I'm not complaining."

VI. Effectiveness of Enhancement Projects Presentation

Tracy Hillman gave a presentation on the effectiveness of tributary habitat enhancement projects (see Attachment 2). He stated that he and his coauthors (Phil Roni and Jen O'Neal) prepared a report for BPA that addressed six policy-level questions (the report was made available to the Committee members). These questions were identified by the region and answers to them will help guide the next FCRPS BiOp. In order to answer the questions, Tracy and his coauthors reviewed well over 1,000 published and unpublished papers. Of those papers, 617 met their criteria for relevance. Tracy shared the number of papers associated with different categories of enhancement actions and the countries in which the studies were conducted. He also identified the intensively monitored watersheds located throughout the Pacific Northwest.

Although the purpose of the paper was to answer the six policy-level questions, Tracy's presentation focused on what works and why. He identified six characteristics of successful projects and identified reasons why good intension fail. He referred to some of the failures as "Myths of Restoration." He concluded by providing eight recommendations.

VII. Information Updates

The following information updates were provided during the meeting.

1. Approved Payment Requests from August to November:

   Rock Island Plan Species Account:

   - $162.50 to Clifton Larson Allen for Rock Island financial administration in July 2017.
   - $2,135.41 to Cascade Columbia Fisheries Enhancement Group for the Permitting Nutrient Enhancement Project.
   - $1.891.75 to Trout Unlimited for the MVID Instream Flow Improvement Project.
   - $125.00 to Clifton Larson Allen for Rock Island financial administration in August 2017.
   - $117.50 to Clifton Larson Allen for Rock Island financial administration in September 2017.
   - $556.41 to Chelan County PUD for project coordination and administration during the third quarter of 2017.
   - $2,190.97 to Trout Unlimited for the Beaver Fever – Restoring Ecosystem Function Project.
   - $1,827.95 to Trout Unlimited for the MVID Instream Flow Improvement Project.
   - $162.50 to Clifton Larson Allen for Rock Island financial administration in October 2017.
   - $6,828.79 to Cascade Columbia Fisheries Enhancement Group for the White River Floodplain Connection Project.
   - $1,000.00 to the Upper Columbia Salmon Recovery Board for the Upper Columbia Science Conference.

   Rocky Reach Plan Species Account:

   - $162.50 to Clifton Larson Allen for Rocky Reach financial administration in July 2017.
   - $4,080.73 to Okanogan Conservation District for the Similkameen RM 3.8 Rehabilitation Project.

- $1,191.16 to Okanogan Conservation District for the Similkameen RM 3.8 Rehabilitation Project.
- $125.00 to Clifton Larson Allen for Rocky Reach financial administration in August 2017.
- $117.50 to Clifton Larson Allen for Rocky Reach financial administration in September 2017.
- $417.05 to Chelan County PUD for project coordination and administration during the third quarter of 2017.
- $11,000.00 to Chelan-Douglas Land Trust for the Cottonwood Bridge Removal Project.
- $2,614.51 to Okanogan Conservation District for the Similkameen RM 3.8 Rehabilitation Project (withholding 10% until final report is received).
- $162.50 to Clifton Larson Allen for Rocky Reach financial administration in October 2017.
- $10,000.00 to Chelan-Douglas Land Trust for the Cottonwood Bridge Removal Project.
- $290.50 to Okanogan Conservation District for the Similkameen RM 3.8 Rehabilitation Project (this was the 10% that was withheld from the final invoice).
- $1,000.00 to the Upper Columbia Salmon Recovery Board for the Upper Columbia Science Conference.

Wells Plan Species Account:

- $195.03 to Chelan County PUD for project coordination and administration during the third quarter of 2017.
- $376.94 to Trout Unlimited for the MVID Instream Flow Improvement Project.
- $2,192.00 to Douglas County PUD for Wells Administration.
- $1,000.00 to the Upper Columbia Salmon Recovery Board for the Upper Columbia Science Conference.

2. Tracy Hillman reminded the Committees of the email that Steve Kolk (BOR) sent the Committees in late September providing an update on the Middle Entiat Restoration Project. In his email, Steve asked if the Committees would like him to attend a future meeting and provide additional updates. The Committees indicated that at this time there is no need for Steve to provide an update in person. Email updates will suffice.
3. Tracy Hillman reminded the Committees that the Upper Columbia Science Conference, which is hosted by the Upper Columbia Salmon Recovery Board, will be on 24 and 25 January 2018 in Wenatchee. In October, each Committee agreed to donate $1,000.00 to the Conference. Funding will come from administrative expenses (not to exceed $80,000 per year per account) under the Plan Species Accounts. This level of sponsorship identifies the Committees as "Gold Sponsors."
4. Tracy Hillman said the Rocky Reach Tributary Committee approved a budget amendment and scope change for the Clear Creek Fish Passage and Instream Flow Enhancement Project in August. In early August, the sponsor (Trout Unlimited) asked to add activities related to water/electrical lines and treatment building to the deliverables. Specific activities included clearing/grubbing, trenching, piping, electrical, plumbing/mechanical, building construction,

moving chlorine injection and backup power equipment to a new location, inspections, and final approvals. In addition, the sponsor asked for an additional $77,174.40 to complete the project. Although the Rocky Reach Tributary Committee approved the scope change and budget amendment, which increased the total contribution from the Committee to $146,674.40, the Committee let the sponsor know they are growing increasingly concerned with the planning, management, and implementation of this project. This was the fifth amendment to this project. The Committee trusts that the sponsor will do a better job of planning and managing similar future projects.

5. Chris Fisher asked if the Committees would be interested in reviewing a proposal to fund the monitoring of discharge in select tributaries in the Methow River basin. Chis said the tributaries include Early Winters, Eight-Mile, Gold, Little Bridge, and Libby creeks. In the past, the Rocky Reach Tributary Committee approved funding for a similar monitoring effort in the Okanogan Basin. Members indicated they would review a proposal to monitor discharge, but they would need to know how the work will lead to habitat enhancement projects.
6. Chris Fisher said the Okanagan Nation Alliance is planning wetland construction in the parcel recently acquired with the help of Rock Island Plan Species Account funds. They are also doing floodplain construction near the Town of Oliver.

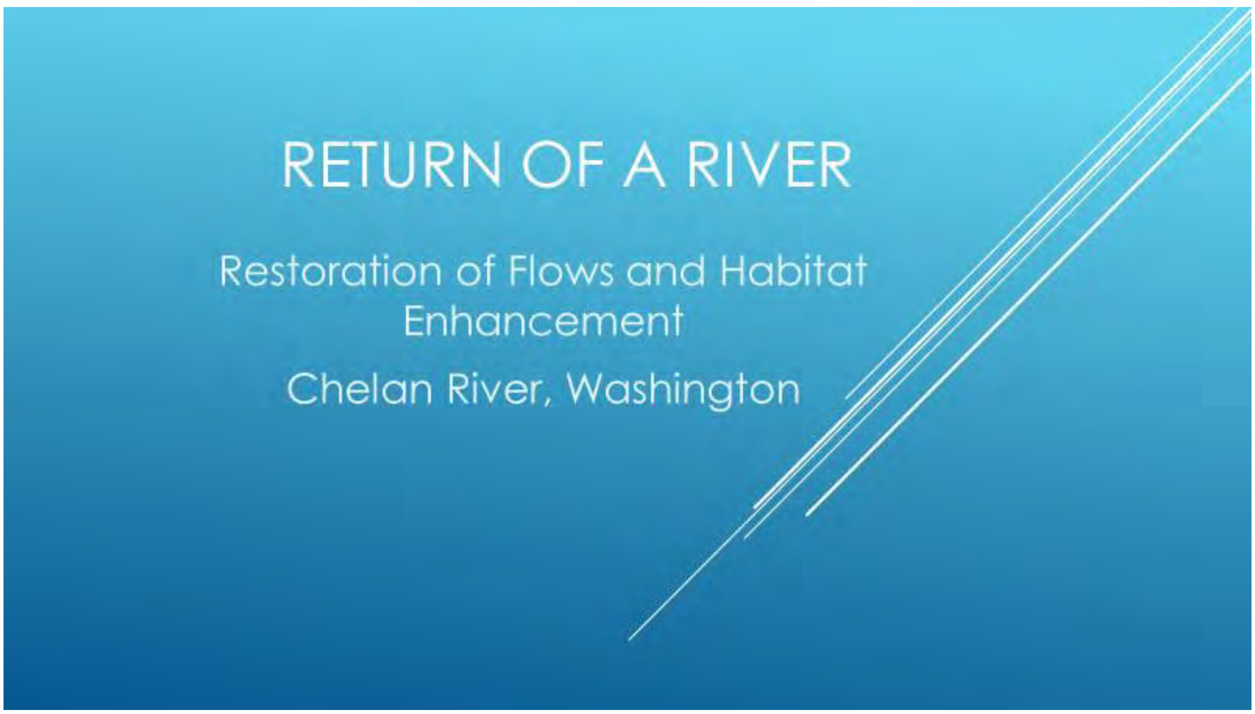
VIII. Next Steps

The next meeting of the Tributary Committees will be on Thursday, 11 January 2018 at Grant PUD in Wenatchee.

Meeting notes submitted by Tracy Hillman (tracy.hillman@bioanalysts.net).

Attachment 1

Presentation by Steve Hays on Restoration of Flows and Habitat Enhancement in the Chelan River

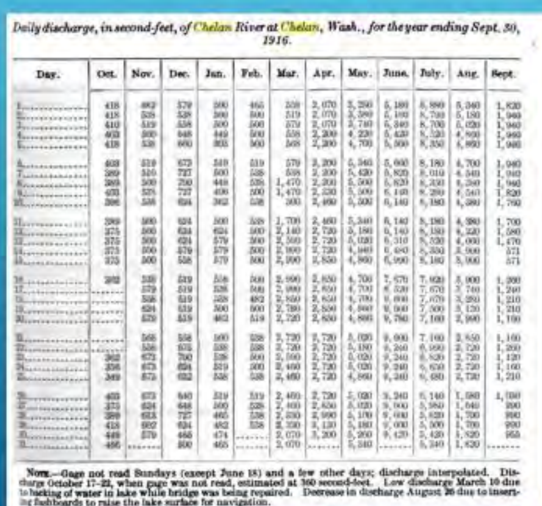


PRE-CHELAN HYDRO CONDITION

Chelan River - Columbia River confluence, est. 1920

Area near the mouth of the Chelan River, where it flows under the railroad bridge and enters Columbia River, early 1920s.

PRE-CHELAN HYDRO CONDITION



Daily discharge, in second-feet, of Chelan River at Chelan, Wash., for the year ending Sept. 30, 1916.

Day.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.
1	418	482	579	500	465	559	2,070	3,290	5,180	8,880	5,340	1,820
2	418	538	538	500	500	519	2,070	3,380	5,180	8,700	5,180	1,940
3	410	519	558	500	500	579	2,070	3,740	5,340	8,700	5,020	1,940
4	403	500	648	449	500	558	2,200	4,220	5,420	8,520	4,900	1,940
5	418	538	660	505	500	568	2,200	4,700	5,500	8,350	4,860	1,940
6	403	519	673	519	519	579	2,200	5,340	5,660	8,180	4,700	1,940
7	389	510	727	500	538	558	2,200	5,420	5,820	8,010	4,540	1,940
8	389	500	700	448	538	1,470	2,200	5,500	5,820	8,350	4,380	1,940
9	403	575	727	406	500	1,470	2,330	5,500	6,140	8,280	4,540	1,820
10	396	538	624	362	538	360	2,460	5,500	6,140	8,180	4,380	1,760
11	389	500	624	500	538	1,700	2,460	5,340	6,140	8,180	4,380	1,700
12	375	500	624	624	500	2,140	2,720	5,180	6,140	8,150	4,220	1,580
13	375	500	624	579	500	2,500	2,720	5,020	6,310	8,520	4,060	1,470
14	375	500	579	579	500	2,800	2,720	4,940	6,480	8,350	3,900	571
15	375	500	558	579	500	2,800	2,850	4,860	6,980	8,180	3,900	571
16	362	538	519	558	500	2,990	2,850	4,700	7,670	7,920	3,900	1,260
17	......	579	519	538	500	2,990	2,850	4,700	8,520	7,670	3,740	1,240
18	......	558	519	538	482	2,850	2,850	4,700	8,690	7,670	3,260	1,210
19	......	624	519	500	500	2,780	2,850	4,940	9,000	7,500	3,120	1,210
20	......	579	519	482	519	2,720	2,850	4,860	9,780	7,180	2,990	1,190
21	......	568	558	500	538	2,720	2,720	5,020	9,600	7,180	2,850	1,160
22	......	538	673	538	538	2,720	2,720	5,180	9,240	6,990	2,720	1,260
23	362	673	700	538	500	2,590	2,720	5,020	9,240	6,820	2,720	1,120
24	356	673	624	519	500	2,460	2,720	5,020	9,240	6,650	2,720	1,160
25	349	673	652	558	538	2,460	2,720	4,860	9,240	6,480	2,720	1,210
26	403	673	640	519	519	2,460	2,720	5,020	9,240	6,140	1,580	1,030
27	375	624	648	500	528	2,460	2,850	5,020	9,000	5,980	1,640	990
28	389	613	727	465	538	2,330	2,990	5,170	9,000	5,820	1,700	990
29	418	667	624	482	528	2,330	3,120	5,180	9,000	5,500	1,700	990
30	449	579	465	474	......	2,070	3,200	5,260	9,420	5,420	1,820	955
31	495	......	500	465	......	2,070	......	5,340	......	5,340	1,820	......

NOTE.—Gage not read Sundays (except June 18) and a few other days; discharge interpolated. Discharge October 17-22, when gage was not read, estimated at 360 second-feet. Low discharge March 10 due to backing of water in lake while bridge was being repaired. Decrease in discharge August 26 due to inserting flashboards to raise the lake surface for navigation.

Looking downstream on site of proposed tail race, 12/15/26

PRE-CHELAN HYDRO CONDITION

Columbia River at flood, Beebe Bridge and Camp #4, 5/30/28

Confluence of Chelan and Columbia rivers, 6/21/27

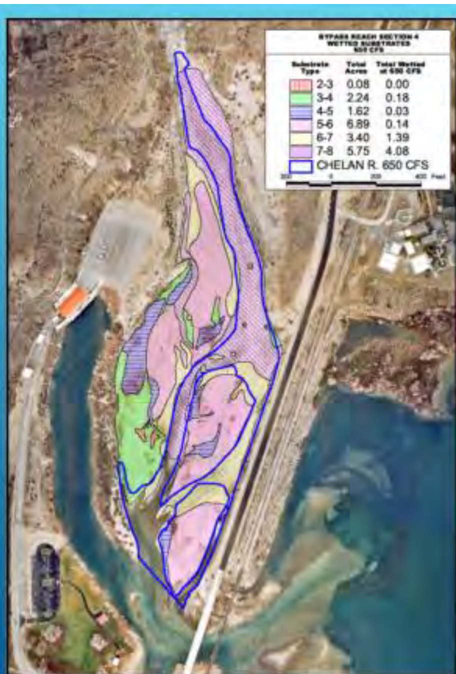
FIRST TWO CHELAN LICENSES

- Lake Chelan Hydroelectric Project Had No Provision for Minimum Flows – River Dry from Lake Chelan Dam to Chelan Falls 9 Months of the Year 1926 – 2009
- Lake Storage Managed Only For Recreation, Power Generation and Flood Control
- 1980s Relicense Focused On Parks, Lake Fisheries and Wildlife
- Restoration of Chelan River Flows and Habitat Not In Terms and Conditions in 1980s

RELICENSING OBJECTIVES

- FERC Relicense Negotiations Included Minimum Flow Regime and Fish Habitat Enhancements for Anadromous Fish Spawning and Rearing
- Habitat Modeling Estimated Possible 2.8 Acres of Chinook and 2.2 Acres of Steelhead Spawning Habitat in Scattered Pockets at 650 cfs Flow
- Existing Tailrace/Columbia River Spawning Habitat 2.8 Acres for Chinook and 2.2 Acres for Steelhead
- Summer Chinook Salmon Had Established Spawning Population on Alluvial Fan at Chelan Falls Beginning in 1980s – Demonstrating Feasibility of Adding Habitat
- Upper Three Reaches Managed for Resident Fish – Goal for Population of 200 Cutthroat Trout, the Native Salmonid
- Habitat Modeling Estimated Flows of 80 cfs – 160 cfs Yielded Most Acres of Habitat
- Main Limiting Factor Summer Water Temperatures > 24 Degrees C

REACH 4 - 2004



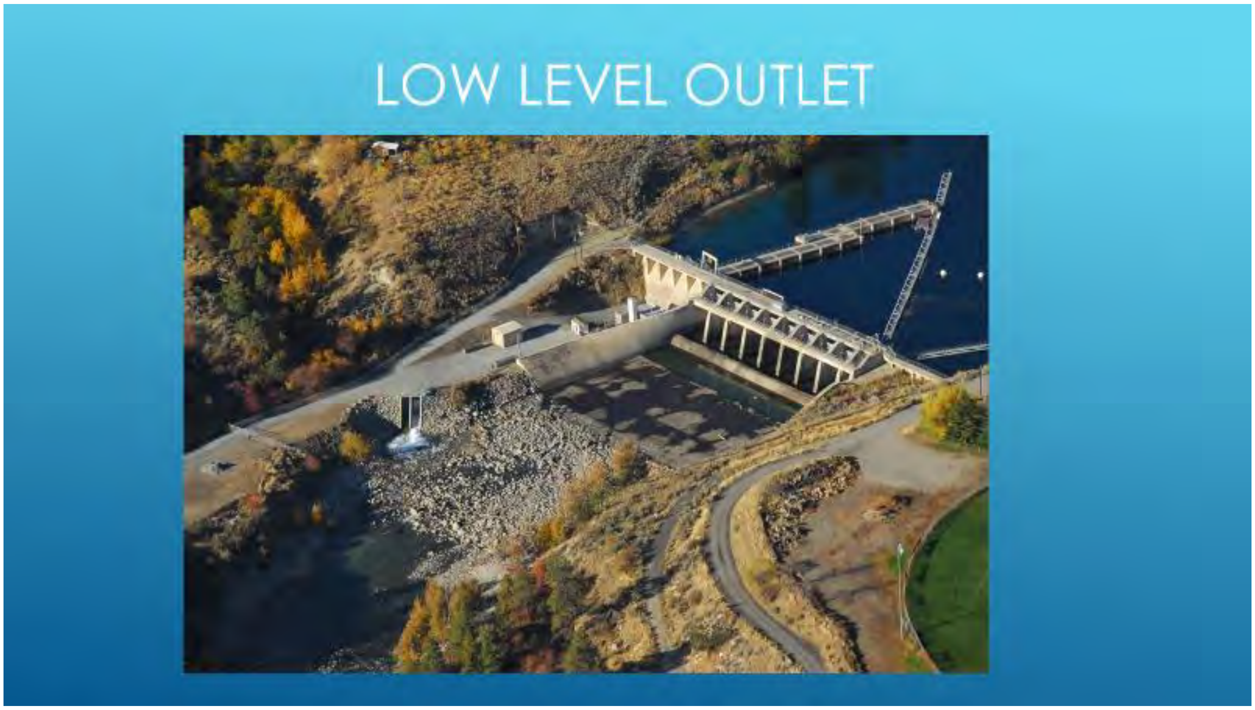
RELICENSING AGREEMENT

- Minimum Flow of 80 cfs Released from Dam, with May 15 – July 15 Minimum of 200 cfs in Average Runoff Years and 320 cfs in High Runoff Years
- Create Approximately 2 Acres of New Spawning and Rearing Habitat in Reach 4
- Fill Portion of Tailrace To Increase Chinook Spawning Habitat and Improve Existing Tailrace Spawning Habitat
- Create Sinuous Habitat Channel with Five Pool/Riffle Components – Boulder and Wood Structure Features for Rearing and Steelhead Spawning Cover
- Use Pumped Flows to Provide Habitat Channel Spawning Depths Velocities: March 15 – May 15 for Steelhead, October 15 – November 30 for Chinook
- Operate Powerhouse As Necessary to Maintain Favorable Spawning and Incubation Conditions, Including Intra-gravel DO in Tailrace
- Investigate Water Temperature Dynamics, Model Studies to Evaluate Potential Temperature Reduction Measures, and Riparian Feasibility Study in Reach 1 for Cutthroat Population

LET'S BUILD IT

Chelan River, Reach 4 and Tailrace
New Stream Channel Construction
Aerial Showing Redds
November 5, 2008

COMPLETED PROJECT


LOW LEVEL OUTLET

REACH 1 – THEN AND NOW

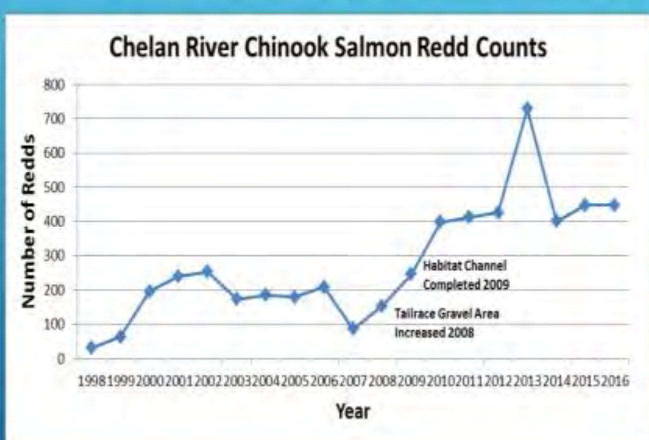

Chelan River before construction, 10/22/25

RESULTS

M&E INCLUDES

- Spawning Surveys for Summer Chinook and Coho in Fall, Steelhead in Spring
- Studies to Determine Powerhouse Operations Necessary to Maintain Intra-Gravel DO ≥ 6.0 mg/l in Tailrace Redds
- Snorkel Surveys Reach 4 and Reach 1
- Egg – Emergence Survival Studies for Chinook and Steelhead
- Macroinvertebrate Population Studies
- Water Temperature Monitoring and Model Study
- Water Quality Assessment for TDG, DO, pH, Turbidity

CHINOOK SPAWNING SURVEYS



Year	Tailrace	Reach 4	Columbia R	Total
2008	153	NA	In tailrace count	153
2009	129	79	58	266
2010	234	115	49	398
2011	192	178	48	418
2012	231	139	56	426
2013	320	269	140	729
2014	246	78	76	400
2015	217	125	106	448
2016	207	167	74	448

CHINOOK ADULT PRODUCTION

Return Year	Hatchery	Wild	Hatchery	Wild
Return Year	Proportion		Number of Fish	
	Hatchery	Wild	Hatchery	Wild
2000	0.65	0.35	304	166
2001	0.74	0.26	731	253
2002	0.74	0.26	433	149
2003	0.80	0.20	337	82
2004	0.43	0.57	178	238
2005	0.59	0.41	310	214
2006	0.36	0.64	149	271
2007	0.67	0.33	127	62
2008	0.56	0.44	280	217
2009	0.96	0.04	600	25

Return Year	Hatchery	Wild	Hatchery	Wild
Return Year	Proportion		Number of Fish	
	Hatchery	Wild	Hatchery	Wild
2010	0.57	0.43	633	485
2011	0.56	0.44	713	567
2012	0.80	0.20	1044	264
2013	0.65	0.35	1090	594
2014	0.34	0.66	370	730
2015	0.50	0.50	713	725
2016	0.52	0.48	471	429

STEELHEAD SPAWNING SURVEYS

STEELHEAD REDD COUNTS	
Year	Redds
2011	21
2012	7
2013	21
2014	0
2015	3
2016	2
2017	29

STEELHEAD EGG – FRY SURVIVAL

Redd	% Live	Female	Male	ATU's at extraction	Depth to top of egg box during excavation (inches)
S2-3	47	C	A	636.74	3
S3-2	42	B	A	637.83	7
S3-3	46	C	B	639.40	10
S4-3	49	C	A	637.27	6
S4-4	58	B	A	639.97	8
S5-1	53	B	B	639.53	6
S5-3	26	C	B	635.57	8
S7-2	45	B	B	634.75	2
S3-TestB	76	B	B	626.95	14
S2-TestC	71	C	A	509.87	5
Average	**51.3**				
Hatchery B	95.9	B	A	NA	NA
Hatchery C	92.1	C	B	NA	NA
Average	**94**				

STEELHEAD SPAWNING GRAVEL

A90F8D56.3gp

SNORKEL SURVEYS REACH 4

HABITAT CHANNEL 2016

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Bull Trout	0	0	0	0	0	0	0	0	1	6	3	3	13
Ch-Adult	0	0	0	0	1	6	31	11	229	166	1	0	445
Ch-1	5	3	15	0	0	0	0	0	0	0	0	1	24
Ch-0	2	218	4,540	0	6,637	7	1	0	0	0	0	0	11,405
Cutthroat Trout	0	7	3	0	7	68	13	3	3	2	0	1	107
Northern Pikeminnow	0	0	0	0	91	2,996	150	0	3	0	0	0	3,240
Rainbow Trout	24	23	46	0	8	36	45	40	29	11	36	41	339
Smallmouth Bass	3	9	32	0	218	324	328	158	29	0	0	3	1,104
Total	34	260	4,636	0	6,962	3,437	568	212	294	185	40	49	16,677

CHINOOK FRY REACH 4

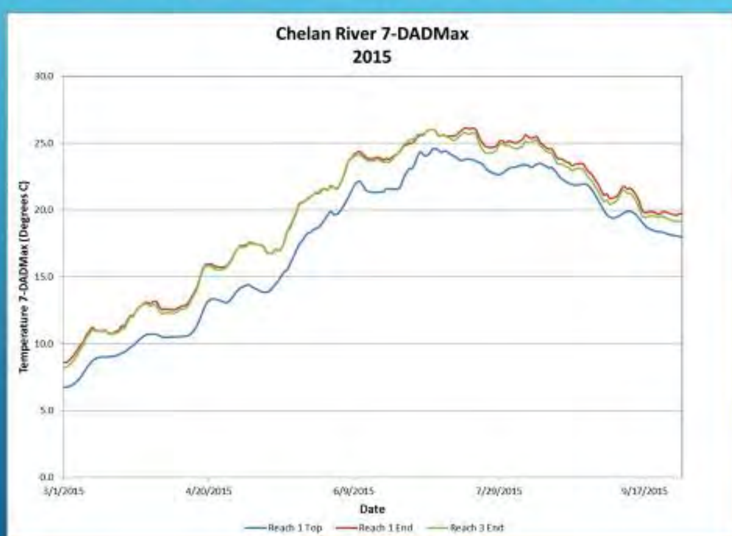
Year	Location	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Nov.
2010	Tailrace	-	-	0	-	-	-	-	-
2010	Channel	-	-	3945	-	-	-	-	-
2010	Pool	-	-	845	-	-	-	-	-
2012	Tailrace	0	0	2670	285	-	0	0	0
2012	Channel	0	0	2312	0	-	0	0	0
2012	Pool	0	8	0	-	-	0	0	0
2013	Tailrace	0	25	9000	5	0	0	0	0
2013	Channel	0	0	3845	1	1	0	0	0
2013	Pool	0	5	30	1	1	0	0	0
2014	Tailrace	0	4090	3000	0	0	0	0	0
2014	Channel	0	11035	4710	0	0	0	0	0
2014	Pool	0	2600	22	0	0	0	0	0
2015	Tailrace	0	50	100	0	0	0	0	0
2015	Channel	0	2073	95	0	0	0	0	0
2015	Pool	2	0	393	0	0	0	0	0
2016	Tailrace	1250	NS	2679	0	0	0	0	0
2016	Channel	3304	NS	6637	6	1	0	0	0
2016	Pool	1236	NS	0	0	0	0	0	0

SNORKEL SURVEYS REACH 1

NS- No Survey		2012			2013			2014		
		March	August	November	April	August	November	April	August	November
Cutthroat Trout	R1	0	NS	0	5	0	0	19	11	20
	R2	0	NS	NS	0	0	0	2	2	1
	R3	8	NS	NS	3	2	0	NS	NS	NS
Rainbow Trout	R1	7	NS	12	5	0	1	5	58	51
	R2	0	NS	NS	0	11	7	5	39	32
	R3	5	NS	NS	5	0	0	NS	NS	NS
		2015			2016					
		April	September	November	January	February	March	May	June	July
Cutthroat Trout	R1	20	24	22	6	12	18	82	189	214
Rainbow Trout	R1	11	24	46	22	39	41	22	34	41
		August	September	October	November	December				
Cutthroat Trout	R1	129	111	86	72	62				
Rainbow Trout	R1	31	44	32	38	14				

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Cutthroat Trout	6	12	18	0	82	189	214	129	111	86	72	62	981
Northern Pikeminnow	1	0	1	0	0	7	29	8	3	0	1	0	50
Rainbow Trout	22	39	41	0	22	34	41	31	44	32	38	14	358
Smallmouth Bass	48	34	87	0	77	95	184	256	23	8	0	12	824
Total	77	85	147	0	181	325	468	424	181	126	111	88	2,213

CHELAN RIVER IS WARM

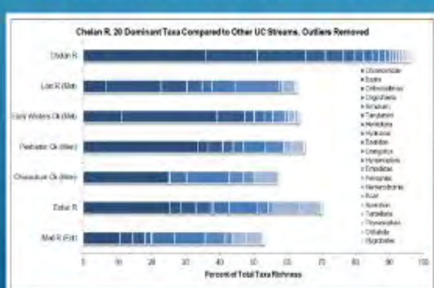


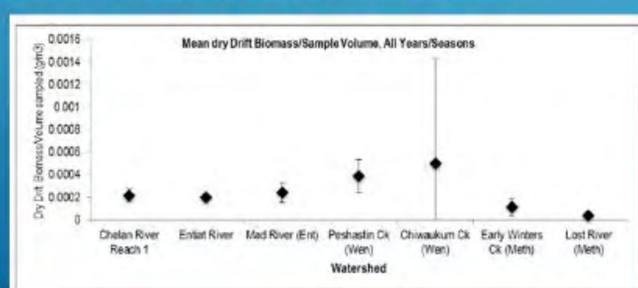
TEMPERATURE MODEL FINDINGS

- Hyporheic Zone Parameters Had Most Influence on Model Calibration
- High Degree of Hyporheic Exchange – 30% of Flow Fraction
- Daily Maximum Temperature Could Be Reduced by Up to 2 Degrees C if Flow Increased from 80 cfs to 500 cfs
- However, Daily Minimum Temperature Would Increase by the Same Amount and Hyporheic Influence Could be Reduced
- Mature Riparian Vegetation Only Reduce Maximum Temperature by 0.1 Degrees C

MACROINVERTEBRATE STUDIES

- Benthic and Drift Samples had Limited Species Richness – Similar to Upstream Above Dam Samples
- Some Drift Samples in Tailrace and Habitat Channel Had High Abundance of Lake Species – Cladocerans and Copepods
- Dominant Taxa Were Chironomidae, Baetis and Orthocladinae
- Drift Abundance in Reach 1 Similar to CHaMP Data for Local Streams





CUTTHROAT DON'T LOOK STARVED

Cutthroat Trout stocked in Reach 1 on 3/24/15 and recaptured 6/24/15 (photo by Graham Simon, WDFW)

I'M NOT COMPLAINING

QUESTIONS?

Attachment 2

Presentation by Tracy Hillman on Effectiveness of Tributary Habitat Enhancement Projects

Purpose

Respond to six, policy-level questions:

- What are the effects of habitat actions on habitat conditions?
- Which actions are most effective in producing desired habitat conditions for salmonids?
- How do salmonids respond to changes in habitat conditions?
- What are the effects of individual actions on fish at the site, reach, and watershed scales?
- Are benefits sustained over time?
- Which actions provide the greatest benefit to fish?

2

Approach

Conducted a comprehensive review of published and unpublished literature (reviewed 617 papers).

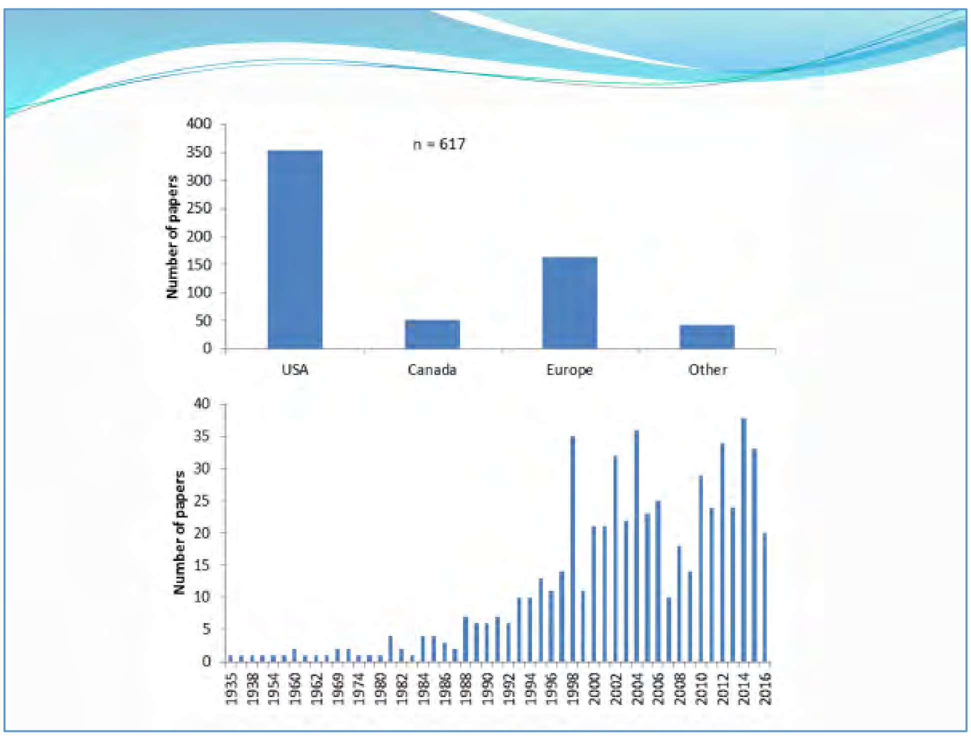
Criteria for relevance:

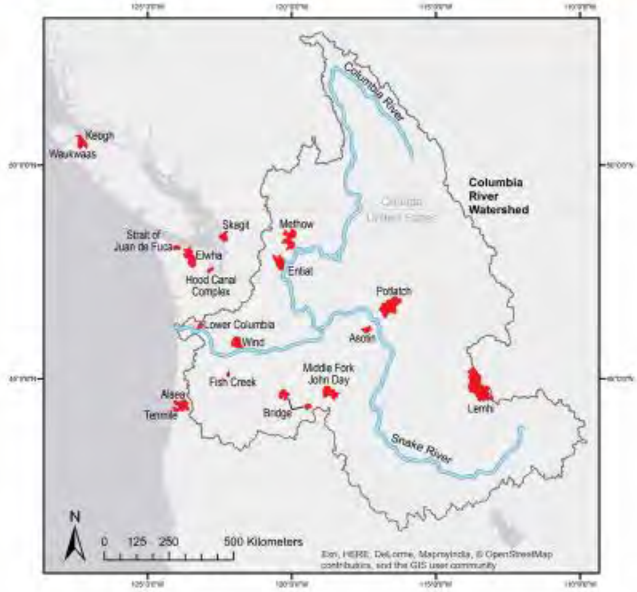
- Paper must describe results from monitoring and evaluation of enhancement actions.
- Paper must provide quantitative information on physical and biological response to enhancement.

Compiled an annotated bibliography of all papers reviewed and summarized results for eight categories of enhancement.

3

PROJECT CATEGORY	SUBCATEGORY	NUMBER OF STUDIES
Fish Passage	Barrier Removal Entrainment	56
Instream Structures	Large wood and boulder placement Engineered Logjams Gravel addition Beaver enhancement structures	254
Off-Channel/Floodplain Habitat	Reconnection Levee Removal/Setback Side Channel and Pond Construction/Creation Channel Enhancement/Re-meandering	133
Riparian Improvement	Riparian Plantings and Silviculture Treatment Riparian Fencing and Grazing Invasive Species Control	77
Sediment Reduction	Road Agricultural practices	33
Flow Augmentation	Water release or improvement Irrigation improvement	24
Nutrient Enhancement	Salmon carcasses or carcass analogs Organic or inorganic nutrient addition	38
Acquisition and Protection	Land acquisition, lease, or easement	1





6

What Works and Why?

Implementing the *right action* in the *right place* at the *right time*!

Right Action:

- Actions that remove or minimize threats causing limiting factors.
- Actions that address the factors affecting the limiting life stage.

Right Place:

- Actions that improve or are not affected by degraded upstream process.
- Actions that treat a large percentage of the degraded habitat (20%).

Right Time:

- Actions that are sequenced appropriately.

7

Characteristics of Successful Enhancement Work:

- Understanding the habitat requirements of the target species and their life-history characteristics.
- Assessments that identify enhancement opportunities and provide a clear understanding of the problems and limiting life-stage and habitats.
- Implementation plans that prioritize locations for enhancement and prioritize actions (sequencing).

8

Characteristics of Successful Enhancement Work:

- Extensive coordination among stakeholders, landowners, funding and monitoring entities, and implementers.
- Success is directly related to the size or magnitude of the treatment.
- Incorporation of effectiveness monitoring within an adaptive management framework.

9

Why Do Good Intensions Fail?

- **Pristine Fantasy** – Assuming we can achieve some pre-development condition or single endpoint.
- **Field of Dreams** – Focus solely on the physico-chemical conditions.
- **Copy-Cat Approach** – Over use of a method that is not sufficiently validated.
- **Fast Forward** – Belief we can accelerate ecosystem structure and function.

10

Why Do Good Intensions Fail?

- **Command and Control** – Illusion that we can control nature (focus on treating symptoms).
- **Cornucopian Belief** – Technology will solve the problem.
- **Ecological Trap** – When good animals love bad habitat.
- **Perceptual Trap** – When good animals avoid good habitat.

11

Recommendations

- Protect high-quality habitat.
- Focus on removing or reducing the threats or key limiting factors that degrade habitat conditions.
- Address and work within natural watershed processes.
- Screen water-withdrawal structures to reduce entrainment.

12

Recommendations

- Reconnect spawning and rearing areas.
- Instream structures should be used in concert with actions that improve watershed processes.
- Nutrient enrichment projects should be considered experimental.
- Extensive coordination among all parties.

13


14

Appendix D
List of Rock Island Habitat Conservation Plan Committees Members

Rock Island Mid-Columbia HCP Committees, 2017

Policy Committee

Name	Organization
John Ferguson (Chairman)	Anchor QEA, LLC
Randy Friedlander	Colville Confederated Tribes
Keith Truscott (Jan-Apr)	Chelan PUD
Alene Underwood (Apr-Dec)	Chelan PUD
Ritchie Graves	National Marine Fisheries Service
Jim Craig	U.S. Fish and Wildlife Service
Jim Brown	Washington Department of Fish and Wildlife
Steve Parker	Yakama Nation

Coordinating Committee

Name	Organization
John Ferguson (Chairman)	Anchor QEA, LLC
Kirk Truscott	Colville Confederated Tribes
Lance Keller	Chelan PUD
Scott Carlon	National Marine Fisheries Service
Jim Craig	U.S. Fish and Wildlife Service
Jeff Korth (Jan-Aug)	Washington Department of Fish and Wildlife
Chad Jackson (Aug-Dec)	Washington Department of Fish and Wildlife
Bob Rose (Jan-Aug)	Yakama Nation
Keely Murdoch (Aug-Dec)	Yakama Nation

Hatchery Committee

Name	Organization
Tracy Hillman (Chairman)	BioAnalysts, Inc.
Kirk Truscott	Colville Confederated Tribes
Alene Underwood (Jan-Apr)	Chelan PUD
Catherine Willard (Apr-Dec)	Chelan PUD
Justin Yeager	National Marine Fisheries Service
Matt Cooper	U.S. Fish and Wildlife Service
Mike Tonseth	Washington Department of Fish and Wildlife
Tom Scribner	Yakama Nation

Tributary Committee

Name	Organization
Tracy Hillman (Chairman)	BioAnalysts, Inc.
Chris Fisher	Colville Confederated Tribes
Steve Hays	Chelan PUD
Justin Yeager	National Marine Fisheries Service
Kate Terrell	U.S. Fish and Wildlife Service
Jeremy Cram	Washington Department of Fish and Wildlife
Lee Carlson	Yakama Nation

Appendix E
Statements of Agreement for Habitat Conservation Plan Coordinating Committees

Final
Rock Island Habitat Conservation Plan
Coordinating Committee

Statement of Agreement
February 3, 2017

Acknowledgement of Rock Island
Powerhouse 1 Units B1-B4 Consultation

Agreement Statement
The Rock Island HCP Coordinating Committee (CC) have reviewed the draft letter to the Federal Energy Regulatory Commission (FERC) regarding the upcoming maintenance activities at units B1-B4 in Powerhouse 1 at Rock Island Dam, and agree the proposed work will not adversely affect aquatic resources or Chelan PUD's obligations under the HCP.

Background

Beginning in April 2016, the CC was made aware of the maintenance activities proposed to occur to rehabilitate units B1-B4 in Powerhouse 1 at Rock Island Dam. During the October 25, 2016 CC meeting, Brett Bickford, Chelan PUD Engineering and Project Management Director, formally presented the activities to occur from 2017 to 2020, complete with a description of turbine components to be replaced and those components to remain the same.

A new modern turbine design with tighter operating tolerances and fixed blade angle positioned for optimum flow conditions supporting efficient power generation are expected to benefit fish passage survival. Additionally, laminar flow conditions associated with peak generating capability equate to providing fish the best possible flow conditions for turbine route passage. In 2013, the HCP Coordinating Committee approved Chelan PUD's 2013 Comprehensive Progress Report that concluded Chelan PUD had reached no net impact at Rock Island with respect to all planned species.[1] Chelan PUD's achievement of no net impact in 2013 was successfully achieved while operating the vintage 1933 units. The proposed rehabilitation work will not alter the HCP Coordinating Committee's 2013 finding of no net impact and in fact, Chelan PUD anticipates that the new modern design of present day turbines will offer additional survival benefit of fish passing through the rehabbed B1-B4 units. A project survival standard check-in study is scheduled for 2020 (post B1-B4 rehab) to verify continued achievement of the juvenile survival standard. The schedule has all PH1 units in operation by April 2020 providing the best chance for success during the 2020 HCP check-in.

On November 15, 2016, Chelan PUD provided to the CC a draft letter addressed to FERC for agency and committee comments. After completion of a 30 day review on December 15, 2016, and receiving no comments, Chelan PUD filed the letter with FERC.

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[1] Statement of Agreement, Approval of Rock Island and Rocky Reach HCPs 2013 Comprehensive Progress Report (Approved February 26, 2013).

FINAL

Rocky Reach and Rock Island Habitat Conservation Plans Coordinating Committees

Statement of Agreement

Designation of Juvenile Coho in Phase III (Standard Achieved) at the Rock Island and Rocky Reach Projects

(March 30, 2017)

Agreement Statement

The Rock Island and Rocky Reach HCP Coordinating Committees (CC) have reviewed PIT-tag based estimates of juvenile coho passage survival compared with PIT-tag based yearling Chinook passage survival in the Columbia River hydropower system, prepared by J. Skalski and R. Townsend (2017). The CC agrees that comparison of PIT-tag based juvenile coho survival and yearling Chinook survival using juveniles released in the Methow sub-basin upstream of the Rocky Reach Project over seven consecutive migration years (2010-2016) demonstrates that juvenile coho survive hydropower system passage similar to yearling Chinook. Because juvenile coho and yearling Chinook passage survival is comparably similar, and because Chelan PUD has measured direct passage survival of yearling Chinook through Rocky Reach ($\hat{S}$ = 92.72) and Rock Island ($\hat{S}$ = 93.75) Projects in HCP acoustic tag survival studies, the CC also agrees that juvenile coho survival can be estimated using Chelan PUD's yearling Chinook acoustic tag survival estimates and coho PIT-tag based survival estimates. Yearling Chinook are in Phase III (Standard Achieved) at both Rock Island and Rocky Reach Projects. The CC acknowledges that based on the estimated juvenile coho Project survivals of 93.98% at Rock Island and 92.94% at Rocky Reach (Skalski and Townsend 2017), the CC agrees to move juvenile coho at both Projects from Phase III Standard Achieved Interim-Value to designation of Phase III Standard Achieved, with 93% survival at both Projects.

Background

The Rocky Reach and Rock Island HCP Coordinating Committees reviewed and approved an SOA on June 26, 2007 and agreed that (1) an interim coho juvenile survival value of 93% would be assumed and (2) juvenile coho survival studies would not be performed unless there was compelling information that demonstrated hydro project operations were having an impact greater than seven percent mortality on coho. As approved, juvenile coho were designated as Phase III (Standard Achieved – Interim Value) for the Rocky Reach and Rock Island projects.

Comparison of Juvenile Coho and Yearling Chinook PIT-tag Survival Estimates Through the Mid-Columbia

PIT-tag based estimates of survival for hatchery released juvenile coho and hatchery released yearling Chinook through the Mid-Columbia can be used to evaluate how juvenile coho survive relative to yearling Chinook. Skalski and Townsend (2017) analyzed PIT-tagged juvenile coho and PIT-tagged yearling Chinook released from Winthrop National Fish Hatchery, Methow Hatchery and all Methow Sub-basin acclimation sites to estimate juvenile passage survival from Rocky Reach tailrace to McNary tailrace, and survival from McNary to John Day tailrace, 2010 through 2016 (Table 1) .

Table 1. Cormack-Jolly-Seber PIT tag survival estimates of juvenile coho salmon and yearling Chinook salmon from Rocky Reach (RRH) to McNary (MCN) and McNary to John Day (JD) for pooled releases from the Winthrop National Fish Hatchery, Methow Hatchery, and Methow sub-basin final acclimation sites.

Year	Release Sizes Coho/Chinook	PIT Survival Coho/Chinook RRH to MCN	$\hat{S}$ SE Coho/Chinook	PIT Survival Coho/Chinook MCN to JD	$\hat{S}$ SE Coho/Chinook
2010	11,859 / 25,806	88.15% / 76.17%	(0.0915)/ (0.0421)	96.73%/ 100.1%	(0.1570)/ (0.1228)
2011	20,873 / 28,117	66.55% / 62.65%	(0.0411)/ (0.0314)	120.3%/ 97.11%	(0.1778)/ (0.1022)
2012	17,891 / 29,569	67.78% / 72.07%	(0.0362)/ (0.0336)	84.39%/ 78.38%	(0.0742)/ (0.0549)
2013	23,851 / 35,498	83.34%/ 82.15%	(0.0547)/ (0.0423)	83.26%/ 91.25%	(0.0931)/ (0.0916)
2014	23,489 / 22,475	72.60%/ 75.39%	(0.0436)/ (0.0565)	87.25%/ 93.0%	(0.0822)/ (0.1255)
2015	24,233 / 31,913	75.18%/ 71.08%	(0.0863)/ (0.0422)	91.69%/ 80.44%	(0.2036)/ (0.0837)
2016	17,885 / 31,884	67.73% / 76.09%	(0.0223)/ (0.0252)	98.66%/79.70%	(0.0828)/ (0.0502)

(Source: Skalski and Townsend 2017)

The PIT-tag survival estimates for juvenile coho and yearling Chinook were generated for fish migrating in the same river reaches in the same years, Rocky Reach to McNary and McNary to John Day, 2010 to 2016 (Skalski and Townsend 2017). Comparison of Rocky Reach to McNary reach survival estimates suggest juvenile coho salmon and yearling Chinook have the most comparable survivals with a survival ratio near 1.0000. In six of seven years of comparison, reach survival ratios for juvenile coho to yearling Chinook were not significantly different between the two species and the seven year weighted mean reach survival ratio was not significantly different (weighted mean=0.9549; SE=0.0307; P=0.1921) (Table 2).

Table 2. Ratios of multiple-project (hydro system) reach survivals for the above Rocky Reach release groups of juvenile coho and yearling Chinook salmon, (2010–2016). Numbers in bold indicate survival ratios that are significantly different from 1 ($P < 0.05$).

Species Ratio	Year	Rocky Reach to McNary	P (≠ 1)	McNary to John Day	P (≠ 1)
Coho/Yrl Chinook	2010	1.1573 (0.1361)	0.2478	0.9602 (0.1949)	0.8382
	2011	1.0623 (0.0845)	0.4612	1.2392 (0.2248)	0.2873
	2012	0.9405 (0.0667)	0.3720	1.0767 (0.1210)	0.5264
	2013	1.0145 (0.0846)	0.8641	0.9124 (0.1371)	0.5231
	2014	0.9630 (0.0925)	0.6890	0.9382 (0.1544)	0.6888
	2015	1.0577 (0.1367)	0.6730	1.1399 (0.2795)	0.6168
	2016	0.8901 (0.0416)	**0.0082**	1.2379 (0.1299)	0.0670

(Source: Skalski and Townsend 2017)

Projection of Coho Salmon Project Survival Using Acoustic Tag/PIT Tag Survival Estimates

A ratio estimator was used to project coho salmon acoustic-tag passage survival based on PIT-tag data on juvenile coho salmon, and PIT-tag and acoustic-tag data on yearling Chinook salmon. Using PIT-tag releases, reach survivals from Rocky Reach tailrace (detections in the Rocky Reach bypass) to McNary tailrace were estimated for coho and yearling Chinook salmon for the years 2010–2016 (Table 1). In addition, acoustic-tag investigations were performed on yearling Chinook salmon at Rocky Reach (i.e., 2010, 2011) and Rock Island (i.e., 2007, 2008, and 2010) as part of the HCPs' survival compliance testing. Assuming the PIT-tag studies and acoustic-tag studies are each reliably estimating the same quantities, ratios of reach survivals for juvenile coho and yearling Chinook salmon should be the same whether they were estimated using acoustic or PIT tags.

Table 3: PIT-tag reach survival estimates from Rocky Reach tailrace to McNary tailrace $\left(\hat{S}^{\mathrm{PIT}}_{\mathrm{RR-MCN}}\right)$, ¼-root survival $\left(\hat{S}^{1/4}\right)$, and coho-to-Chinook-salmon survival ratios through the four Mid-Columbia projects $\left(\hat{R}\right)$. Standard error in parentheses.

	$\hat{S}^{\mathrm{PIT}}_{\mathrm{RR-MCN}}$		$\hat{S}^{1/4}$		
Year	Coho	Chinook	Coho	Chinook	$\hat{\bar{R}}^{\mathrm{PIT}}_{\mathrm{Coho/Chin}}$
2010	0.8815	0.7615	0.9690	0.9342	1.037
2011	0.6655	0.6265	0.9032	0.8897	1.015
2012	0.6778	0.7207	0.9074	0.9214	0.985
2013	0.8334	0.8215	0.9554	0.9520	1.004
2014	0.7260	0.7539	0.9231	0.9318	0.991
2015	0.7518	0.7108	0.9312	0.9182	1.014
2016	0.6773	0.7609	0.9072	0.9340	0.971
				Average	**1.0024** (0.0084)

(Source: Skalski and Townsend 2017)

The value of $\hat{\hat{R}}$ = **1.0024** in Table 3 above was used to project average direct-measured yearling Chinook salmon acoustic tag passage survival at the Rocky Reach Project of $\hat{S}_{\mathrm{Chin}_{\mathrm{ACO}}}$ = 0.9272 into a coho salmon project passage survival estimate, where

$$\begin{aligned}\hat{S}_{\mathrm{Coho}_{\mathrm{ACO}}} &= \hat{\hat{R}}^{\mathrm{PIT}}_{\mathrm{Coho/Chin}} \cdot \hat{\hat{S}}_{\mathrm{Chin}_{\mathrm{ACO}}} \\ &= 1.0024(0.9272) \\ &= \mathbf{0.9294}\ \left(\widehat{\mathrm{SE}} = 0.0081\right).\end{aligned}$$

The same coho-to-Chinook-salmon survival ratio of $\hat{\hat{R}}$ = **1.0024** was used to project average direct-measured yearling acoustic tag passage survival at the Rock Island Project of $\hat{S}_{\mathrm{Chin}_{\mathrm{ACO}}}$ = 0.9375 into a coho salmon project passage survival estimate, where

$$\begin{aligned}\hat{S}_{\mathrm{Coho}_{\mathrm{ACO}}} &= \hat{\hat{R}}^{\mathrm{PIT}}_{\mathrm{Coho/Chin}} \cdot \hat{\hat{S}}_{\mathrm{Chin}_{\mathrm{ACO}}} \\ &= 1.0024(0.9375) \\ &= \mathbf{0.9398}\ \left(\widehat{\mathrm{SE}} = 0.0233\right).\end{aligned}$$

Skalski, J.R. and R. L. Townsend, 2017. Comparison of Juvenile Survival of Chinook Salmon, Sockeye Salmon, Steelhead, and Coho Salmon through the Chelan PUD Projects, 2010-2016. Columbia Basin Research, School of Aquatic and Fishery Science, University of Washington. January 26, 2017.

Appendix F
Statements of Agreement for Habitat Conservation Plan Hatchery Committees

Rocky Reach and Rock Island HCP Hatchery Committees
Statement of Agreement

Monitoring and Evaluation Reporting Schedule for the Douglas PUD, Grant PUD and Chelan PUD Hatchery Programs, dated March 13, 2017
(Chelan PUD, NMFS, USFWS, WDFW, YN, and CCT approved on March 13, 2017)

Statement

The Rocky Reach and Rock Island Habitat Conservation Plans (HCP) Hatchery Committees (HC) approve the Monitoring and Evaluation Reporting Schedule for the Douglas PUD, Grant PUD and Chelan PUD Hatchery Programs, dated March 13, 2017. Any future alterations of the schedule will require HCP Hatchery Committees approval.

Background

Chelan PUD's HCPs specify the need to update the hatchery monitoring and evaluation (M&E) plan every five years and to comprehensively review the hatchery program every 10 years utilizing new information from the M&E program. The National Marine Fisheries Service Section 10(A)(1)(a) and 10(A)(1)(b) Endangered Species Act permits for Chelan PUD's hatchery programs and the *Monitoring and Evaluation Plan for PUD Hatchery Programs* also contain reporting requirements for hatchery M&E information. To date, these reporting requirements have not aligned, which has resulted in a disjointed review and input cycle to inform updates to M&E plans, recalculation of hatchery production, evaluation of M&E objectives, status of meeting permit requirements, and adaptive management actions. The document, Monitoring and Evaluation Reporting Schedule for the Douglas PUD, Grant PUD and Chelan PUD Hatchery Programs, dated March 13, 2017, optimizes the sequence of hatchery M&E reporting and is the new reporting schedule for hatchery M&E information.

Rocky Reach and Rock Island HCP Hatchery Committees
FINAL Statement of Agreement
Regarding District's Coho Obligation
November 15th, 2017

Approved as follows: CCT approved via email on November 14, 2017, and Chelan PUD, WDFW, USFWS, NMFS, and YN approved on November 15, 2017.

Statement

The Rocky Reach and Rock Island HCP Hatchery Committees (hereafter "Committees") agree that Chelan PUD shall provide coho compensation for the Methow River and Wenatchee River sub-basins at a rate equivalent to 7.0% at each project to meet Chelan PUD's No Net Impact hatchery obligations for brood years 2017 to 2021 (release years 2019 to 2023); therefore, 7.0% will be used as the coho hatchery compensation rate until the next scheduled hatchery compensation recalculation (2023). Methodology described in the SOA Regarding the 2013 No Net Impact Recalculation Methodology (dated July 20th, 2011) will be used to calculate hatchery compensation levels for coho.

Background

On June 20, 2007, the Committees agreed to implement coho hatchery compensation as detailed in Section 8.4.3.a of the Rocky Reach and Rock Island HCPs and agreed that the District shall begin providing hatchery compensation no later than October 1, 2007. On March 28, 2017, the Rocky Reach and Rock Island Coordinating Committees agreed to use Chelan PUD's yearling Chinook acoustic tag survival estimates and coho PIT-tag based survival estimates to estimate juvenile coho survival of 93.98% at Rock Island and 92.94% at Rocky Reach (Skalski and Townsend 2017) which culminated in a 93% survival value at both projects.

Calculations for the Methow Sub-basin Coho Reintroduction Project

Compensation for **hatchery-origin smolts** will be determined by multiplying the Program's annual release targets from the Methow sub-basin coho reintroduction project by the unavoidable project mortality (1-(0.93 x 0.93)) for Rocky Reach and Rock Island.

Compensation for **natural-origin smolts** produced is determined by:

- Mean NOR[1] to Rocky Reach (return years 2008 to 2011 and 2013 to 2015) = 43
- Mean NOR in absence of project mortality: 43/0.9300 = 46
- Adult equivalents to meet NNI: 46-43=3
- Mean 8-year SAR (release years 2008-2015 Methow sub-basin hatchery program) = 0.59%
- Compensation for natural-origin smolts: 3/0.0059 = 508 smolts

Calculations for the Wenatchee Sub-basin Coho Reintroduction Project

Compensation for **hatchery-origin smolts** will be determined by multiplying the Program's annual release targets from the Wenatchee sub-basin coho reintroduction project by the unavoidable project mortality (1-0.93) for Rock Island.

Compensation for **natural-origin smolts** is determined by:

- Mean NOR to Rock Island (return years 2007-2016) = 529
- Mean NOR in absence of project mortality: 529/0.9300 = 569
- Adult equivalents to meet NNI: 569-529 = 40
- Mean 10 year SAR[2] (release years 2006-2015 Wenatchee sub-basin hatchery program) = 0.75%
- Compensation for natural-origin smolts: 40/0.0075 = 5,333 smolts

[1]Natural-origin return=NOR
[2]SAR=releases from the Wenatchee hatchery programs and returns to Priest Rapids Dam (versus Rock Island Dam due to historic variable PIT tag detection efficiency at the adult ladders).

Appendix G
2016 Rock Island Dam Smolt Monitoring Program and Gas Bubble Trauma Evaluation Final Report

2016 Rock Island Dam Smolt Monitoring Program and Gas Bubble Trauma Evaluation Final Report

Chelan County Public Utility District # 1
Wenatchee, Washington

By

Scott A. Hopkins
&
Lance M. Keller

December 2016

Table of Contents

Table of Contents ii
List of Tables iii
List of Figures iv
List of Appendices iv
Summary v
Introduction 1
Methods 2
  Bypass Trap Operation 2
  Sampling 2
  PIT Tagging 3
  Gas Bubble Trauma 4
Results and Discussion 5
  Bypass Trap Operation 5
  Species Composition and Passage Timing 5
    Yearling Chinook 5
    Subyearling Chinook 5
    Steelhead 5
    Sockeye 5
    Coho 5
    Total Salmonid Run 6
  Run-of-River Condition Evaluations 7
    Descale 7
    Injury 7
    Mortality 7
  PIT Tagging 8
  Mark and Tag Recaptures 8
    PIT Tags 8
  Incidental Species 8
  Gas Bubble Trauma 9
  River Flows 10
  Fish Spill 11
Acknowledgments 12
References 13

List of Tables

Table 1 Fish Passage Center fish identification criteria…………………………3

Table 2 Weekly quotas for PIT tagging of salmon and steelhead at Rock Island Dam Juvenile Sampling Facility, 2016…………….…………….......4

Table 3 Fork length and descaling criteria for each species PIT tagged at the Rock Island Dam Juvenile Sampling Facility, 2016……….……….......4

Table 4 Juvenile salmonid collection counts and run timing (middle 80%) for The Rock Island Dam Juvenile Sampling Facility, 2016..…....….…….6

Table 5 Summary of descale, injury, and mortality for all species at the Rock Island Dam Juvenile Sampling Facility, 2016……………….…...7

Table 6 Number of salmonids PIT tagged during the 2016 Rock Island Dam Juvenile Sampling Facility monitoring season……..……………….....8

Table 7 Incidental species collected at the Rock Island Dam Juvenile Sampling Facility, 2016…………………..………………………………...8

Table 8 Number of juvenile salmon and steelhead examined for external signs of GBT, 2016……………………………………................... 9

Table 9 Rock Island Dam total river flows and powerhouse operation by month, 2016...10

Table 10 Rock Island Fish Spill Program Results, 2016………………………..11

List of Figures

Figure 1	Aerial view of Rock Island Dam	14
Figure 2	Plan view of Rock Island Dam Powerhouse # 2 Juvenile Bypass	15
Figure 3	Annual species percent composition of fish collected at the RIJSF, 2016	16
Figure 4	Percent of descale, injury and mortality by species at the RIJSF, 2016	17
Figure 5	Percent of descale, injury and mortality for all species at the RIJSF, 2016	18

List of Appendices

Appendix A	Rock Island Dam Juvenile Sampling Facility daily collection Data. April through August, 2016	A1
Appendix B	Sampling data of descale, injury, and mortality for all species. April through August, 2016	B1
Appendix C	Rock Island Dam daily mean for total river flow, powerhouse and spill April through August, 2016	C1
Appendix D	Juvenile salmonids and steelhead examined for GBT signs at RIJSF, 2016.	D1

SUMMARY

Outmigrating juvenile Chinook *Oncorhynchus tshawytscha,* Sockeye *O. nerka*, Coho *O. kisutch* salmon and steelhead *O. mykiss* were enumerated, examined for PIT tags, and evaluated for descaling, injury and mortality at the Rock Island Dam Juvenile Sampling Facility. This facility is operated by Chelan County Public Utility District # 1 (CCPUD) personnel daily April 1 to August 31. Yearling and subyearling Chinook Salmon as well as steelhead were examined for gas bubble trauma between April 12 and July 19. This was the thirty-second consecutive year that the juvenile salmonid spring and summer outmigration was monitored at Rock Island Dam. Species composition and condition data were transmitted daily to the Fish Passage Center (FPC), which manages the Smolt Monitoring Program (SMP) throughout the Columbia River Basin. Data collected by the SMP provides information for in-season management decisions regarding juvenile anadromous fish passage. Total river flow and Rock Island Powerhouse 2 flow during bypass trap operations averaged 131.25 kcfs and 91.29 kcfs, respectively. Spill for fish passage began on April 11 and continued through August 12.

In 2016, the Rock Island Dam Juvenile Sampling Facility (RIJSF) collected 126,705 juvenile salmonids. The middle 80% of the combined juvenile salmonid outmigration (all species) passed Rock Island Dam during a 32 day period from late April to late May. Duration of the middle 80% passage was 18 days for yearling Chinook Salmon, 53 days for subyearling Chinook Salmon, 23 days for steelhead, 20 days for Sockeye Salmon and 17 days for Coho Salmon. Of the 126,705 fish examined for condition, 0.72% were descaled (>20%), 0.43% injured and 0.71% mortalities. A total of 2,200 yearling Chinook Salmon, subyearling Chinook Salmon, and steelhead were examined for gas bubble trauma, with 0.59% showing some external signs. A total of 19,511 Chinook Salmon, Sockeye Salmon and steelhead were tagged with passive integrated transponder (PIT) tags between April 5 and August 13. Incidental catch totaled 842 fish comprised of adult steelhead, adult Chinook Salmon, adult Sockeye Salmon, jack Chinook Salmon, Rainbow Trout, Bull Trout, Kokanee, Mountain Whitefish, adult Lamprey, juvenile Lamprey, and Northern Pikeminnow.

INTRODUCTION

In 1982, the Northwest Power Planning Council developed a fish and wildlife program to protect, mitigate, and enhance fish and wildlife resources impacted by the construction and operation of the Columbia River Basin hydroelectric facilities. This program established a water budget that allocates upstream water storage for in-stream flow supplementation, which is intended to improve passage conditions for downstream migrating salmon and steelhead. The program also called for studies to monitor juvenile fish migration timing and survival (McDonald and Keesee 1997). The fisheries agencies and tribes formed the Fish Passage Center (FPC) to interact with hydro system operators and regulators in managing anadromous fish passage. Technical advice regarding flow, spill, and fish facility operations is provided to fisheries managers. The FPC developed the Smolt Monitoring Program (SMP) to assess daily information for in-season management decisions. Several sites were selected on the Columbia and Snake rivers as smolt monitoring stations. Rock Island Dam was selected as one of these stations (1985) because it is the first dam downstream from all major salmon and steelhead production tributaries on the mid-Columbia River (Figure 1; McDonald and Keesee 1997).

The SMP at Rock Island Dam was designed to index the daily number of outmigrating juvenile salmonids (i.e., target species) to include Chinook Salmon *Oncorhynchus tshawytscha, S*ockeye Salmon *O. nerka, C*oho Salmon *O. kisutch,* and steelhead *O. mykiss.* Observations were reported as wild or hatchery based on an excised fin(s) or external marks or tags including anchor tags, visual implant elastomer (VIE) tags, and previously passive integrated transponder (PIT) tagged fish. The PIT tagging program was implemented with a goal of tagging a random sample from the middle 80% of the outmigration of yearling and subyearling Chinook Salmon, Sockeye Salmon, and both hatchery and wild steelhead. Data collected under the SMP and PIT tagging programs allows for the comparison and evaluation of year to year migration timing, magnitude, and travel time of juvenile salmonids, both naturally and hatchery produced.

Chelan County Public Utility District # 1 (CCPUD) began spilling water for fish passage at Rock Island Dam to meet fish survival goals of the Rock Island Habitat Conversation Plan (HCP) that CCPUD entered into with state and federal resource agencies and Native American tribes. Studies have reported the level of total dissolved gas (TDG) at hydropower facilities can be affected as a result of spill (Ebel et al. 1975; Weitkamp and Katz 1975). High levels of TDG and the resulting supersaturated water can cause gas bubble trauma (GBT) in aquatic species. The presence of GBT can manifest as bubbles or blisters under the skin in juvenile salmonids (Weitkamp and Katz 1980). In 1996, the SMP implemented GBT monitoring at Rock Island Dam juvenile bypass sampling facility to focus on detecting external signs of GBT.

METHODS

Bypass Trap Operation

The Rock Island Dam Juvenile Sampling Facility operated from April 1 through August 31. Operations were conducted by CCPUD Fish and Wildlife personnel 7 days a week with 24 hour sampling periods from 09:00 am to 09:00 am. Fish were collected from Powerhouse # 2 turbine intake gatewells and the fishway attraction water intake. Fish entering the gatewells and attraction water intakes pass into a bypass channel through a series of submerged orifices. Incline dewatering screens separate fish from the bypass flow and deposit them into a sampling raceway (Figure 2). Fish were held in the raceway (4.4 cubic meters) for up to 24 hours. Each day at 0900 fish were crowded from the raceway into an elevator hopper and hoisted to the upper deck of the trap. Fish were transferred from the hopper via water to water using a 4 inch flex hose into an aluminum holding tank (4.0 cubic meters) in the fish sampling building. After examination, fish were transferred to a recovery tank (1.35 cubic meters) before release into the tailrace area. Two 5 hp submersible pumps installed in the right bank fish ladder provided a continuous supply of river water to the holding, sampling and recovery tanks.

Sampling

All fish collected were enumerated and examined. Groups of between 30 and 50 fish were netted using sanctuary nets into a sampling tank where they were anesthetized with a solution of tricaine methanosulfonate (MS-222: 1ml/2.11 liters) before being sampled and PIT tagged. An ionic salt solution (i.e. Pro Poly Aqua) was added to all sampling tanks within the fish sampling building to reduce handling stress and to promote healing after PIT tagging. All salmonids were enumerated by species, scanned for PIT tags, visually inspected for anchor tags, VIE tags, clipped fins, eroded fins and assessed for descale, injury and mortality.

After sampling, all fish were transferred to a recovery tank. When all fish had fully recovered from the anesthetic (1 hour minimum), they were released via a 10 cm aluminum pipe from the recovery tank to the tailrace of Rock Island Dam. The release area of the tailrace was protected from avian predation with parallel strands of stainless steel wire mounted above the pipe outlet and across the tailrace of the dam. The U.S. Department of Agriculture, Wildlife Services (USDA) suppressed predation by various piscivorous birds and northern pikeminnow in the tailrace using non-lethal and lethal means.

The physical condition of target salmonids was determined by estimating the degree of descaling on each live salmonid. Salmonids with descale greater than 20% on any one side were counted as decaled. Any fish with descale greater than 20% on any one side, except Sockeye Salmon (> 5%), or which had any visible injury, were not used for PIT tagging. Injury and mortality were enumerated for each species. In 2000, the FPC changed the identification criteria for smolt monitoring purposes to better quantify Endangered Species Act (ESA) listed versus non-listed populations (Table 1). Juvenile salmonids were classified as clipped or unclipped based on the presence of absence of the adipose fin. This change was due to recovery efforts of stocks listed under the ESA in the Columbia River Basin.

Unclipped steelhead were examined for visual implant elastomer (VIE) tags, eroded fins, or any combination of marks. Steelhead that were unclipped, but possessed frayed or eroded fins were classified as an “eroded fin” and enumerated as an unclipped hatchery fish with no distinguishing marks or tags. Only unclipped steelhead that possessed none of these distinguishing marks or tags were classified as wild steelhead. Yearling Chinook, subyearling Chinook, Coho, and Sockeye Salmon were classified as clipped or unclipped.

Table 1. FPC fish identification criteria.

Species	Fork length (mm)	Classification
Chinook yearling*	80 – 180	Clipped/ Unclipped
Chinook subyearling*	61 – 160	Clipped/ Unclipped
Chinook fry	< 61	Clipped/ Unclipped
Coho	61 – 180	Clipped/ Unclipped
Coho fry	< 61	Unclipped
Sockeye	< 211	Clipped/ Unclipped
	> 211	Kokanee
Steelhead	< 301	Clipped/ Unclipped
	> 301	Rainbow Trout
Steelhead fry	< 61	Unclipped

*Determined by emigration timing and fork length.

PIT Tagging

Sub-samples of yearling Chinook, subyearling Chinook, and Sockeye Salmon as well as steelhead were PIT tagged each week using quotas established by the FPC (Table 2). If any week’s quota was not met, the remainder was not added to the following week’s quota. The criteria used to determine fish origin remained the same as in previous years (i.e., hatchery or unknown). The complex marking schemes of hatchery fish precluded the presence of an adipose fin as an accurate indicator of wild fish, therefore fish with an adipose fin present are classified as fish of unknown origin per SMP guidelines. In 2016, the tagging of yearling Chinook and steelhead was conducted by Real Time Research and Oregon State University (RTR/OSU), with funding from the U.S. Army Corps of Engineers (USACE) to evaluate avian predation in the hydro system, and utilized species origin classification of hatchery, wild, and unknown origin.

Taggers for CCPUD injected tags by hand using a 10cc medical syringe with a push-rod mechanism and a 12-gauge hypodermic needle. Syringes and needles were sterilized for a minimum of 15 minutes in 91% isopropyl alcohol before each use. Fish used for PIT tagging must fall within length and condition limits established to help minimize mortality of fish placed under additional stresses (Table 3). Tagging data was electronically transferred to the Passive Integrated Transponder Information System (PTAGIS) daily. The FPC will report the results of the 2016 Rock Island Dam PIT tag program in the 2016 annual report.

Table 2. Weekly quotas for PIT tagging Rock Island Dam Juvenile Sampling Facility, 2016.

	Quotas				
Week of	Unclipped Chinook Yearling	Unclipped Chinook Subyearling	Unclipped Sockeye	Hatchery Steelhead	Wild Steelhead
17-Apr	600		600	200	
24-Apr	600		600	400	200
01-May	600		600	400	200
08-May	600		600	400	200
15-May	600		600	400	200
22-May	600		600	400	200
29-May	200			400	200
05-Jun				200	
12-Jun					
19-Jun		600			
26-Jun		600			
03-Jul		600			
10-Jul		600			
17-Jul		600			
24-Jul		600			
31-Aug		600			
07-Aug		600			
Season Totals	3,800	4,800	3,600	2,800	1,200

Table 3. Fork length and descaling criteria for each species PIT tagged at the Rock Island Dam Juvenile Sampling Facility, 2016.

Species	Fork length (mm)		Descaling
	Minimum	Maximum	

Chinook yearling*	80	180	< 20%
Chinook subyearling*	60	135	< 20%
Steelhead	120	280	< 20%
Sockeye	70	200	< 5%

*Determined by emigration timing and fork length.

Gas Bubble Trauma

Yearling and sub-yearling Chinook Salmon and steelhead were examined for evidence of GBT between 12 April and 19 July 2016. Each week a random sample of up to 100 target species fish were examined twice per week. Target species were considered Yearling Chinook Salmon and steelhead in the spring and subyearling Chinook Salmon in the summer. Examinations followed FPC standardized procedure as outlined by FPC (2016).

RESULTS AND DISCUSSION

Species Composition and Passage Timing

Yearling Chinook

A total of 30,042 yearling Chinook Salmon (26,468 clipped and 3,574 unclipped) were collected during the sampling season. Yearling Chinook Salmon were collected beginning on 1 April and collected daily from 1 April until 4 June. The last clipped and unclipped yearling Chinook Salmon was collected on 13 August and 7 June, respectively. Duration of the middle 80% yearling emigration was 18 days (Table 4).

Subyearling Chinook

A total of 14,821 subyearling Chinook Salmon (423 clipped, 8,068 unclipped, and 6,330 classified as fry) were collected during the sampling season. Subyearling Chinook Salmon were first collected on 1 April and daily through 25 August. The last collection of clipped subyearling Chinook Salmon was 23 July. Unclipped subyearling Chinook Salmon and unclipped Chinook Salmon fry were last collected on 31 August and 1 August, respectively. Duration of the middle 80% sub-yearling emigration was 53 days (Table 4).

Steelhead

A total of 12,080 steelhead (7,226 clipped and 4,854 unclipped) were collected during the sampling season. Steelhead were first collected on 2 April and daily between 2 April and 28 June. The last unclipped and clipped steelhead was collected on 28 August and 12 July, respectively. The duration of the middle 80% steelhead emigration was 23 days (Table 4).

Sockeye

A total of 38,450 Sockeye Salmon (3 clipped, 38,444 unclipped, and 3 fry) were collected during the sampling season. Sockeye Salmon were first collected 1 April, and collected daily between 1 April and 29 May. The last clipped and unclipped Sockeye Salmon were collected on 27 June and 26 August, respectively. The duration of the middle 80% sockeye salmon emigration was 20 days (Table 4).

Coho

A total of 31,312 Coho Salmon (126 clipped, 31,183 unclipped, and 3 fry) were collected during the sampling season. Coho Salmon were first collected on 1 April and were collected daily between 8 April and 18 June. The last clipped and unclipped Coho Salmon were collected on 7 June and 19 July, respectively. The duration of the middle 80% Coho Salmon emigration was 17 days (Table 4).

Total Salmonid Run

The Rock Island Dam Juvenile Bypass Trap Facility collected a total of 126,705 juvenile salmonids in 2016. Sockeye salmon comprised 30.3% of the season total followed by Coho (24.7%), yearling Chinook (23.7%), subyearling Chinook (11.7%) and steelhead (9.5%) (Figure 3). Species composition of smolts in daily samples is presented in Appendix A. Peak passage occurred on 3 May with predominately Sockeye salmon. Adipose clipped juveniles accounted for 27.3% of the season total. The duration of the middle 80% salmonid emigration was 32 days (Table 4).

Table 4. Juvenile salmonid collection counts and run timing (middle 80%) for the Rock Island Dam Juvenile Sampling Facility, 2016.

Number				Dates		
10%	50%	90%		10%	50%	90%
Chinook yearling						
3,347	15,673	27,264		23-Apr	1-May	10-May
Chinook subyearling						
6,616	10,348	14,133		9-Jun	28-Jun	23-Jul
Steelhead						
1,319	6,200	10,870		28-Apr	8-May	20-May
Sockeye						
4,181	20,705	34,760		21-Apr	3-May	10-May
Coho						
4,257	17,564	28,130		3-May	11-May	19-May
All target juveniles						
13,585	64,493	114,418		23-Apr	5-May	24-May

Run-of-River Fish Condition Evaluations

All juvenile salmonids that were collected at the Rock Island Dam Juvenile Sampling Facility (RIJSF) were routinely inspected for descale, injury and mortality. A total of 126,705 fish were examined for condition during the 2016 sampling season (Table 5). Proportions of descale, injury and mortality of target salmonids sampled at RIJSF are shown in Figures 4 & 5. The results from daily samples are reported in Appendix B.

Descale

Fish were examined for descaling on all live target salmon and steelhead during the 2016 sampling season, with the exception of salmonid fry due to their small size. A fish with more than 20% descale on one side was classified as descaled. Of the fish examined, the percent classified as descaled was 0.72% (n=911).

Injury

Injury is characterized as lacerations or bruises occurring to any part of the head or body. These types of injuries can lead to mortality. In 2016, the percent injury was 0.43% (n=542, all species).

Mortality

Mortalities collected during the sampling season were categorized as *facility*, *sample*, or *tagging* caused mortalities. A *facility* mortality is any fish recently dead or near death on arrival to the raceway which exhibit fresh descale or injury. A *sample* mortality is any fish killed as a result of the sampling activity. A *tagging* mortality is any fish that dies as a result of injury or stress during the PIT tagging process. In 2016, the total percent mortality was 0.71% (n=906) for all target species.

During the first day of operation on April 1, 2017, a higher than normal mortality rate of 52.74% (n=77) was observed. All of the mortalities observed were subyearling Chinook fry determined to be caused by increased velocities across the traveling screens due to a regulating gate set too far open. The regulating gate was adjusted accordingly, and a decrease in mortality was observed over the following days. The overall observed mortality for all species during the month of April 2017 was 1.19%, with the recorded mortality on April 1, 2017 accounting for 20.3% of that rate.

Table 5. Summary of Descale, Injury, and Mortality for All Species, 2016, RIJSF.

2016	Number Examined	Number OK	Number Descaled	Percent Descale	Number Injured	Percent Injured	Mortality			Percent Mortality
							Facility	Sample	Tagging	
Yearlings	30,042	29,773	119	**0.40%**	87	**0.29%**	53	8	0	**0.20%**
Subyearling	14,821	14,188	74	**0.50%**	104	**0.70%**	426	15	5	**3.01%**
Steelhead	12,080	11,930	99	**0.82%**	43	**0.36%**	8	0	0	**0.07%**
Coho	31,312	30,992	178	**0.57%**	83	**0.27%**	56	3	0	**0.19%**
Sockeye	38,450	37,455	441	**1.15%**	225	**0.59%**	287	41	2	**0.86%**
All Species	126,705	124,338	911	**0.72%**	542	**0.43%**	830	67	7	**0.71%**

PIT Tagging

A total of 19,511 juvenile salmonids were PIT tagged between 5 April and 13 August (Table 6). Tagging of yearling Chinook Salmon, Sockeye Salmon and steelhead occurred from 5 April to 14 June. Tagging of wild, hatchery, and unknown steelhead, as well as wild, hatchery, and unknown yearling Chinook Salmon, was performed by RTR/OSU, with funding from the USACE. This tagging was part of a USACE and OSU study to evaluate the impacts of avian predation on salmonid smolts from the mid-Columbia and Snake Rivers. Tags for the predation study were provided by USACE. Tagging of unknown Sockeye Salmon and unknown subyearling Chinook Salmon was performed by CCPUD personnel using origin criteria and PIT tags provided by the FPC. Tagging of subyearling Chinook Salmon occurred between 13 June and 13 August.

Table 6. Number of salmonids PIT tagged during the 2016 RIJSF monitoring season.

Yearling Chinook[1]				Unclipped Chinook Subyearling	Unclipped Sockeye	Steelhead[1]			
Hatchery	Wild	Unknown	Total			Hatchery	Wild	Unknown	Total
4,478	579	3	5,060	4,069	4,109	4,392	1,762	119	6,273

1 Fish were tagged by RTR/OSU

Mark and Tag Recaptures

All target salmonids and steelhead were visual and electronically examined for external and internal marks or tags.

PIT Tags

A total of 2,709 previously PIT tagged juvenile salmon and steelhead from upriver sources were detected at the RIJSF in 2016.

Incidental species

A total of 842 non-target fish representing multiple species were collected and enumerated(Table 7). Among the non-target species collected, there were 150 Pacific lamprey, 111 adult steelhead, 2 adult chinook and 35 adult sockeye. There were also 50 mini-jack chinook, 1 bull trout, 196 rainbow trout, 94 kokanee, 189 pikeminnow, and 8 whitefish. In addition, there were 6 fish that crews recorded as “others” but are not part of the SMP reporting protocol (FPC 2016). All non-target fish were either returned to the fish ladder or directly to the river.

Table 7. Incidental species collected at Rock Island Juvenile Sampling Facility, 2016

Juvenile and Adult Lamprey

Date	Juvenile Lamprey AP		Juvenile Lamprey AB		Juvenile Lamprey AS		Juvenile Lamprey MP		Adult Lamprey Pacific		Adult Lamprey W. Brook	
	Count	Mort.	Count	Mort.	Count	Mort.	Count	Mort.	Count	Mort.	Count	Mort.
April	4	0	0	0	0	0	78	4	0	0	0	0
May	0	0	0	0	0	0	1	0	3	0	0	0
June	0	0	0	0	0	0	5	0	1	0	0	0
July	2	0	0	0	0	0	19	0	1	0	0	0
August	1	0	0	0	0	0	2	0	33	0	0	0
Total	**7**	**0**	**0**	**0**	**0**	**0**	**105**	**4**	**38**	**0**	**0**	**0**

Table 7. Incidental species collected at Rock Island Juvenile Sampling Facility, 2016, (cont.)

Adult Salmonids, Adult Steelhead and Trout

Date	Adult Steelhead		Adult Chinook		Adult Sockeye		Adult Coho		Bull Trout		Rainbow Trout	
	Count	Mort.	Count	Mort.	Count	Mort.	Count	Mort.	Count	Mort.	Count	Mort.
April	9	0	0	0	1	0	0	0	1	0	62	0
May	4	0	1	0	0	0	0	0	0	0	109	1
June	0	0	0	0	3	0	0	0	0	0	17	0
July	0	0	0	0	27	6	0	0	0	0	5	0
August	0	0	1	0	4	2	0	0	0	0	3	1
Total	**13**	**0**	**2**	**0**	**35**	**8**	**0**	**0**	**1**	**0**	**196**	**2**

Other Incidental Species

Date	Mini-Jack		Kokanee		Pikeminnow		Sturgeon		Mountain Whitefish		Other	
	Count	Mort.	Count	Mort.	Count	Mort.	Count	Mort.	Count	Mort.	Count	Mort.
April	30	0	40	0	5	0	0	0	0	0	0	0
May	20	0	50	2	14	1	0	0	1	1	2	1
June	0	0	3	0	150	4	0	0	3	1	0	0
July	0	0	1	0	16	1	0	0	2	0	1	0
August	0	0	0	0	4	0	0	0	2	0	3	0
Total	**50**	**0**	**94**	**2**	**189**	**6**	**0**	**0**	**8**	**2**	**6**	**1**

Gas Bubble Trauma Monitoring

Unpaired fins and eyes were examined for signs of GBT from 12 April thru 19 July. Examinations were performed a total of 22 days (Appendix D). The sampling goal of 100 fish was reached on all of the 22 sample days (100%). Yearling Chinook Salmon and steelhead were sampled 12 days and 13 days respectively. Subyearling Chinook Salmon were sampled 10 days. A total of 2,200 juvenile salmonids and steelhead were examined for external signs of GBT (Table 8). A total of 13 fish showed signs of GBT (0.59%). A rank was assigned to fish examined for GBT based on the area percent of fins or eyes covered with bubbles (0 = no bubbles, 1 =1-5%, 2 = 6-25%, 3 = 26-50%, 4 = 50-100%). All 13 recorded signs of GBT were in the fins of examined juvenile salmon and steelhead. Of the 13 fish that showed signs of GBT, 12 were recorded with a rank of “1” and 1 was recorded with a rank of “2”.

Table 8. Number of juvenile salmon and steelhead examined for external signs of GBT, 2016.

Species	Number of Fish Examined	Fish with GBT		Area Affected with GBT			
				Fins		Eyes	
		N	%	*N*	%	*N*	%
Chinook yearling	717	*10*	1.39%	*10*	1.39%	*0*	0.00%
Steelhead	495	*2*	0.40%	*2*	0.40%	*0*	0.00%
Chinook subyearling	988	*1*	0.10%	*1*	0.10%	*0*	0.00%
Total	**2,200**	***13***	**0.59%**	***13***	**0.59%**	***0***	**0.00%**

River Flows

River flows were recorded daily from 1 April through 31 August (daily mean flows were calculated for the 24 hour period from 09:00 a.m. to 09:00 a.m.). Daily mean river flows ranged from a low on 28 August of 73.20 kcfs to a high on 22 April of 217.00 kcfs (Table 9). Spill for fish passage at Rock Island Dam began on 11 April and ran continuously through 12 August (Table 10). Powerhouse # 1 flows ranged from 2.40 kcfs on 10 August to 32.20 kcfs on 19 April. Powerhouse # 2 (PH-2) flows ranged from 60.50 kcfs on 26 August to 122.80 kcfs on 16 April. Daily mean total river flow for the sampling season was 131.25 kcfs.

Table 9. Rock Island Dam total river flow and powerhouse operations by month, 2016.

Mean Flow (kcfs)					
	April	**May**	**June**	**July**	**August**
Total River Flow (Range)	162.11 (77.20-217.00)	144.60 (91.40-175.70)	136.01 (89.80-155.50)	116.64 (89.90-144.80)	98.07 (73.20-115.70)

Powerhouse # 1 (Range) %	27.36 (9.10-32.20) 16.88%	25.44 (8.70-31.00) 17.59%	17.63 (7.20-26.20) 12.96%	9.99 (5.00-17.90) 8.56%	13.38 (2.40-26.70) 13.64%
Powerhouse # 2 (Range) %	108.36 (67.10-122.80) 66.84%	100.24 (66.30-118.50) 69.32%	90.61 (61.10-103.00) 66.62%	82.23 (62.10-100.00) 70.50%	75.56 (60.50-86.80) 77.05%
Spill (Range) %	25.06 (0.00-68.20) 15.46%	17.44 (11.30-27.00) 12.06%	26.27 (20.00-30.40) 19.32%	22.92 (20.70-29.30) 19.65%	8.02 (0.00-23.80) 8.17%

Fish Spill

Table 10. Rock Island Fish Spill Program Results, 2016.

Rock Island Spring Fish Spill

Species:	Juvenile steelhead, yearling Chinook, Sockeye (smolts)
Fish Spill target percentage:	10% of day average flow
Spill Start, Stop dates:	Start April 10, 0001 hours; Stop May 28, 2400 hours
End Spring Spill percentage:	15.59% (9.95% fish spill + 5.64% forced spill)
Number of spill days:	49 (1,176 hours)
Average daily plant discharge:	160,343 cfs (4/10-5/28)
Average daily total spill rate:	25,005 cfs
Average daily fish spill rate:	15,961 cfs
Hours forced spill > 10% fish spill:	511 of 1,176 total hours

Rock Island Summer Fish Spill

Target species:	Subyearling Chinook (smolts)
Spill Start, Stop dates:	Start May 29, 0001 hours; Stop August 11, 2400 hours
Total spill days:	75 (1,800 hours)
Spill target percentage:	20% of day average flow at RI
End season spill percentage**:**	19.90% (19.87% fish spill + 0.03% forced spill)
Average daily plant discharge:	120,671 cfs (5/29-8/11)
Average daily total spill rate:	24,012 cfs
Average daily fish spill rate:	23,977 cfs
Hours forced spill > 20% fish spill:	5 of 1,800 total hours

ACKNOWLEDGMENTS

The Rock Island Dam juvenile fish bypass monitoring program was funded by the Bonneville Power Administration, U.S. Department of Energy, as part of the Northwest Power Planning Council's Fish and Wildlife Program. We wish to thank Michele DeHart, Brandon Chockley, and Chris McCarty of the FPC, and Pacific States Marine Fisheries Commission who provided continued support for the Smolt Monitoring Program throughout the monitoring season. Chelan County PUD provided the facility, equipment and personnel to conduct the monitoring. We would also like to thank the following Chelan County PUD Natural Resource Division Fish and Wildlife personnel for their valuable work contributions to the Smolt Monitoring and PIT tagging programs at the Rock Island Dam Smolt Monitoring Facility: Todd West, Steve Hemstrom, Dave Beardsley, Todd Jackson, and Nathan Clark.

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Figure 1. Aerial View of Rock Island Dam

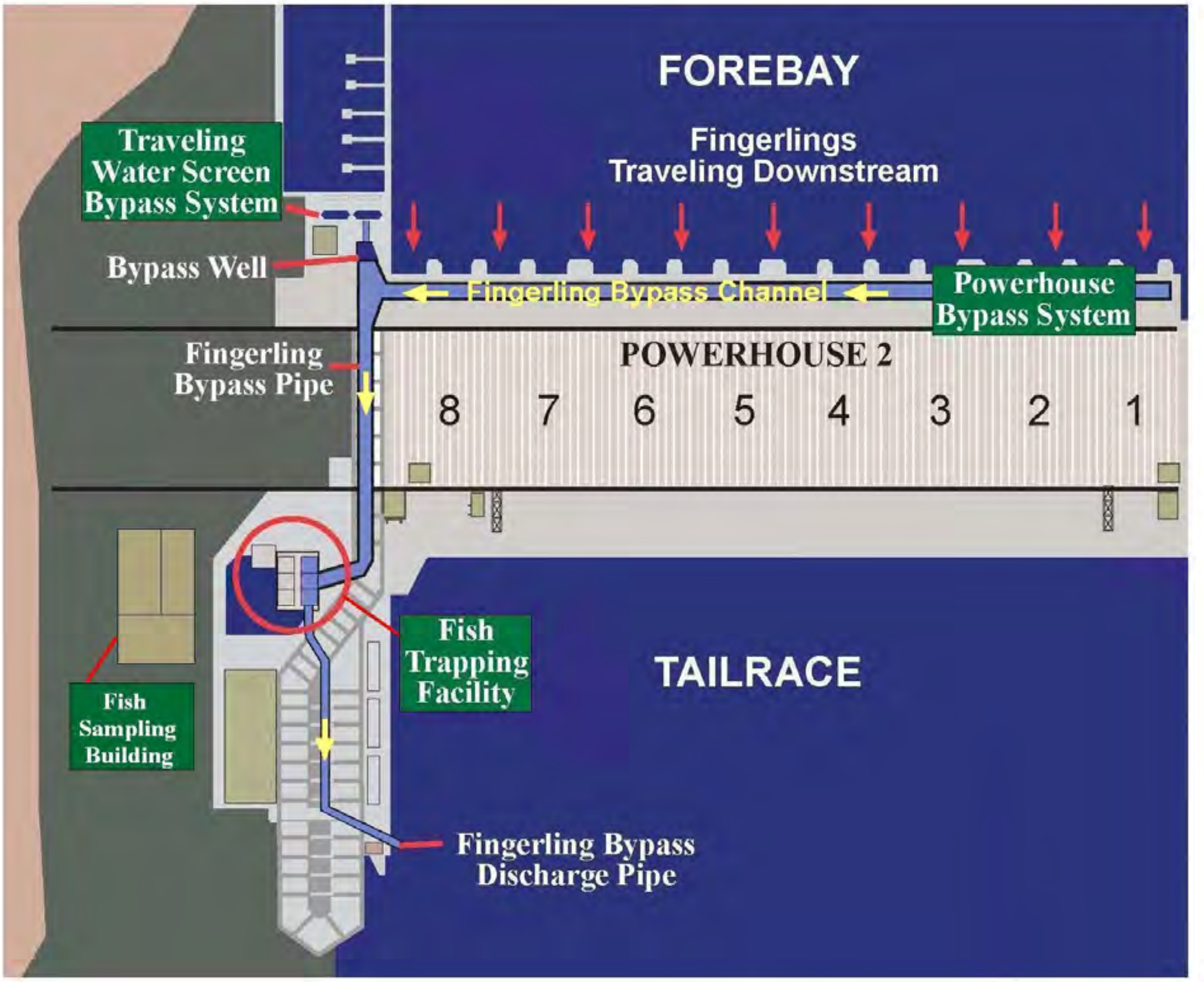

Figure 2. Plan view of Rock Island Dam Powerhouse # 2 Juvenile Bypass and Collection System

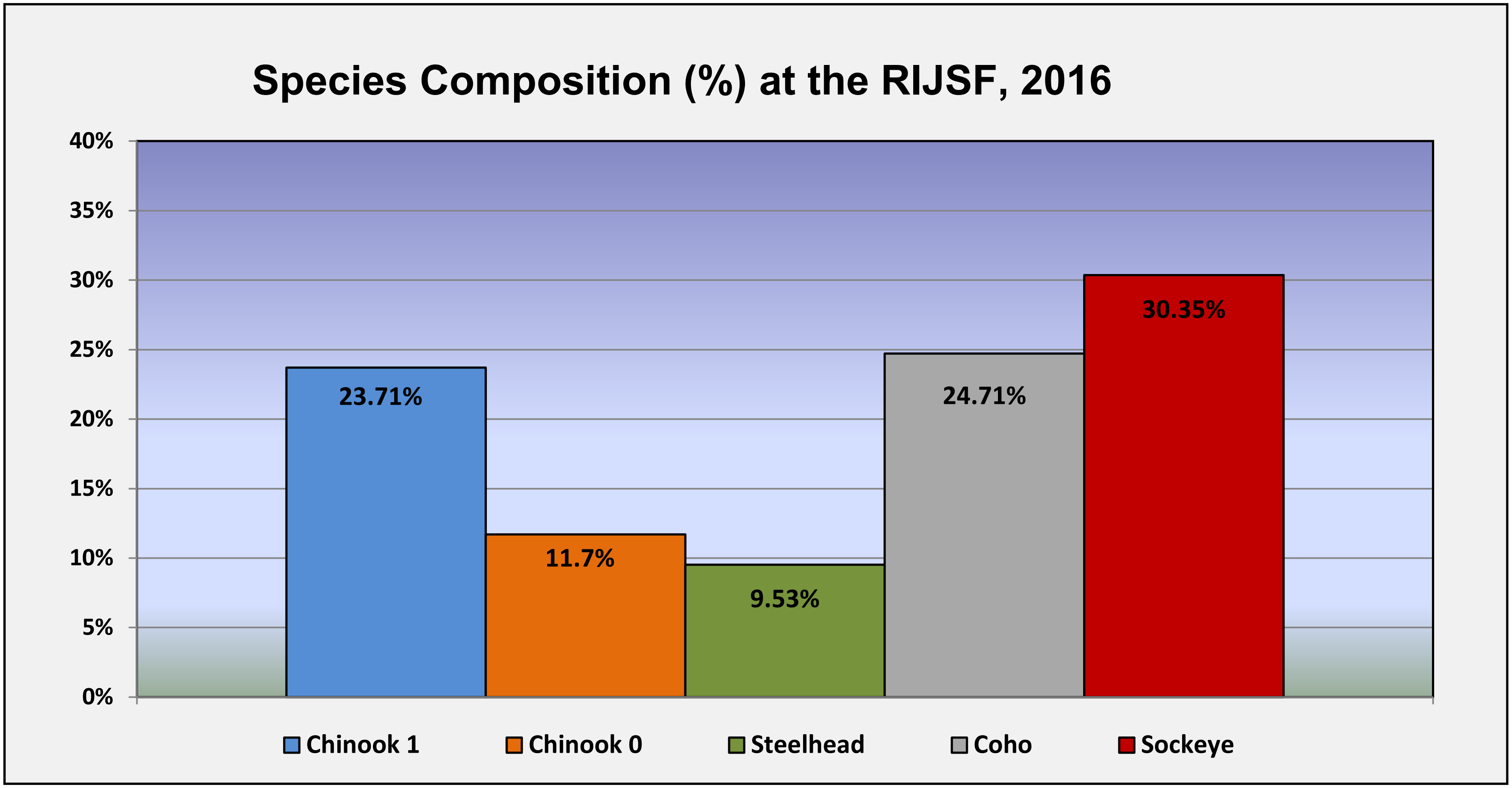

Figure 3. Annual species percent composition of fish collected at the RIJSF, 2016.

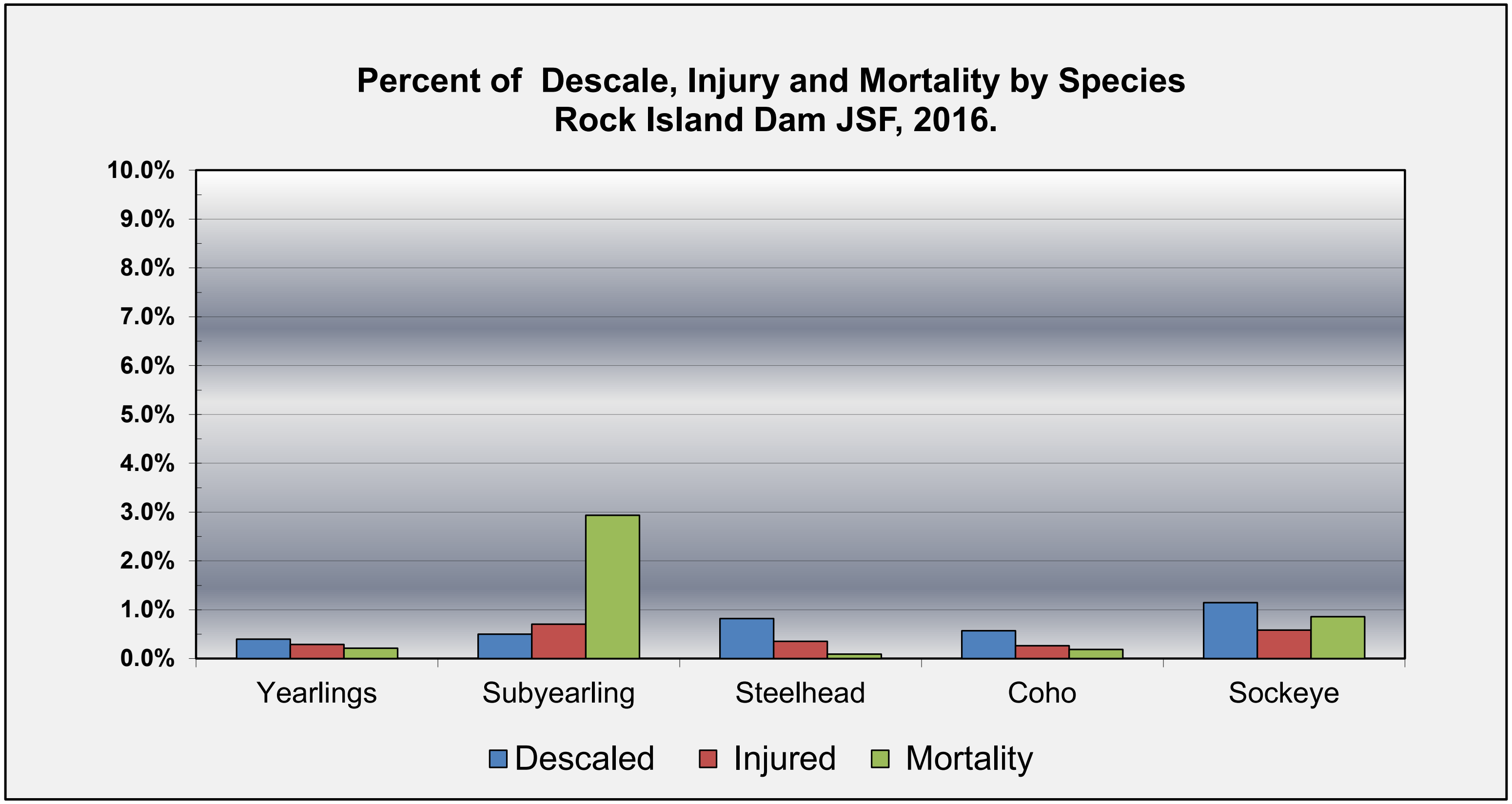

Figure 4. Percent of descale, injury and mortality by species of fish collected at the RIJSF, 2016.

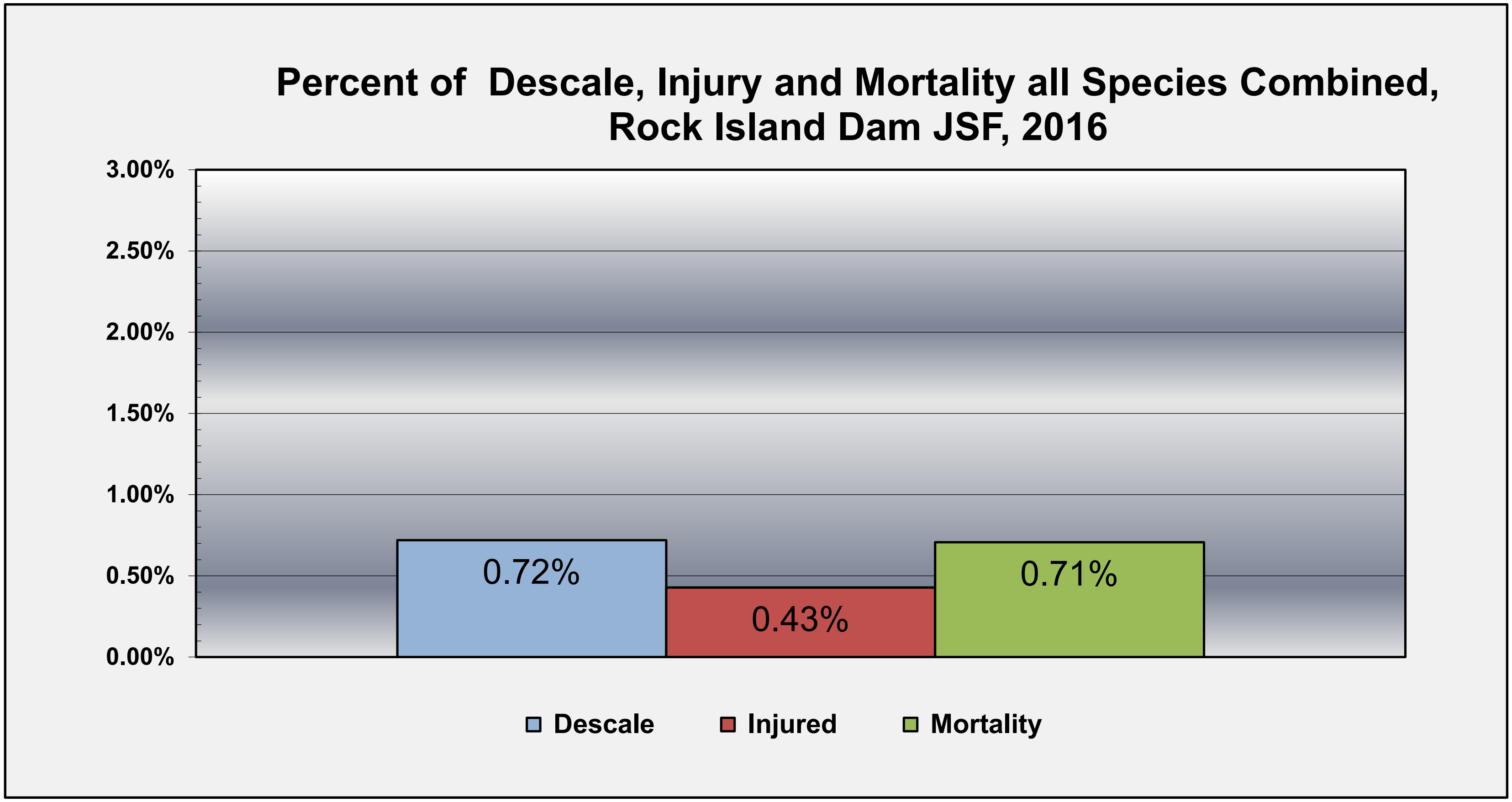

Figure 5. Percent of descale, injury and mortality for all Species of fish collected at the RIJSF, 2016.

Appendix A. Rock Island Dam Juvenile Sampling Facility daily Collection data, April Through August, 2016.

Numbers of Smolts Handled															
(U= unclipped, C= clipped, & EF U = eroded fin unclipped)															
Date	Chinook Yearlings		Chinook Sub-yearlings			Steelhead			Coho			Sockeye			Total
	U	C	U	C	Fry	U	EF U	C	U	C	Fry	U	C	Fry	
1-Apr	3	1	0	0	135	0	0	0	1	0	0	6	0	0	**146**
2-Apr	2	0	0	0	181	1	0	0	0	0	0	5	0	0	**189**
3-Apr	3	4	0	0	266	1	0	0	1	0	0	11	0	0	**286**
4-Apr	9	1	0	0	432	3	0	0	1	0	0	64	0	0	**510**
5-Apr	13	3	0	0	463	5	0	0	1	0	0	153	0	1	**639**
6-Apr	10	2	0	0	612	7	0	0	2	0	0	147	0	0	**780**
7-Apr	16	3	0	0	205	12	0	1	0	0	0	119	0	0	**356**
8-Apr	21	36	0	0	306	9	0	0	1	0	0	169	0	0	**542**
9-Apr	13	30	0	0	143	5	0	0	3	0	0	201	0	0	**395**
10-Apr	17	47	0	0	170	15	0	0	2	0	0	285	0	0	**536**
11-Apr	24	129	0	0	331	11	0	0	8	0	1	405	0	0	**909**
12-Apr	24	88	0	0	270	38	0	1	4	0	0	550	0	1	**976**
13-Apr	12	61	0	0	202	24	0	0	1	0	0	396	0	0	**696**
14-Apr	13	21	0	0	124	19	0	1	6	0	0	316	0	0	**500**
15-Apr	15	33	0	0	115	30	0	0	6	0	0	380	0	0	**579**
16-Apr	23	48	0	0	54	20	0	2	1	0	0	320	0	0	**468**
17-Apr	43	132	0	0	22	28	0	0	4	0	0	139	0	0	**368**
18-Apr	36	161	0	0	20	49	0	2	9	0	0	94	0	0	**371**
19-Apr	35	268	0	0	18	39	0	9	16	0	0	39	0	0	**424**
20-Apr	39	324	0	0	11	41	1	3	19	0	0	66	0	0	**504**
21-Apr	53	437	0	0	11	55	0	16	32	0	0	314	0	0	**918**
22-Apr	62	477	0	0	27	51	0	20	32	1	0	438	0	0	**1108**
23-Apr	47	508	0	0	50	62	7	27	56	0	0	628	0	0	**1385**
24-Apr	50	323	0	0	40	30	2	24	20	0	0	759	0	0	**1248**
25-Apr	51	377	0	0	164	51	5	42	66	0	0	245	0	0	**1001**
26-Apr	91	818	0	0	66	65	13	51	108	0	0	142	0	0	**1354**
27-Apr	103	836	0	0	20	73	12	59	71	0	0	219	1	0	**1394**
28-Apr	146	1433	0	0	9	116	15	146	99	0	0	1172	0	0	**3136**
29-Apr	194	2406	0	0	13	112	20	229	186	0	0	1180	0	0	**4340**
30-Apr	211	2658	0	0	7	118	19	348	396	1	0	2144	0	0	**5902**
Apr Total	**1379**	**11665**	**0**	**0**	**4487**	**1090**	**94**	**981**	**1152**	**2**	**1**	**11106**	**1**	**2**	**31960**
1-May	228	2401	0	0	2	130	44	379	652	0	0	2262	0	0	**6098**
2-May	237	2058	0	0	10	117	33	391	921	4	0	2943	0	0	**6714**
3-May	220	2034	1	1	15	133	49	327	1523	2	0	4391	0	0	**8696**
4-May	197	1836	0	0	13	157	12	236	1531	0	0	2205	0	0	**6187**
5-May	145	1357	2	1	4	121	33	234	1314	0	0	1627	0	0	**4838**
6-May	98	600	1	4	45	111	25	191	1118	0	0	2184	0	0	**4377**
7-May	126	789	7	7	24	148	35	394	1475	1	0	3204	0	0	**6210**
8-May	143	591	4	3	45	157	32	546	1553	2	1	1819	1	0	**4897**
9-May	133	541	6	2	62	113	48	561	1708	5	0	1226	0	0	**4405**
10-May	99	387	1	3	45	122	45	455	1801	3	0	1789	0	0	**4750**
11-May	117	447	2	4	28	157	61	402	2784	11	0	1167	0	0	**5180**
12-May	152	471	2	1	21	135	48	441	2246	23	0	905	0	0	**4445**
13-May	93	363	8	0	11	143	31	306	2210	5	0	487	0	0	**3657**
14-May	62	214	4	1	7	122	41	327	1947	10	0	440	0	0	**3175**
15-May	29	167	3	1	6	113	24	208	1239	10	0	146	0	0	**1946**

16-May	27	105	4	0	6	91	22	137	1099	5	0	91	0	0	**1587**
17-May	22	75	3	0	16	56	17	80	502	7	0	55	0	0	**833**
18-May	9	45	7	1	11	42	17	87	746	11	0	81	0	0	**1057**
19-May	10	20	5	0	10	30	18	70	503	3	0	48	0	0	**717**
20-May	2	16	1	4	6	47	12	41	287	3	0	20	0	0	**439**
21-May	8	14	2	3	5	37	23	60	467	0	0	40	0	0	**659**
22-May	6	16	9	8	7	42	21	65	433	3	0	38	0	0	**648**
23-May	5	31	5	5	9	50	13	39	306	2	0	23	0	0	**488**
24-May	3	34	12	5	10	46	11	38	268	5	0	23	0	0	**455**
25-May	6	31	8	22	14	40	19	43	286	3	0	14	0	0	**486**
26-May	8	35	12	15	28	34	6	27	270	3	0	13	0	0	**451**
27-May	4	22	20	15	35	34	1	23	158	2	0	14	0	0	**328**
28-May	5	35	23	18	36	21	10	26	163	0	0	8	0	0	**345**
29-May	0	28	47	79	34	59	2	28	159	0	0	13	0	0	**449**
30-May	0	15	27	35	73	16	0	21	61	0	0	0	0	0	**248**
31-May	0	4	16	9	24	9	0	3	12	0	0	3	0	0	**80**
May Total	**2194**	**14,782**	**242**	**247**	**662**	**2633**	**753**	**6186**	**29,742**	**123**	**1**	**27279**	**1**	**0**	**84,845**
1-Jun	0	3	3	11	7	10	4	5	9	0	0	5	0	0	**57**
2-Jun	0	7	9	5	11	19	0	2	25	0	0	4	0	0	**82**
3-Jun	0	3	19	11	16	20	1	11	45	0	0	4	0	0	**130**
4-Jun	0	1	21	17	9	11	2	6	36	0	0	0	0	0	**103**
5-Jun	0	0	43	23	32	11	1	8	47	0	0	8	0	0	**173**
6-Jun	0	0	59	19	80	8	0	3	17	0	0	4	0	0	**190**
7-Jun	1	0	91	11	112	8	1	3	11	1	0	0	0	0	**239**
8-Jun	0	1	90	3	61	7	1	4	21	0	0	0	0	0	**188**
9-Jun	0	1	115	14	86	18	0	0	32	0	0	0	0	0	**266**
10-Jun	0	0	150	9	94	9	2	1	6	0	0	1	0	0	**272**
11-Jun	0	1	135	8	43	13	0	1	4	0	0	0	0	0	**205**
12-Jun	0	0	194	6	67	4	2	2	4	0	0	1	0	0	**280**
13-Jun	0	0	178	0	79	7	1	0	2	0	0	0	0	0	**267**
14-Jun	0	0	199	4	81	2	4	0	3	0	0	1	0	0	**294**
15-Jun	0	0	157	7	84	5	2	0	2	0	0	0	0	0	**257**
16-Jun	0	2	161	1	65	9	3	0	2	0	0	0	0	0	**243**
17-Jun	0	0	83	1	18	5	3	1	1	0	0	1	0	0	**113**
18-Jun	0	0	98	5	15	1	0	0	2	0	0	0	0	0	**121**
19-Jun	0	0	38	0	8	3	0	0	0	0	0	0	0	0	**49**
20-Jun	0	0	99	1	14	1	3	0	2	0	0	0	0	0	**120**
21-Jun	0	0	183	5	21	3	3	0	2	0	0	0	0	0	**217**
22-Jun	0	1	211	1	25	1	3	0	0	0	0	0	0	0	**242**
23-Jun	0	0	198	0	10	1	2	0	0	0	0	0	0	0	**211**
24-Jun	0	0	169	0	18	3	3	0	1	0	0	1	0	0	**195**
25-Jun	0	0	182	4	3	7	4	0	1	0	0	0	0	0	**201**
26-Jun	0	0	206	3	7	7	1	1	1	0	0	1	0	0	**227**
27-Jun	0	0	167	2	6	0	3	2	0	0	0	0	1	0	**181**
28-Jun	0	0	197	1	11	0	2	3	1	0	0	0	0	0	**215**
29-Jun	0	0	147	0	14	0	0	0	0	0	0	1	0	0	**162**
30-Jun	0	0	156	0	8	0	1	0	1	0	0	0	0	0	**166**
Jun Total	**1**	**20**	**3758**	**172**	**1105**	**193**	**52**	**53**	**278**	**1**	**0**	**32**	**1**	**0**	**5,666**
1-Jul	0	0	290	0	10	4	5	1	4	0	0	1	0	0	**315**
2-Jul	0	0	309	0	19	5	0	0	0	0	0	0	0	0	**333**
3-Jul	0	0	228	0	11	1	0	1	2	0	0	1	0	0	**244**

Appendix A. Rock Island Dam Juvenile Sampling Facility daily Collection data, April Through August, 2016.

4-Jul	0	0	241	0	2	2	1	0	2	0	0	1	0	0	**249**
5-Jul	0	0	187	1	3	1	0	0	0	0	0	3	0	0	**195**
6-Jul	0	0	183	0	6	1	1	1	1	0	0	0	0	0	**193**
7-Jul	0	0	190	0	3	1	2	0	0	0	0	2	0	0	**198**
8-Jul	0	0	181	0	1	0	0	0	0	0	0	1	0	0	**183**
9-Jul	0	0	126	1	0	0	0	0	0	0	1	0	0	0	**128**
10-Jul	0	0	98	0	1	2	0	1	0	0	0	1	0	0	**103**
11-Jul	0	0	84	1	0	4	0	1	0	0	0	0	0	0	**90**
12-Jul	0	0	74	0	1	0	0	1	0	0	0	0	0	0	**76**
13-Jul	0	0	77	0	1	0	0	0	0	0	0	2	0	0	**80**
14-Jul	0	0	67	0	2	0	1	0	0	0	0	0	0	0	**70**
15-Jul	0	0	63	0	1	0	1	0	0	0	0	0	0	0	**65**
16-Jul	0	0	66	0	3	0	1	0	0	0	0	0	0	0	**70**
17-Jul	0	0	68	0	2	0	0	0	1	0	0	0	0	0	**71**
18-Jul	0	0	52	0	1	0	0	0	0	0	0	0	0	0	**53**
19-Jul	0	0	272	0	1	2	0	0	1	0	0	3	0	0	**279**
20-Jul	0	0	118	0	1	1	0	0	0	0	0	0	0	0	**120**
21-Jul	0	0	85	0	2	0	0	0	0	0	0	3	0	0	**90**
22-Jul	0	0	63	0	2	0	0	0	0	0	0	1	0	1	**67**
23-Jul	0	0	261	1	0	0	0	0	0	0	0	1	0	0	**263**
24-Jul	0	0	87	0	0	0	0	0	0	0	0	0	0	0	**87**
25-Jul	0	0	69	0	0	0	0	0	0	0	0	0	0	0	**69**
26-Jul	0	0	68	0	0	0	0	0	0	0	0	0	0	0	**68**
27-Jul	0	0	40	0	1	0	1	0	0	0	0	0	0	0	**42**
28-Jul	0	0	58	0	0	0	0	0	0	0	0	1	0	0	**59**
29-Jul	0	0	65	0	0	0	0	0	0	0	0	0	0	0	**65**
30-Jul	0	0	28	0	0	0	0	0	0	0	0	0	0	0	**28**
31-Jul	0	0	29	0	1	0	0	0	0	0	0	0	0	0	**30**
Jul Total	**0**	**0**	**3827**	**4**	**75**	**24**	**13**	**6**	**11**	**0**	**1**	**21**	**0**	**1**	**3983**
1-Aug	0	0	36	0	1	0	0	0	0	0	0	0	0	0	**37**
2-Aug	0	0	34	0	0	0	0	0	0	0	0	2	0	0	**36**
3-Aug	0	0	22	0	0	0	0	0	0	0	0	0	0	0	**22**
4-Aug	0	0	26	0	0	0	0	0	0	0	0	0	0	0	**26**
5-Aug	0	0	11	0	0	0	0	0	0	0	0	0	0	0	**11**
6-Aug	0	0	12	0	0	0	0	0	0	0	0	0	0	0	**12**
7-Aug	0	0	7	0	0	0	0	0	0	0	0	1	0	0	**8**
8-Aug	0	0	8	0	0	0	0	0	0	0	0	0	0	0	**8**
9-Aug	0	0	7	0	0	0	0	0	0	0	0	0	0	0	**7**
10-Aug	0	0	4	0	0	0	0	0	0	0	0	0	0	0	**4**
11-Aug	0	0	3	0	0	0	0	0	0	0	0	0	0	0	**3**
12-Aug	0	0	7	0	0	0	0	0	0	0	0	0	0	0	**7**
13-Aug	0	1	6	0	0	0	0	0	0	0	0	0	0	0	**7**
14-Aug	0	0	3	0	0	0	0	0	0	0	0	1	0	0	**4**
15-Aug	0	0	3	0	0	0	0	0	0	0	0	0	0	0	**3**
16-Aug	0	0	9	0	0	1	0	0	0	0	0	0	0	0	**10**
17-Aug	0	0	3	0	0	0	0	0	0	0	0	0	0	0	**3**
18-Aug	0	0	6	0	0	0	0	0	0	0	0	0	0	0	**6**
19-Aug	0	0	6	0	0	0	0	0	0	0	0	1	0	0	**7**
20-Aug	0	0	8	0	0	0	0	0	0	0	0	0	0	0	**8**
21-Aug	0	0	3	0	0	0	0	0	0	0	0	0	0	0	**3**
22-Aug	0	0	1	0	0	0	0	0	0	0	0	0	0	0	**1**

Appendix A. Rock Island Dam Juvenile Sampling Facility daily Collection data, April Through August, 2016.

	Chinook 1 U	Chinook 1 C	Chinook 0 U	Chinook 0 C	Chinook 0 Fry	Steelhead U	Steelhead EF U	Steelhead C	Coho U	Coho C	Coho Fry	Sockeye U	Sockeye C	Sockeye Fry	Total
23-Aug	0	0	5	0	0	0	0	0	0	0	0	0	0	0	**5**
24-Aug	0	0	3	0	0	0	0	0	0	0	0	0	0	0	**3**
25-Aug	0	0	1	0	0	0	0	0	0	0	0	0	0	0	**1**
26-Aug	0	0	0	0	0	0	0	0	0	0	0	1	0	0	**1**
27-Aug	0	0	1	0	0	0	0	0	0	0	0	0	0	0	**1**
28-Aug	0	0	1	0	0	1	0	0	0	0	0	0	0	0	**2**
29-Aug	0	0	2	0	0	0	0	0	0	0	0	0	0	0	**2**
30-Aug	0	0	1	0	0	0	0	0	0	0	0	0	0	0	**1**
31-Aug	0	0	2	0	0	0	0	0	0	0	0	0	0	0	**2**
Aug Total	**0**	**1**	**241**	**0**	**1**	**2**	**0**	**0**	**0**	**0**	**0**	**6**	**0**	**0**	**251**

	Chinook 1		Chinook 0			Steelhead			Coho			Sockeye			
	U	**C**	**U**	**C**	**Fry**	**U**	**EF U**	**C**	**U**	**C**	**Fry**	**U**	**C**	**Fry**	**Season Grand Total**
Season Totals	**3574**	**26,468**	**8068**	**423**	**6330**	**3942**	**912**	**7226**	**31,183**	**126**	**3**	**38444**	**3**	**3**	
	11.9%	**88.1%**	**54.4%**	**2.9%**	**42.7%**	**32.6%**	**7.5%**	**59.8%**	**99.6%**	**0.4%**	**0.0%**	**100.0%**	**0.0%**	**0.0%**	
	30,042		**14,821**			**12,080**			**31,312**			**38,450**			**126,705**

Appendix B. Sampling data for observation of descale, injury, and mortality for all species. April to August, 2016.

All Species								
Date	Number Examined	Number OK	Number Descaled	Percent Descale	Number Injured	Percent Injured	Mortality	Percent Mortality
1-Apr	146	67	0	0.00%	2	1.37%	77	52.74%
2-Apr	189	174	0	0.00%	1	0.53%	14	7.41%
3-Apr	286	274	0	0.00%	2	0.70%	10	3.50%
4-Apr	510	492	0	0.00%	2	0.39%	16	3.14%
5-Apr	639	613	1	0.16%	13	2.03%	12	1.88%
6-Apr	780	753	0	0.00%	13	1.67%	14	1.79%
7-Apr	356	340	0	0.00%	1	0.28%	15	4.21%
8-Apr	542	503	0	0.00%	9	1.66%	30	5.54%
9-Apr	395	386	1	0.25%	4	1.01%	4	1.01%
10-Apr	536	524	3	0.56%	4	0.75%	5	0.93%
11-Apr	909	864	4	0.44%	7	0.77%	34	3.74%
12-Apr	976	937	4	0.41%	12	1.23%	23	2.36%
13-Apr	696	682	3	0.43%	3	0.43%	8	1.15%
14-Apr	500	488	0	0.00%	1	0.20%	11	2.20%
15-Apr	579	554	7	1.21%	4	0.69%	14	2.42%
16-Apr	468	455	3	0.64%	3	0.64%	7	1.50%
17-Apr	368	359	5	1.36%	3	0.82%	1	0.27%
18-Apr	371	364	4	1.08%	2	0.54%	1	0.27%
19-Apr	424	419	2	0.47%	0	0.00%	3	0.71%
20-Apr	504	497	2	0.40%	1	0.20%	4	0.79%
21-Apr	918	912	1	0.11%	2	0.22%	4	0.44%
22-Apr	1108	1090	12	1.08%	2	0.18%	4	0.36%
23-Apr	1385	1361	4	0.29%	7	0.51%	13	0.94%
24-Apr	1248	1225	13	1.04%	3	0.24%	7	0.56%
25-Apr	1001	992	4	0.40%	3	0.30%	3	0.30%
26-Apr	1354	1331	5	0.37%	13	0.96%	5	0.37%
27-Apr	1394	1372	7	0.50%	5	0.36%	10	0.72%
28-Apr	3136	3095	29	0.92%	6	0.19%	6	0.19%
29-Apr	4340	4271	36	0.83%	21	0.48%	12	0.28%
30-Apr	5902	5849	30	0.51%	11	0.19%	12	0.20%
Apr Total	**31960**	**31243**	**180**	**0.56%**	**160**	**0.50%**	**379**	**1.19%**
1-May	6098	6045	22	0.36%	5	0.08%	26	0.43%
2-May	6714	6570	75	1.12%	27	0.40%	32	0.48%
3-May	8696	8577	73	0.84%	23	0.26%	23	0.26%
4-May	6187	6101	40	0.65%	15	0.24%	31	0.50%
5-May	4838	4756	41	0.85%	22	0.45%	19	0.39%
6-May	4377	4333	21	0.48%	16	0.37%	7	0.16%
7-May	6210	6110	38	0.61%	15	0.24%	47	0.76%
8-May	4897	4823	28	0.57%	20	0.41%	26	0.53%
9-May	4405	4304	51	1.16%	21	0.48%	29	0.66%
10-May	4750	4666	38	0.80%	19	0.40%	27	0.57%
11-May	5180	5094	35	0.68%	25	0.48%	26	0.50%

12-May	4445	4352	45	1.01%	25	0.56%	23	0.52%
13-May	3657	3600	31	0.85%	15	0.41%	11	0.30%
14-May	3175	3138	21	0.66%	8	0.25%	8	0.25%
15-May	1946	1919	13	0.67%	8	0.41%	6	0.31%
16-May	1587	1569	4	0.25%	9	0.57%	5	0.32%
17-May	833	818	9	1.08%	3	0.36%	3	0.36%
18-May	1057	1034	12	1.14%	9	0.85%	2	0.19%
19-May	717	708	4	0.56%	3	0.42%	2	0.28%
20-May	439	435	3	0.68%	1	0.23%	0	0.00%
21-May	659	649	4	0.61%	3	0.46%	3	0.46%
22-May	648	638	0	0.00%	7	1.08%	3	0.46%
23-May	488	477	6	1.23%	5	1.02%	0	0.00%
24-May	455	441	4	0.88%	1	0.22%	9	1.98%
25-May	486	476	3	0.62%	4	0.82%	3	0.62%
26-May	451	436	5	1.11%	4	0.89%	6	1.33%
27-May	328	321	0	0.00%	1	0.30%	6	1.83%
28-May	345	340	0	0.00%	0	0.00%	5	1.45%
29-May	449	439	7	1.56%	0	0.00%	3	0.67%
30-May	248	240	0	0.00%	3	1.21%	5	2.02%
31-May	80	75	2	2.50%	1	1.25%	2	2.50%
May Total	**84845**	**83484**	**635**	**0.75%**	**318**	**0.37%**	**398**	**0.47%**
1-Jun	57	57	0	0.00%	0	0.00%	0	0.00%
2-Jun	82	81	1	1.22%	0	0.00%	0	0.00%
3-Jun	130	124	1	0.77%	0	0.00%	5	3.85%
4-Jun	103	98	3	2.91%	0	0.00%	2	1.94%
5-Jun	173	166	3	1.73%	2	1.16%	2	1.16%
6-Jun	190	183	3	1.58%	1	0.53%	3	1.58%
7-Jun	239	234	1	0.42%	4	1.67%	0	0.00%
8-Jun	188	181	1	0.53%	2	1.06%	4	2.13%
9-Jun	266	258	1	0.38%	1	0.38%	6	2.26%
10-Jun	272	270	1	0.37%	0	0.00%	1	0.37%
11-Jun	205	201	0	0.00%	1	0.49%	3	1.46%
12-Jun	280	273	0	0.00%	2	0.71%	5	1.79%
13-Jun	267	264	2	0.75%	0	0.00%	1	0.37%
14-Jun	294	288	2	0.68%	3	1.02%	1	0.34%
15-Jun	257	254	0	0.00%	0	0.00%	3	1.17%
16-Jun	243	240	0	0.00%	2	0.82%	1	0.41%
17-Jun	113	109	1	0.88%	0	0.00%	3	2.65%
18-Jun	121	117	0	0.00%	2	1.65%	2	1.65%
19-Jun	49	48	0	0.00%	0	0.00%	1	2.04%
20-Jun	120	119	0	0.00%	0	0.00%	1	0.83%
21-Jun	217	212	0	0.00%	0	0.00%	5	2.30%
22-Jun	242	232	2	0.83%	2	0.83%	6	2.48%
23-Jun	211	207	0	0.00%	1	0.47%	3	1.42%
24-Jun	195	190	1	0.51%	3	1.54%	1	0.51%
25-Jun	201	196	2	1.00%	0	0.00%	3	1.49%
26-Jun	227	220	2	0.88%	2	0.88%	3	1.32%
27-Jun	181	176	2	1.10%	1	0.55%	2	1.10%

28-Jun	215	212	1	0.47%	0	0.00%	2	0.93%
29-Jun	162	158	0	0.00%	2	1.23%	2	1.23%
30-Jun	166	161	2	1.20%	2	1.20%	1	0.60%
Jun Total	**5666**	**5529**	**32**	**0.56%**	**33**	**0.58%**	**72**	**1.27%**
1-Jul	315	299	2	0.63%	5	1.59%	9	2.86%
2-Jul	333	322	4	1.20%	1	0.30%	6	1.80%
3-Jul	244	240	2	0.82%	2	0.82%	0	0.00%
4-Jul	249	241	2	0.80%	1	0.40%	5	2.01%
5-Jul	195	190	2	1.03%	1	0.51%	2	1.03%
6-Jul	193	187	2	1.04%	0	0.00%	4	2.07%
7-Jul	198	197	1	0.51%	0	0.00%	0	0.00%
8-Jul	183	181	1	0.55%	0	0.00%	1	0.55%
9-Jul	128	125	1	0.78%	2	1.56%	0	0.00%
10-Jul	103	95	2	1.94%	4	3.88%	2	1.94%
11-Jul	90	88	0	0.00%	1	1.11%	1	1.11%
12-Jul	76	74	0	0.00%	0	0.00%	2	2.63%
13-Jul	80	76	1	1.25%	1	1.25%	2	2.50%
14-Jul	70	69	0	0.00%	0	0.00%	1	1.43%
15-Jul	65	63	1	1.54%	0	0.00%	1	1.54%
16-Jul	70	70	0	0.00%	0	0.00%	0	0.00%
17-Jul	71	68	2	2.82%	1	1.41%	0	0.00%
18-Jul	53	50	2	3.77%	1	1.89%	0	0.00%
19-Jul	279	267	4	1.43%	1	0.36%	7	2.51%
20-Jul	120	108	9	7.50%	2	1.67%	1	0.83%
21-Jul	90	89	0	0.00%	1	1.11%	0	0.00%
22-Jul	67	65	1	1.49%	0	0.00%	1	1.49%
23-Jul	263	257	4	1.52%	1	0.38%	1	0.38%
24-Jul	87	82	3	3.45%	2	2.30%	0	0.00%
25-Jul	69	67	2	2.90%	0	0.00%	0	0.00%
26-Jul	68	65	3	4.41%	0	0.00%	0	0.00%
27-Jul	42	39	1	2.38%	0	0.00%	2	4.76%
28-Jul	59	57	2	3.39%	0	0.00%	0	0.00%
29-Jul	65	62	2	3.08%	1	1.54%	0	0.00%
30-Jul	28	24	1	3.57%	0	0.00%	3	10.71%
31-Jul	30	29	0	0.00%	0	0.00%	1	3.33%
Jul Total	**3983**	**3846**	**57**	**1.43%**	**28**	**0.70%**	**52**	**1.31%**
1-Aug	37	37	0	0.00%	0	0.00%	0	0.00%
2-Aug	36	30	3	8.33%	2	5.56%	1	2.78%
3-Aug	22	21	1	4.55%	0	0.00%	0	0.00%
4-Aug	26	23	0	0.00%	0	0.00%	3	11.54%
5-Aug	11	10	1	9.09%	0	0.00%	0	0.00%
6-Aug	12	12	0	0.00%	0	0.00%	0	0.00%
7-Aug	8	8	0	0.00%	0	0.00%	0	0.00%
8-Aug	8	7	1	12.50%	0	0.00%	0	0.00%
9-Aug	7	6	0	0.00%	1	14.29%	0	0.00%
10-Aug	4	4	0	0.00%	0	0.00%	0	0.00%
11-Aug	3	3	0	0.00%	0	0.00%	0	0.00%
12-Aug	7	7	0	0.00%	0	0.00%	0	0.00%

13-Aug	7	7	0	0.00%	0	0.00%	0	0.00%
14-Aug	4	3	1	25.00%	0	0.00%	0	0.00%
15-Aug	3	3	0	0.00%	0	0.00%	0	0.00%
16-Aug	10	10	0	0.00%	0	0.00%	0	0.00%
17-Aug	3	3	0	0.00%	0	0.00%	0	0.00%
18-Aug	6	6	0	0.00%	0	0.00%	0	0.00%
19-Aug	7	6	0	0.00%	0	0.00%	1	14.29%
20-Aug	8	8	0	0.00%	0	0.00%	0	0.00%
21-Aug	3	3	0	0.00%	0	0.00%	0	0.00%
22-Aug	1	1	0	0.00%	0	0.00%	0	0.00%
23-Aug	5	5	0	0.00%	0	0.00%	0	0.00%
24-Aug	3	3	0	0.00%	0	0.00%	0	0.00%
25-Aug	1	1	0	0.00%	0	0.00%	0	0.00%
26-Aug	1	1	0	0.00%	0	0.00%	0	0.00%
27-Aug	1	1	0	0.00%	0	0.00%	0	0.00%
28-Aug	2	2	0	0.00%	0	0.00%	0	0.00%
29-Aug	2	2	0	0.00%	0	0.00%	0	0.00%
30-Aug	1	1	0	0.00%	0	0.00%	0	0.00%
31-Aug	2	2	0	0.00%	0	0.00%	0	0.00%
Aug Total	**251**	**236**	**7**	**2.79%**	**3**	**1.20%**	**5**	**1.99%**
Totals	**126,705**	**124,338**	**911**	**0.72%**	**542**	**0.43%**	**906**	**0.72%**

Appendix C. Rock Island Dam daily mean for total river flow, powerhouse and spill.
April through August, 2016

Date	Total	PH-1	PH-2	Spill	PH-2 %
1-Apr	90.10	13.20	75.90	0.00	84.24%
2-Apr	118.80	26.00	91.80	0.00	77.27%
3-Apr	77.20	9.10	67.10	0.00	86.92%
4-Apr	122.60	23.70	97.90	0.10	79.85%
5-Apr	134.10	30.10	102.70	0.30	76.58%
6-Apr	145.80	30.60	113.50	0.70	77.85%
7-Apr	141.50	30.10	110.30	0.10	77.95%
8-Apr	109.00	19.60	88.30	0.10	81.01%
9-Apr	111.80	20.50	90.20	0.00	80.68%
10-Apr	121.80	23.70	91.50	5.40	75.12%
11-Apr	145.40	28.70	100.10	15.10	68.84%
12-Apr	158.30	29.00	108.50	19.40	68.54%
13-Apr	159.80	29.00	108.80	20.50	68.09%
14-Apr	184.00	30.40	122.70	29.50	66.68%
15-Apr	187.60	30.90	118.40	36.70	63.11%
16-Apr	195.90	29.40	122.80	42.10	62.69%
17-Apr	198.30	32.20	121.50	43.10	61.27%
18-Apr	209.70	32.10	119.40	56.60	56.94%
19-Apr	188.90	32.20	119.90	35.30	63.47%
20-Apr	193.50	31.30	120.40	40.30	62.22%
21-Apr	173.50	27.90	117.70	26.40	67.84%
22-Apr	217.00	28.10	119.20	68.20	54.93%
23-Apr	201.40	29.20	114.40	56.20	56.80%
24-Apr	192.00	30.40	115.70	44.40	60.26%
25-Apr	191.30	28.90	110.50	50.50	57.76%
26-Apr	183.10	24.90	117.90	38.80	64.39%
27-Apr	182.30	27.40	114.70	38.70	62.92%
28-Apr	186.90	31.10	117.90	36.40	63.08%
29-Apr	181.50	30.80	118.30	30.90	65.18%
30-Apr	160.20	30.20	112.70	15.90	70.35%
April Mean	**162.11**	**27.36**	**108.36**	**25.06**	**66.84%**
1-May	145.00	28.50	99.20	15.80	68.41%
2-May	167.30	30.50	115.40	19.80	68.98%
3-May	167.40	30.30	113.20	22.50	67.62%
4-May	158.20	29.40	107.80	19.50	68.14%
5-May	156.10	28.60	104.90	21.20	67.20%
6-May	173.30	30.50	114.30	27.00	65.95%
7-May	164.90	30.30	112.80	20.30	68.41%
8-May	150.60	29.10	104.20	15.80	69.19%
9-May	146.60	28.50	99.70	16.90	68.01%
10-May	153.50	29.00	103.50	19.50	67.43%
11-May	175.70	31.00	118.50	24.80	67.44%
12-May	166.10	30.10	112.20	22.40	67.55%
13-May	170.90	30.50	115.70	23.10	67.70%

Appendix C. Rock Island Dam daily mean for total river flow, powerhouse and spill.
April through August, 2016

14-May	158.80	29.70	108.70	18.90	68.45%
15-May	141.30	26.30	99.10	14.50	70.13%
16-May	139.70	24.10	98.90	15.20	70.79%
17-May	145.40	28.50	99.90	15.60	68.71%
18-May	152.90	29.20	105.50	16.70	69.00%
19-May	124.40	23.10	86.70	13.20	69.69%
20-May	117.90	13.10	90.40	12.90	76.68%
21-May	123.60	21.20	89.20	11.70	72.17%
22-May	91.40	12.20	66.30	11.50	72.54%
23-May	102.80	8.70	81.40	11.30	79.18%
24-May	145.40	28.30	101.40	14.20	69.74%
25-May	146.00	28.30	102.80	13.40	70.41%
26-May	136.40	24.80	97.40	12.60	71.41%
27-May	132.80	26.20	92.50	12.60	69.65%
28-May	143.00	28.30	100.30	12.80	70.14%
29-May	151.10	28.80	105.60	15.10	69.89%
30-May	106.70	11.30	69.10	24.90	64.76%
31-May	127.40	10.10	90.80	25.00	71.27%
May Mean	**144.60**	**25.44**	**100.24**	**17.44**	**69.32%**
1-Jun	140.80	19.00	91.60	28.70	65.06%
2-Jun	140.80	22.80	89.70	26.70	63.71%
3-Jun	128.40	16.90	81.80	28.20	63.71%
4-Jun	155.50	26.20	99.30	28.50	63.86%
5-Jun	150.50	19.40	100.90	28.70	67.04%
6-Jun	148.40	24.20	93.70	29.10	63.14%
7-Jun	151.80	25.60	96.00	28.60	63.24%
8-Jun	141.60	22.00	91.00	27.10	64.27%
9-Jun	117.50	10.00	78.00	28.10	66.38%
10-Jun	133.10	19.80	89.40	22.40	67.17%
11-Jun	123.10	10.70	85.40	25.50	69.37%
12-Jun	127.80	12.80	89.90	23.70	70.34%
13-Jun	134.30	17.80	90.90	24.10	67.68%
14-Jun	127.00	10.90	87.40	27.10	68.82%
15-Jun	131.30	12.20	90.20	27.40	68.70%
16-Jun	136.70	18.20	92.10	25.00	67.37%
17-Jun	130.60	12.90	93.60	22.70	71.67%
18-Jun	125.20	15.70	85.80	22.10	68.53%
19-Jun	89.80	7.20	61.10	20.00	68.04%
20-Jun	118.10	9.20	84.40	23.10	71.46%
21-Jun	119.80	9.80	84.90	23.60	70.87%
22-Jun	145.60	20.10	99.80	24.00	68.54%
23-Jun	148.60	24.80	96.00	26.30	64.60%
24-Jun	140.40	21.00	90.90	27.00	64.74%
25-Jun	145.30	19.70	97.90	26.30	67.38%
26-Jun	154.10	23.50	103.00	26.10	66.84%
27-Jun	141.50	19.10	92.20	28.70	65.16%

Appendix C. Rock Island Dam daily mean for total river flow, powerhouse and spill.
April through August, 2016

28-Jun	145.00	16.50	97.50	29.50	67.24%
29-Jun	142.60	16.70	94.90	29.50	66.55%
30-Jun	145.00	24.20	88.90	30.40	61.31%
June Mean	**136.01**	**17.63**	**90.61**	**26.27**	**66.62%**
1-Jul	140.90	15.90	94.20	29.30	66.86%
2-Jul	144.80	17.50	100.00	25.80	69.06%
3-Jul	116.20	9.10	82.00	23.60	70.57%
4-Jul	129.30	10.30	94.10	23.40	72.78%
5-Jul	119.90	10.70	83.60	24.20	69.72%
6-Jul	120.50	11.30	82.30	25.50	68.30%
7-Jul	138.10	15.50	95.30	25.80	69.01%
8-Jul	131.00	16.70	87.10	25.70	66.49%
9-Jul	117.20	9.70	82.90	23.10	70.73%
10-Jul	102.60	8.10	72.00	21.00	70.18%
11-Jul	89.90	5.40	62.10	20.90	69.08%
12-Jul	116.50	5.10	86.60	23.40	74.33%
13-Jul	102.00	5.00	73.10	22.40	71.67%
14-Jul	119.30	5.40	90.10	22.30	75.52%
15-Jul	114.90	5.40	86.20	21.80	75.02%
16-Jul	128.10	16.70	87.00	23.00	67.92%
17-Jul	113.70	5.00	84.90	22.30	74.67%
18-Jul	120.50	5.70	92.60	20.70	76.85%
19-Jul	117.30	5.70	88.00	22.10	75.02%
20-Jul	109.70	10.10	75.40	22.70	68.73%
21-Jul	117.80	10.10	83.70	22.40	71.05%
22-Jul	108.30	8.80	76.40	21.40	70.54%
23-Jul	94.20	8.50	63.40	20.80	67.30%
24-Jul	102.90	9.70	70.80	20.90	68.80%
25-Jul	99.00	6.80	67.80	22.80	68.48%
26-Jul	105.70	9.50	72.90	21.80	68.97%
27-Jul	115.50	17.90	73.90	22.30	63.98%
28-Jul	126.50	11.50	91.30	22.20	72.17%
29-Jul	126.60	11.60	90.60	22.90	71.56%
30-Jul	125.20	11.60	89.50	22.60	71.49%
31-Jul	101.60	9.30	69.30	21.50	68.21%
July Mean	**116.64**	**9.99**	**82.23**	**22.92**	**70.50%**
1-Aug	110.00	9.50	78.10	21.00	71.00%
2-Aug	114.40	9.30	79.70	23.80	69.67%
3-Aug	97.20	9.50	63.20	22.90	65.02%
4-Aug	109.70	10.20	75.60	22.40	68.92%
5-Aug	115.70	11.30	81.00	21.90	70.01%
6-Aug	108.30	15.00	72.40	19.40	66.85%
7-Aug	106.50	10.10	76.60	18.20	71.92%
8-Aug	88.40	7.90	60.50	18.60	68.44%
9-Aug	100.80	6.70	72.30	20.30	71.73%
10-Aug	98.20	2.40	74.30	20.00	75.66%

Appendix C. Rock Island Dam daily mean for total river flow, powerhouse and spill. April through August, 2016

11-Aug	101.60	4.10	75.70	20.30	74.51%
12-Aug	114.00	8.90	86.50	17.10	75.88%
13-Aug	96.80	12.60	83.10	0.00	85.85%
14-Aug	92.50	15.80	75.60	0.00	81.73%
15-Aug	95.90	15.40	79.50	0.00	82.90%
16-Aug	100.10	21.80	77.30	0.00	77.22%
17-Aug	94.60	22.50	71.10	0.00	75.16%
18-Aug	112.80	26.70	85.20	0.00	75.53%
19-Aug	111.60	23.40	84.50	2.60	75.72%
20-Aug	99.60	11.80	86.80	0.00	87.15%
21-Aug	92.90	13.40	78.40	0.00	84.39%
22-Aug	86.40	12.60	72.80	0.00	84.26%
23-Aug	95.70	23.40	74.40	0.00	77.74%
24-Aug	86.70	16.60	69.10	0.00	79.70%
25-Aug	93.80	13.20	79.50	0.00	84.75%
26-Aug	83.90	22.40	60.50	0.00	72.11%
27-Aug	101.40	18.80	81.50	0.00	80.37%
28-Aug	73.20	9.40	62.90	0.00	85.93%
29-Aug	93.20	10.60	81.50	0.00	87.45%
30-Aug	87.80	10.30	76.50	0.00	87.13%
31-Aug	76.40	9.20	66.20	0.00	86.65%
August Mean	**98.07**	**13.38**	**75.56**	**8.02**	**77.05%**
Season Mean	**131.25**	**18.71**	**91.29**	**19.87**	**69.55%**

Appendix H
2016 Northern Pikeminnow Predator Control Program Rocky Reach and Rock Island Hydroelectric Projects Final Summary Report

Northern Pikeminnow Predator Control Program
Rocky Reach and Rock Island Hydroelectric Projects
Final Summary Report
2016

Northern Pikeminnow *(Ptychocheilus oregonensis)* Chelan County PUD Rocky Reach Dam, 2006.

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December 30, 2016

Abstract

This report provides information on Chelan PUD's Northern Pikeminnow (*Ptychocheilus oregonensis*) control programs for 2016. This program entails the use of deck and boat fishermen (USDA), long liners (Columbia Research), the East Wenatchee Rotary Club Pikeminnow Derby, as well as several miscellaneous efforts throughout the year.

Northern Pikeminnow are one of the most abundant predators of juvenile steelhead and salmonids (*Oncorhynchus spp.*) in the Columbia River. In 1998, the American Fisheries Society (AFS) formally changed the common name of this fish from Northern Squawfish to Northern Pikeminnow. Pikeminnow may concentrate in hydroelectric project tailraces during the late spring and summer months, concurrent with the juvenile salmonid migrations. The Public Utility District No. 1 of Chelan County (District) initiated a pikeminnow removal program in 1994 at Rocky Reach dam and extended the program to include Rock Island in 1995. Since 1996, the District has contracted annually with the United States Department of Agriculture Wildlife Services (USDA) to carry out this program. In addition to the USDA program, Chelan PUD conducted a pilot study using set-lines in 2005 under contract with Columbia Research. The objective of the set-line program was to remove pikeminnow from over-wintering habitats before the start of out-migration of salmonid smolts. The District also provides funding for the annual Pikeminnow Derby sponsored by the East Wenatchee Rotary Club. This year marked the 24th consecutive year for the annual derby and the 21st consecutive year that the District has provided funding for the event.

In 2016, a total of 91,522 pikeminnow were removed from Rocky Reach and Rock Island reservoirs (60,327 by USDA, 27,472 by Columbia Research, 2,347 during the Pikeminnow Derby, and 1,376 by miscellaneous projects).

Table of Contents

Abstract ii
List of Tables iv
List of Figures iv
Introduction 1
Program Objectives 1
Methods and Materials 2
  USDA 2
  Columbia Research 2
  East Wenatchee Rotary Club 3
  Chelan County PUD #1 3
Program Contracts and Compensation 3
  USDA 3
  Columbia Research 3
  East Wenatchee Rotary Club 3
Results 3
  USDA 3
    Pikeminnow Size Distribution 4
    Pikeminnow Catch Rates 6
    Cost Benefit Analysis 7
    Non-Target Fish Species 7
  Columbia Research 8
    Pikeminnow Size Distribution 8
    Pikeminnow Catch Rates 10
    Cost Benefit Analysis 11
    Non-Target Fish Species 11
  East Wenatchee Rotary Club 11
Discussion 12
  USDA 12
  Columbia Research 13
  East Wenatchee Rotary Club 14
  Chelan County PUD 14
Project Recommendations 15
  USDA 15
  Columbia Research 15
  East Wenatchee Rotary Club 15
Literature Cited 16

List of Tables

Table 1 Total pikeminnow removed from Rocky Reach and Rock Island projects by USDA from May through October, 2003 to 2016 4

Table 2 Size and number of pikeminnow captured by USDA that were measured from the Rocky Reach and Rock Island reservoirs in 2016 4

Table 3 The mean fork length (mm) of pikeminnow removed by USDA at Rocky Reach and Rock Island project, 2003 to 2016. 6

Table 4 The overall rod and reel CPAH for USDA pikeminnow anglers from May to October, 2003 to 2016..6

Table 5 Cost of USDA pikeminnow program and the cost per fish breakdown from 2003 to 2016 7

Table 6 Total pikeminnow removed from Rocky Reach and Rock Island projects by Columbia Research, 2005 to 2016 8

Table 7 Size and number of pikeminnow capture by Columbia Research in Rocky Reach and Rock Island reservoirs in 2016..8

Table 8 The mean fork length of pikeminnow removed by Columbia Research set-line fishing at Rocky Reach and Rock Island projects, 2003 to 2016 10

Table 9 Annual catch per unit effort (CPUE) for Columbia Research in Rocky Reach and Rock Island reservoirs, 2008 to 2016..10

Table 10 Cost of Columbia Research set-line program in Rocky Reach and Rock Island and the cost per fish breakdown, 2005 to 2016 11

Table 11 Total pikeminnow removed from Rocky Reach and Rock Island reservoirs during the East Wenatchee Rotary Pikeminnow Derby, 1996 to 2016 12

List of Figures

Figure 1 Mean fork lengths (mm) for pikeminnow captured by Columbia Research and the USDA, 2003 to 2016...13

Figure 2 Breakdown of pikeminnow contributions from Chelan County PUD’s different pikeminnow programs, 2010 to 2016 14

Introduction

Northern Pikeminnow (*Ptychocheilus oregonensis*) are native to the Columbia River. Burley and Poe (1994) identified pikeminnow as the most abundant predator on out-migrating juvenile steelhead and salmonids (*Oncoryhynchus spp*.) in the mid-Columbia River between Priest Rapids and Chief Joseph dams. They also concluded that the highest abundance of pikeminnow concentrate in the tailrace areas. Loch et al (1994) reported that the highest consumption of juvenile salmonids takes place within the tailraces of dams and those pikeminnow densities in these areas increase during the late spring and summer. Pikeminnow are believed to become highly piscivorous on juvenile salmonids at approximately 280 mm (11 inches) and their predation rate on juvenile salmonids increase significantly as their size and age increases (Peterson, 2001).

In an effort to reduce predation on juvenile salmonids, the District implemented a pikeminnow removal program (Program) in 1994 in the Rocky Reach project area and in1995 the program was expanded to include the Rock Island project area. From 1996 to present time, the District has contracted with the United States Department of Agriculture, Wildlife Services (USDA) to employ anglers to fish for pikeminnow during the summer months from the District's dams and reservoirs. The program has continued to focus on increasing fishing effort, increasing pikeminnow catch totals, and evaluating catch data to characterize attributes of the pikeminnow populations in the reservoirs. As a result, the USDA fish for a longer duration and with multiple boats. From 2005 to current, the District has contracted Columbia Research to fish for pikeminnow within the District's reservoirs with set-lines in an effort to remove pikeminnow from deeper over-wintering areas. Chelan PUD has also provided funding for the annual Pikeminnow Derby sponsored by the East Wenatchee Rotary Club. This year marked the 21st consecutive year that the District has partnered with the Rotary Club.

Program Objectives

The objectives for the 2016 pikeminnow removal program were three-fold:

1) Reduce the number of pikeminnow in the Rocky Reach and Rock Island tailraces and reservoirs in order to reduce predation on juvenile anadromous salmon and steelhead smolts.

2) Continue to evaluate the efficiency of angling methods and the timing of seasonal fish movement to improve the efficiency and harvest.

3) Continue to evaluate current and historic catch statistics characterize effects of the removal program on pikeminnow populations in Rocky Reach and Rock Island reservoirs.

Methods and Materials

USDA

Since 1996, the District has contracted the USDA to conduct pikeminnow fishing from Rocky Reach and Rock Island projects. The USDA employs approximately 17 anglers to fish during the summer months. Crews consist of four 3-person boat crews, one 3-person crew at Rocky Reach dam, and one 2-person crew at Rock Island dam. Boat crews fished for 23 weeks from 25 April to 28 September. Deck crews fished for 16 weeks from 25 April to 12 August.

Each angler is outfitted with two fishing rods and reels, assorted tackle, tackle box, small ice chest (for keeping bait cool), fillet knife (for cutting bait), pliers, line clippers, personal floatation device, hard hat, 5 gallon bucket, and data sheets to record weekly catch. Each crew also carries a District radio or cell phone for communication. For more detail description of equipment used by anglers, please refer to West (2001).

Anglers fish a variety of locations within the tailraces and reservoirs in search of the most productive fish locations. Early in the fishing season when catch rates are low, anglers move in search of "hot spots". Later in the season when flows reside, water temperatures increase, and when anglers become more familiar with pikeminnow holding areas and feeding activity, the anglers are able to concentrate their efforts in established locations.

Each crew leader is in charge of recording specific information. Data is collected weekly from each crew including; total number of pikeminnow caught, total number of hours fished, fishing locations, number of non-target fish captured, and the dates that were fished. Twice a week anglers are required to measure fork length on all pikeminnow in order to evaluate the size distribution. Upon capture, pikeminnow are measured, euthanized, and their carcasses are returned to the river. All non-target species are released immediately back into the reservoir.

Columbia Research

Set-lines are the primary fishing technique used by Columbia Research to capture and remove pikeminnow. Set-lines are long weighted nylon lines with buoys attached at each end. The weighted rope allows the set-line to sink and remain on the bottom of the reservoir where pikeminnow tend to congregate during the winter months. Approximately 120 small hooks are attached to each line. Each hook is tied to a leader that contains a small float, which allows the hook to float slightly off the bottom substrate. An 8-pound test leader allows non-target species to break free from the set-line upon capture.

Each day, between 15 and 20 set-lines are deployed and allowed to fish for 24 hours. Deployment of set-lines occurs in the Rocky Reach and Rock Island reservoirs and varies in depth between 10 feet to 150 feet. Once set-lines are retrieved and non-target species are released, pikeminnow are measured (fork length) and turned into the District for rendering. Columbia Research provides the District with specific information including; the number of pikeminnow caught on each set-line, fork length (mm), depth and location of each set-line, and set-line time. They also provide the District with any incidental species encountered during set-line retrieval.

East Wenatchee Rotary Club
The East Wenatchee Rotary Club takes place during the last week in June. During this two-day event, sportsmen fish Rocky Reach and Rock Island reservoirs for pikeminnow. After each day, the anglers submit their fish for count and total weight. Prizes are awarded to individuals who catch the most pikeminnow by weight. Daily prizes are awarded for the largest fish and the most fish as well.

Chelan County PUD #1
In past years, the District has either contracted or operated a pikeminnow trapping project using modified lamprey traps. Traps were very effective during peak pikeminnow migration season. However, trap efficiency is significantly decreased during seasons of above average adult Sockeye Salmon runs. The last year traps were used was in 2010. For an overview on trap configurations, please refer to Mallas and Stevenson, 2008. For past catch data, please refer to Keller et. al., 2010.

Program Contracts and Compensation

USDA
The USDA receives compensation on an hourly basis for labor through an annual contract. The contract is typically less than 7 months in duration, from May through mid-October. In 2016, the contract payout was $402,710.00. USDA rod and reel fishing activities for the tailrace and boat crews takes place 5 days a week for 8 hours each day.

Columbia Research
In 2016, Columbia Research received $3.00 for each fish between 127 mm and 227 mm and $7.25 for each fish great than 227 mm in fork length. Columbia Research received no compensation for fish measuring less than 127 mm. Columbia Research anglers fish 7 days a week, for up to 15 hours a day during the contract period. In 2016, Columbia Research conducted set-line fishing in the Rocky Reach and Rock Island reservoirs in two distinct seasons. In the spring Columbia fished from April into July, and in the fall from October into November. The total contract payout was $179,906.75.

East Wenatchee Rotary Club
The District contracts with the East Wenatchee Rotary Club to hold the annual Pikeminnow Derby. In 2016, this contract was $20,000 with specific requirements for anglers to fish in Rocky Reach and Rock Island reservoirs only.

Results

USDA
Since 2003, the USDA has removed 607,514 pikeminnow from the Rocky Reach and Rock Island projects. In 2016, USDA crews removed 60,327 pikeminnow from May through mid-October. (Table 1).

Table 1. Total pikeminnow removed from Rocky Reach and Rock Island projects by USDA from May through October 2003 to 2016.

Year	USDA
2003	19,754
2004	36,145
2005	39,818
2006	40,747
2007	46,240
2008	42,158
2009	50,333
2010	47,354
2011	36,401
2012	36,118
2013	47,563
2014	44,826
2015	59,730
2016	60,327
Total	**607,514**

Pikeminnow Size Distribution

The USDA submitted length measurements to the District weekly. Fish lengths are recorded into size categories 10 mm in length. A total of 25,000 pikeminnow were measured in 2016. Of the pikeminnow measured, 21,431 were less than or equal to 250 mm, and 3,569 were greater than 250 mm (Table 2).

Table 2. Size and number of pikeminnow captured by USDA that were measured from the Rocky Reach and Rock Island reservoirs in 2016.

Size (mm)	USDA
100-110	594
111-120	1,039
121-130	1,677
131-140	2,423
141-150	2,971
151-160	2,806
161-170	2,601
171-180	2,200
181-190	1,571
191-200	1,071
201-210	623
211-220	479
221-230	475
231-240	446
241-250	455
251-260	409

261-270	359
271-280	362
281-290	284
291-300	315
301-310	273
311-320	215
321-330	255
331-340	171
341-350	171
351-360	150
361-370	95
371-380	108
381-390	82
391-400	67
401-410	65
411-420	39
421-430	43
431-440	33
441-450	20
451-460	18
461-470	8
471-480	8
481-490	8
491-500	3
501-510	3
511-520	0
521-530	2
531-540	0
541-550	0
551-560	0
561-570	0
571-580	1
581-590	0
591-600	2

The overall mean fork length of pikeminnow removed from both Rocky Reach and Rock Island in 2016 was 183 mm. The mean length for Rocky Reach and Rocky Island were 177 mm and 233 mm respectively. Overall mean lengths have been generally decreasing over time and mean lengths in 2016 were the lowest since measurements began in 2003 (Table 3).

Table 3. The mean fork length (mm) of pikeminnow removed during USDA fishing at Rocky Reach and Rock Island projects, 2003 to 2016.

Year	Rocky Reach Mean Length (mm)	Rock Island Mean Length (mm)	Overall Mean Length (mm)
2003	232	249	236
2004	231	264	239
2005	223	254	237
2006	235	257	244
2007	236	251	244
2008	229	254	242
2009	239	252	245
2010	219	248	229
2011	200	262	218
2012	202	263	219
2013	195	247	207
2014	204	252	212
2015	181	262	192
2016	177	233	183

Pikeminnow Catch Rates

In 2003, 2004, and 2005 the angler hours were reported as fishing day (8 hours). From 2006 through 2016, anglers fishing from the dam reported their time as "angling hours" while boat anglers reported fishing time as boat hours". Angling hours were just that – defined as the number of hours the tailrace crews spent fishing. Boat hours are defined as the number of hours the boat was in the water. It does not include the time required to launch or load the boat, refuel, or purchasing equipment. The catch per angler hour (CPAH) increased every year through 2008. The CPAH then began to decrease through 2012 before it began to generally increase again to 5.8 in 2016 (Table 4).

Table 4. The overall rod and reel CPAH for USDA pikeminnow anglers from May to October, 2003 to 2016.

Year	Angler Hours	Fish Captured	CPAH
2003	6,857.00	19,754	2.9
2004	11,676.00	36,145	3.1
2005	10,849.00	39,818	3.7
2006	9,159.50	40,747	4.4
2007	9,513.50	46,240	4.9
2008	8,317.50	42,158	5.1
2009	10,004.50	50,333	5.0
2010	10,187.50	47,354	4.6
2011	10,300.75	36,401	3.5
2012	10,261.05	36,118	3.5

2013	10,387.75	47,563	4.6
2014	10,333.60	44,826	4.3
2015	10,251.00	59,730	5.8
2016	10,438.50	60,327	5.8

Cost Benefit Analysis

Expenditures for the USDA portion of the pikeminnow predator program have fluctuated since the initial start of the contract in 1996. Since 2013, the cost per fish has been near or below $7.00 with the exceptions of years 2011 through 2014 when prices reached a peak in 2012 at $9.85 per fish (Table 5).

Table 5. Cost of USDA pikeminnow program and the cost per fish breakdown from 2003 to 2016.

Year	Cost of Program	Fish Captured	Cost per fish
2003	$135,709.98	19,754	$6.87
2004	$237,834.10	36,145	$6.58
2005	$255,233.38	39,818	$6.41
2006	$263,225.62	40,747	$6.46
2007	$253,395.20	46,240	$5.48
2008	$264,752.24	42,158	$6.28
2009	$327,164.50	50,333	$6.50
2010	$332,425.08	47,354	$7.02
2011	$342,533.41	36,401	$9.41
2012	$355,685.00	36,118	$9.85
2013	$360,780.96	47,563	$7.59
2014	$373,112.00	44,826	$8.32
2015	$397,619.00	59,730	$6.66
2016	$402,710.00	60,327	$6.68

Non-Target Fish Species

Rod and reel angling is one preferred pikeminnow removal method because baits can be tailored to exploit primarily pikeminnow and is the least harmful to non-target species. Non target species caught in 2016 included; chiselmouth (*Acrocheilus alutaceus*), peamouth (*Mylocheilus caurinus*), large scale and bridgelip suckers (*Catostomus spp*.), mottled sculpin (*Cottus bairdii*), bass (*Micropterus dolomieu*), mountain whitefish (*Prosopium williamsoni*), walleye (*Sander vitreum*), yellow perch (*Perca flavescens*), white sturgeon (*Acipenser transmontanus*), carp (*Cyprinus carpio*), adult and juvenile salmon, and adult steelhead and resident rainbow trout (*Oncorhynchus mykiss*). In 2016, all non-target fish were released unharmed back to the river.

Columbia Research

Columbia Research has removed 320,865 pikeminnow from Rocky Reach and Rock Island reservoirs from 2005-2016. In 2016, set-lines run by Columbia Research produced 27,472 pikeminnow (Table 6).

Table 6. Total pikeminnow removed from Rocky Reach and Rock Island projects by Columbia Research from 2005 to 2016.

Year	Columbia Research
2005	19,337
2006	22,418
2007	21,301
2008	21,472
2009	31,683
2010	31,620
2011	32,846
2012	29,526
2013	29,310
2014	27,090
2015	26,790
2016	27,472
Total	320,865

Pikeminnow Size Distribution

Columbia Research submitted length measurements to the District for all pikeminnow captured. Fish lengths are recorded into size categories 10 mm in length. Of the pikeminnow measured, 11,780 were less than or equal to 250 mm, and 15,692 were greater than 250 mm (Table 7).

Table 7. Size and number of pikeminnow captured by Columbia Research in Rocky Reach and Rock Island reservoirs in 2016.

Size (mm)	Columbia Research
100-110	0
111-120	0
121-130	0
131-140	406
141-150	417
151-160	367
161-170	361
171-180	416
181-190	343
191-200	443
201-210	388
211-220	502
221-230	1,460

231-240	2,880
241-250	3,797
251-260	3222
261-270	2576
271-280	2460
281-290	2166
291-300	1592
301-310	983
311-320	808
321-330	544
331-340	278
341-350	240
351-360	180
361-370	77
371-380	123
381-390	58
391-400	98
401-410	38
411-420	50
421-430	41
431-440	26
441-450	18
451-460	10
461-470	12
471-480	13
481-490	17
491-500	19
501-510	17
511-520	5
521-530	1
531-540	20
541-550	0

Because the set-line program is an incentive based contract and that the main objective is to target deep over wintering habitats, Columbia Research is required to measure every pikeminnow captured. Both of these factors contribute to Columbia Research producing larger mean lengths compared to other District pikeminnow capture projects. In 2016, the average mean fork lengths in the Rocky Reach reservoir and Rock Island reservoir were 260 mm and 252 mm respectively. The overall 2016 mean fork length was 258 mm. The overall mean fork length for Columbia Research has been trending downwards with the largest mean fork length (282 mm) in 2005 and the smallest mean fork length in 2016 (Table 8).

Table 8. The mean fork length of pikeminnow removed by Columbia Research set-line fishing at Rocky Reach and Rock Island projects, 2005 to 2016.

Year	Rocky Reach Mean Length (mm)	Rock Island Mean Length (mm)	Overall Mean Length (mm)
2005	N/A	N/A	282
2006	N/A	N/A	281
2007	269	294	281
2008	269	268	269
2009	274	272	274
2010	267	256	261
2011	258	270	261
2012	293	288	275
2013	268	273	270
2014	262	274	268
2015	268	276	270
2016	260	252	258

Pikeminnow Catch Rates

In 2016, Columbia Research removed 27,472 pikeminnow during 61,920 hours of set-line effort. This equates to 7,430,400 hook hours as each set line has 120 hooks. The overall catch per unit effort (CPUE) was 0.37 for 2016. The District calculates CPUE as the number of pikeminnow captured per 100 hook hours. In general, the CPUE for Columbia Research has remained pretty constant. The last two years have produced the highest CPUE's at 0.42 and 0.37 (Table 9).

Table 9. Annual catch per unit effort (CPUE) for Columbia Research in Rocky Reach and Rock Island reservoirs, 2008 to 2016.

Year	Total Hook Hours	Fish Captured	CPUE*
2008	6,624,000	21,472	0.32
2009	10,980,000	31,683	0.29
2010	8,517,600	31,620	0.37
2011	10,332,000	32,846	0.32
2012	9,388,800	29,526	0.31
2013	9,129,600	29,310	0.32
2014	8,643,600	27,090	0.31
2015	6,402,240	26,790	0.42
2016	7,430,400	27,472	0.37

*CPUE is calculated as the number of pikeminnow per 100 hook hours.

Cost Benefit Analysis
Columbia Research is compensated on a per-fish basis. Fish captured between 127 mm and 227 mm were compensated at a lower rate than fish captured that measured greater than 227 mm in length. These two size categories are considered "Under" and "Over" the 227 mm delineation. In 2005, Columbia Research received $2.75 or $5.50 per fish depending on size. In 2006, compensation rate increased to $3.00 and $6.00 respectively. In 2007, the compensation rate increased to $3.00 and $6.25 depending on fish size. From 2008 to 2011, Columbia Research received $3.00 or $6.50 per fish. For years 2012 and 2013 the compensation rate increased to $3.00 and $6.75 respectively. From 2014 to 2016 the compensation rate has been $3.00 for fish 127 mm to 227 mm and $7.25 for fish greater than 227 mm in length. No compensation was awarded for any fish measuring less than 127 mm. For the District's total annual compensation to Columbia Research for their pikeminnow efforts and the equivalent annual cost per fish refer to Table 10.

Table 10. Cost of Columbia Research set-line program in Rocky Reach and Rock Island and the cost per fish breakdown from 2005 to 2016.

Year	Cost of Program	Fish Captured	Cost per fish
2005	$99,726.00	19,337	$5.16
2006	$125,000.00	22,418	$5.58
2007	$124,998.75	21,301	$5.87
2008	$124,997.50	21,472	$5.82
2009	$174,999.50	31,683	$5.52
2010	$174,999.50	31,620	$5.53
2011	$180,250.50	32,846	$5.49
2012	$180,000.00	29,526	$6.10
2013	$179,988.75	29,310	$6.14
2014	$179,742.50	27,090	$6.64
2015	$179,998.50	26,790	$6.72
2016	$179,906.75	27,472	$6.55

*CPUE is calculated as the number of pikeminnow per 100 hook hours.

Non-Target Fish Species
The non-target fish species caught by Columbia Research included chiselmouth, peamouth, large scale and bridgelip suckers, mottled sculpin, mountain whitefish, white sturgeon, and burbot (*Lota lota*). In 2016, no adult or juvenile salmon or steelhead were captured. All non-target fish were released unharmed back into the river.

East Wenatchee Rotary Club
The East Wenatchee Rotary Club Annual Pikeminnow Derby has captured 60,415 pikeminnow in 42 days of total fishing since 1996. In 2016, the annual derby produced 2,347 pikeminnow over the 2-day event. There were 98 tickets sold (82 adults and 16 youth). Of the participants, 76 people turned in fish (68 adults and 8 youths). Participation and total number of pikeminnow captured were both down in 2016 (Table 11).

Table 11. Total pikeminnow removed from Rocky Reach and Rock Island reservoirs during the annual Pikeminnow Derby from 1996 to 2016.

Year	Pikeminnow Captured
1996	1,800
1997	2,240
1998	1,847
1999	2,294
2000	1,370
2001	1,601
2002	2,783
2003	2,568
2004	2,943
2005	3,950
2006	3,445
2007	3,812
2008	4,474
2009	3,812
2010	5,027
2011	3,274
2012	2,894
2013	2,944
2014	2,563
2015	2,427
2016	2,347
Total	60,415

Discussion

USDA

The continued success of the USDA program is likely a result from a variety of factors. A key efficiency is credited to a core group of veteran anglers who return to work in the program each year, resulting in better catch rates overall. Experienced anglers are more productive, relying on their knowledge of pikeminnow holding areas in the reservoirs, effective baits, and presentation methods. While the USDA continues to catch similar numbers of pikeminnow each year, the overall average size has dropped considerably over the course of the program. This resulted in the lowest average size observed ever for the program in 2016. The start and duration of the USDA pikeminnow program is designed to coincide with the outmigration period of juvenile salmonids. Smolts arrive at Rocky Reach and Rock Island Dams in early April, and continue passing the dams through the end of August. Pikeminnow primarily ascend the adult fish ladders during mid-May through September. Peak ladder passage occurs in August at Rocky Reach and in mid-July at Rock Island. The highest catch rates for pikeminnow usually occur in July and August for Rocky Reach and Rock Island.

Columbia Research

The objective for the Columbia Research set-line program was to remove large pikeminnow that congregate in deep over-wintering areas. Columbia Research has become very efficient at using set-lines. Because set-line angling is designed to capture fish that hold on or near the river bottom, targeting deep areas within the reservoir where pikeminnow congregate in colder months is effective. Pikeminnow likely move into deep pools where the daily water temperature remains more constant. A fish's metabolic rate decreases over winter periods, and hence it needs less food to survive (Sauter et. al, 1994). By presenting pikeminnow with food that they do not have to chase, they likely expend very little effort and energy to obtain the bait. The boat crew deployed 20 set-lines nearly every day at various depths. In 2016, all fish were caught at depths between the surface and 120 feet with most fish being caught between the surface and 90 feet.

Fishing with set-lines and at deeper depths has resulted in Columbia Research having a larger mean length than USDA over the years. From year to year there is some overlap but it can be seen that the two programs are targeting pikeminnow from different size classes (Figure 1). Also seen in Figure 1 is that the trend for both programs is a reduction in mean length over time. If capture rates can outpace the recruitment rate then this would result in a reduction in mean length over time. Columbia Research's mean length has steadily declined despite the fact they are targeting larger fish for a higher payout. It is predicted that the programs will reach a point where capture rates will off-set the recruitment rates and mean lengths will start to level off.

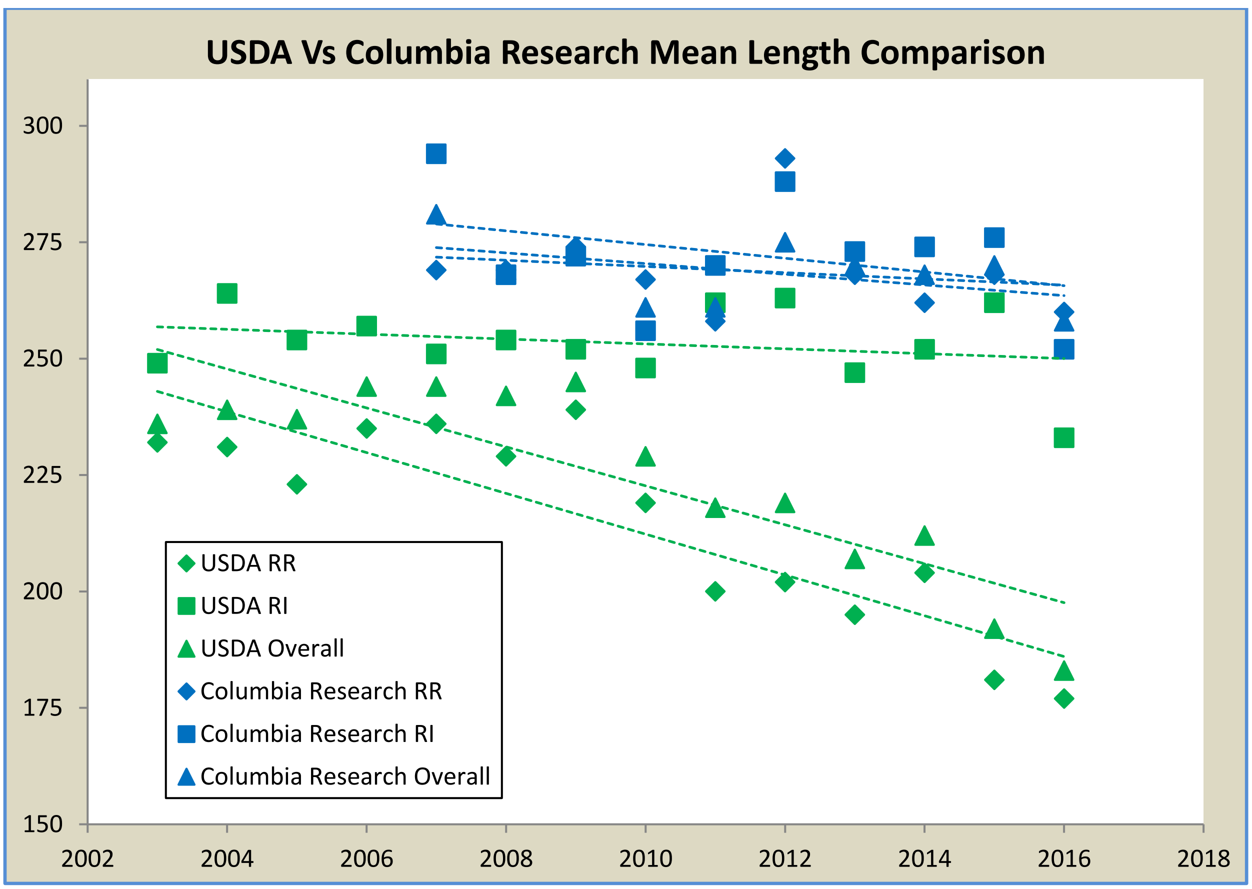

Figure 1. Mean fork lengths (mm) for pikeminnow captured by Columbia Research and the USDA from 2003 to 2016.

East Wenatchee Rotary Derby

The Pikeminnow Derby is nearing its 25th annual event in a few years and marks the District's longest effort toward reduction in pikeminnow numbers. While numbers in the past have been higher, this year's effort was impacted by poor weather on the second fishing day. The derby is only a two-day event and can be influenced heavily by weather. Since the limiting factor is the number of anglers on the river, additional efforts should be put into increasing the number of anglers participating. This was addressed in 2015 by doubling the prize contribution by the District from $10,000 to $20,000.

Chelan County PUD (miscellaneous)

In past years the District has conducted pikeminnow ladder trapping efforts in both Rocky Reach and Rock Island fish ladders. These efforts were abandoned in the 2011 season due to the increased bycatch of adult Sockeye Salmon. With the increased run sizes of Sockeye Salmon and the overall success of the District's other pikeminnow programs, the District abandoned the ladder trapping completely in 2012.

In 2016, there were 1,376 pikeminnow caught in miscellaneous instances. Some of these miscellaneous captures included bycatch at facilities, fish ladder outage rescues, bycatch during miscellaneous studies, and a few targeted angling efforts by District employees. These various events accounted for 1.5% of the total pikeminnow catch in 2016. An overall visual of the District's different pikeminnow programs can be seen in Figure 2.

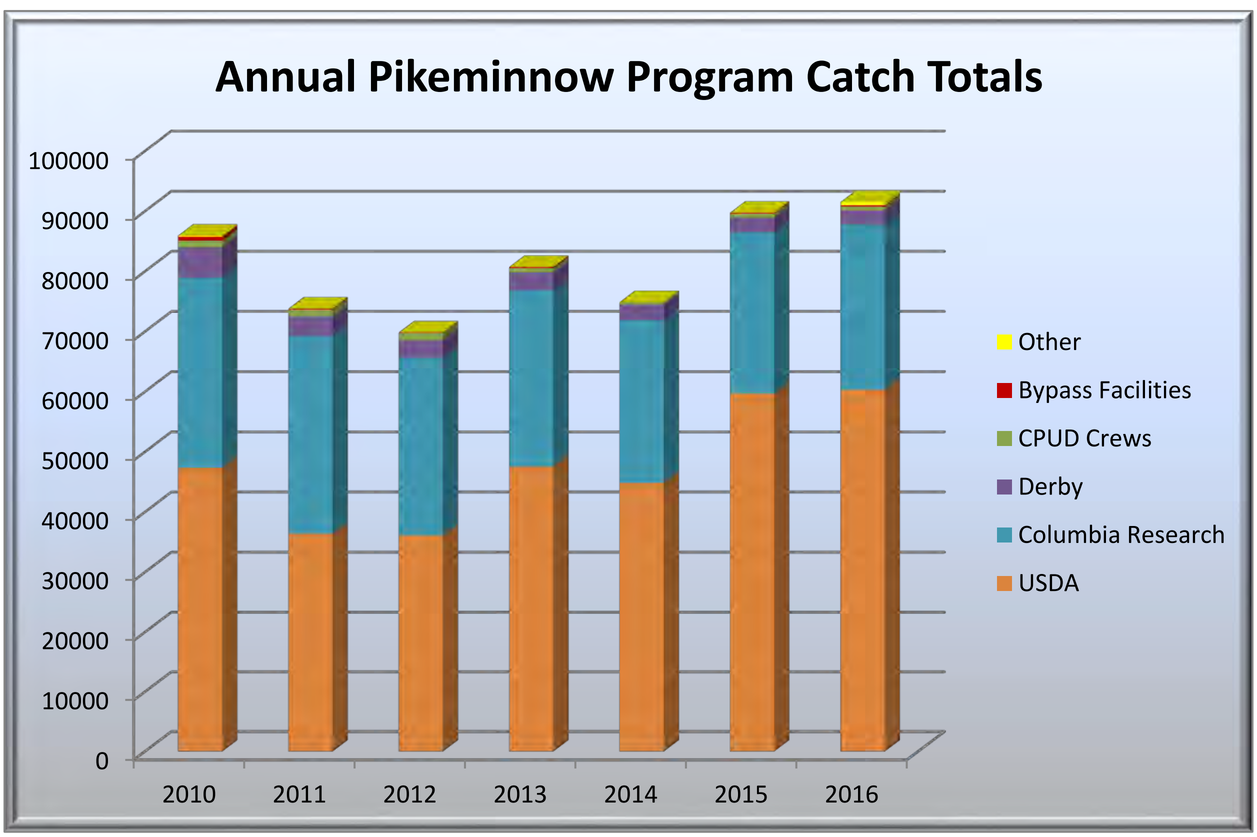

Figure 2. Breakdown of pikeminnow contributions from Chelan County PUD's different pikeminnow programs from 2010 to 2016.

Project Recommendations

USDA

Several factors, including USDA angler skills, reservoir knowledge, increased efforts, and overall program duration combined to make the 2016 the most successful pikeminnow effort to date for the USDA. The USDA anglers continue to maintain excellent pikeminnow catch rates by documenting fish movements and holding locations. We expect that overall catch may increase as anglers continue to learn where pikeminnow reside during the summer and fall months. However, if the program has started to outpace the recruitment efforts, then we may start to see a decrease in total capture numbers. If possible, the District should continue to utilize USDA anglers with experience and knowledge of the reservoirs and who are familiar and adept at the angling techniques used in the program.

Columbia Research

We recommend continuing the set-line program at the 2016 funding and effort level. This program is productive because it compensates on a per fish basis, with no equipment, fuel, or administrative costs. The current recommendation is to continue to start the program in February and continue through November to take advantage of favorable CPUE documented during past fishing efforts in November.

East Wenatchee Rotary Derby

The District should continue to fund the East Wenatchee Rotary Club Pikeminnow Derby at its current funding level. The derby removes a large number of fish in a short time frame of two days. This likely provides an immediate within-year benefit to juvenile survival in the reservoirs. Since 1996 the derby has removed 60,415 pikeminnow in just 42 days of effort. In order to increase overall angler turn out the District should increase efforts to advertise the derby. The increased advertising along with the contribution increase from $10,000 to $20,000 in 2015 should help encourage higher participation. The Rotary Club should continue to host the event concurrent with the peak smolt migrations through Rocky Reach and Rock Island Reservoirs.

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Appendix I
Rock Island Dam Smolt Monitoring and Gas Bubble Trauma Evaluation Plan 2017

Rock Island Dam
Smolt Monitoring and
Gas Bubble Trauma
Evaluation Plan
2017

Public Utility District #1 of Chelan County

Final Plan

Prepared By:

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&
Scott Hopkins

January 2017

Introduction:

The primary objective of the Rock Island Smolt Monitoring Project (RISMP) is to provide information on Mid-Columbia juvenile salmonid out-migration timing to the Fish Passage Center (FPC). Another objective of this project is to provide information to the Columbia River basin-wide database for passive integrated transponder (PIT) tagged fish in coordination with Pacific States Marine Fish Commission (PSMFC). This data will improve the fish managers understanding of smolt out-migration timing and survival in the Columbia River System. A further objective of the project is to monitor downstream migrating juvenile salmonids for signs of gas bubble trauma (GBT).

This program is designed to measure the migration characteristics of emigrating salmonids. It also provides a comparison and evaluation of year-to-year migration information such as travel time and peak abundance. Monitoring at Rock Island Dam is ideal for indexing juvenile salmonid emigration and travel time because the trap site is located down river from four major tributaries and several hatcheries that release fish to the mid-Columbia Basin. Daily collections will be used to compute the 10%, 50%, and 90% dates of passage at the collection site.

Bypass Monitoring Requirements:

Sampling will begin on 1 April 2017 and will be completed on 31 August 2017. Data summary, analysis and report writing will occur throughout the sampling period and be completed by 31 January 2018.

A. Tasks

Public Utility District #1 of Chelan County, hereafter referred to as the District, will monitor the gatewell orifice bypass trap from 1 April to through 31 August 2017. Personnel monitoring the bypass trap at Rock Island Dam will consist of District employees. A District Fish and Wildlife Specialist will supervise the onsite crew at the bypass trap. A permanent District Biologist will oversee the monitoring program.

Fish will be collected continuously during the monitoring period. Fish will be examined during regular work hours (0700–1530 hrs), unless large numbers of fish are entering the flume of the bypass trap, in which case fish would be removed and recorded as the appropriate sample days catch. Fish will be delivered via the bypass elevator to a 12' x 4' x 3.5' aluminum holding tank in the sampling facility, which is plumbed for continuous flow of river water. Small samples (40-60) of fish will be pre-anesthetized using a pre-mixed solution of MS-222 (1.8 ml per gal. of water) before being moved by net into the sorting holding tank with a solution of MS-222 (3.6 ml per gal of water). *** See MS-222 stock solution mixing rates below.** Fish will be identified by species, interrogated for a PIT tag, and examined for marks indicating hatchery origin and descaling. Anesthetized fish will recover in a separate holding tank and be released after they have recovered from anesthesia.

Sub-samples of up to 100 Chinook and steelhead will be examined for signs of GBT twice weekly. The unpaired fins and eyes will be examined for the presence of bubbles. Absence or presence of GBT symptoms as well as the location and severity of symptoms will be reported to the FPC daily throughout the sampling season.

Insertion of PIT tags will begin when an increase in the number of juvenile salmon being captured in the bypass trap is observed, usually around mid-April, and will continue throughout the monitoring season as appropriate for each species. The target of the PIT tagging operation will be the middle 80%, of both the Wenatchee, Methow and Okanogan runs that pass the dam during April and May respectively. Beginning in June, subyearling Chinook will be marked until 4,800 fish have been tagged.

Fish will be injected with PIT tags by hand using a medical syringe/push rod mechanism with a sterile 12-gauge veterinary needle. Tagged fish will be placed on a plastic covered measuring board where the information and length measurements will be recorded by touching the stylus directly on the digitizing board. Data for PIT tagged fish and the number of tagged fish will be recorded directly into a computer via a digitizing board.

Standard PIT tagging procedures will be followed and PIT tags, equipment, and other miscellaneous tagging supplies will be purchased under the RISMP contract. Data will be entered into a computer and supplied to a District Biologist and the FPC daily by modem.

B. RIJSF Sampling

Run-of-river fish collected at the Rock Island Juvenile Sampling Facility (RIJSF) to evaluate fish for the following:

1. Run timing of target species:
    a. Provide standardized juvenile capture rate data to supplement Program RealTime (UW) run-timing predictions
    b. Guide decisions about initiating spring and summer fish spill
        i. Currently spring and summer fish spill occurs at Rock Island Dam

2. Fish species composition:
    a. Guide decisions about starting or stopping spill
        i. Currently spring (10%) and summer (20%) fish spill occurs at Rock Island Dam.
        ii. Report counts and condition of all salmonid species to the FPC daily.

3. Fish condition:
    a. Evaluate run-of-river fish condition for migrating juvenile salmon and steelhead.
        i. Descale: 20% or more scale loss on either side
        ii. Injury: Scratches, bruises, or hemorrhages
        iii. Mortality: Any fish dead on arrival to sampling facility
        iv. Examine juvenile salmonid emigrants for symptoms of GBT twice weekly. Report GBT examination results to FPC when collected.

4. Origin of fish stocks and identification of marked individuals:
    a. PIT tags
    b. Fin clips
    c. Acoustic tags
    d. Other external marks or tags

5. PIT tagging:
    a. Insert PIT tags into between 200 and 600 unclipped Chinook yearlings, unclipped sockeye, hatchery steelhead and wild steelhead weekly (Table 1). Refer to FPC to determine if tagging should start/stop outside the criterion set in Table 1.
    b. Insert PIT tags into as many unclipped subyearling Chinook daily as necessary to reach 600 fish per week over an 8-week period between mid-June and mid-August (seasonal total of 4,800 fish).
    c. Transfer PIT tag generated data to PSMFC PITAGIS system daily.

6. Daily reporting:
    a. Report counts and condition of all salmonid species to the FPC daily.
    b. Report the average river flow, average flow through Powerhouse No.1, average flow through Powerhouse No. 2, and average spill daily.
    c. Report GBT examination results to FPC when collected.

Table 1. Weekly PIT tagging quotas at Rock Island Dam during the 2017 smolt monitoring season. Refer to FPC to determine if tagging should occur outside these time periods.

	Weekly Quotas				
Week Starting	Unclipped Chinook Yearling	Unclipped Chinook Subyearling	Unclipped Sockeye	Hatchery Steelhead	Wild Steelhead
02 Apr					
09 Apr					
16 Apr	600		600	200	
23 Apr	600		600	400	200
30 Apr	600		600	400	200
07 May	600		600	400	200
14 May	600		600	400	200
21 May	600		600	400	200
28 May	200			400	200
04 Jun				200	
11 Jun					
18 Jun		600			
25 Jun		600			
02 Jul		600			
09 Jul		600			
16 Jul		600			
23 Jul		600			
30 Jul		600			
06 Aug		600			
13 Aug					
Season Totals	**3,800**	**4,800**	**3,600**	**2,800**	**1,200**

Daily Protocol for Fish Collection:

Standard Operations:

1. Fish will be collected continuously during the monitoring period 0900-0900 (24 hours).
2. Fish will be examined during regular work hours (0700–1530 hrs), unless large numbers of fish are entering the flume of the bypass trap, in which case fish would be removed and recorded as the appropriate sample days catch.
3. Dewatering screens are raised and fish crowded into the transport elevator.
    a. If large numbers of fish are present in the sampling raceway, use more than one elevator trip. If excessive numbers of fish are present see the Special Operations section.
4. Fish will be delivered via the bypass elevator to a 12' x 4' x 3.5' aluminum holding tank in the sampling facility.
    a. Ensure continuous flow of river water to holding tank.
5. Small samples of fish will be moved into the sorting holding tank with a solution of MS-222 (3.6 ml per gal of water). *** See MS-222 stock solution mixing rates below.**
6. Fish will be identified by species and condition.
    a. Evaluate all steelhead and salmonids for injuries and descaling.
7. Scan each fish for PIT tags, fin clips, external tags and acoustic tags.
8. If needed, collect and hold fish for PIT tagging, acoustic tagging and/or marked releases (Special Operations).
9. Allow anesthetized fish (examined for species composition and fish condition) to recover in the facility's holding tank for at least 1.0 hours.
    a. Release fish after they have recovered from anesthesia.

2017 - MS-222 Recommended Knockdown & Maintenance Dosage

(CCPUD) Stock Solution Mix Ratio MS-222:

1000 grams per 5 gals. of water	*(18.925 liters per 5 gals.)*
200 grams per 1 gal. of water	*(3.785 liters per 1 gal.)*
53 grams per 1 liter of water	

(CCPUD) Stock Solution Used for Fish Examination:

Pre-anesthetized Dose:

Use 1.8 ml of stock solution per gal of water for pre-anesthetized dose

Use 9 ml of stock solution per 5 gals. of water

(CCPUD) Stock Solution Used for Fish Examination:

Knockdown Dose:

Use 3.6 ml of stock solution per 1 gal. of water in knockdown tank ***OR***

Use 18 ml of stock solution per 5 gals. of water

* **The amount of MS-222® used, however, varies throughout the season depending upon**

temperature, the number of fish in each chamber and the species of fish being sedated.

Special Operations:

1) PIT tagging:
   a) Insert PIT tags into between 200 and 600 unclipped Chinook yearlings, unclipped sockeye, hatchery steelhead and wild steelhead weekly (Table 1).
   b) Insert PIT tags into as many unclipped subyearling Chinook daily as necessary to reach 600 fish per week over an 8-week period between mid-June and mid-August (seasonal total of 4,800 fish).
   c) Transfer PIT tag generated data to PSMFC PITAGIS system daily.
   d) Return to step 8 under Standard Operations

2) Excessive Fish:
   a) Upon estimation by the Bypass Crew that the trap contains too many fish (~5,000 fish) to work up in the allotted time period, the Bypass Foreman will **immediately** contact the Fishway Attendant whose name appears on the **Lock-out Tag** (currently Brad Whitehall ext. 4538) on the main RI Bypass trap gate. The designated Fishway Attendant must be present to operate the gate to let fish pass when additional processing time is needed.
   b) When the number of smolts captured in the RI Bypass trap exceeds the capacity of the holding tank up above (5,000 fish depending on species composition), the Bypass Crew will use extra time to work through ***all of the fish in that sample***. When enough fish have been processed the remaining fish down below can be brought up via hopper elevator. If all fish cannot be removed from trap, then at 9:00 a.m. the main RI bypass gate will be opened to allow the following day's fish to return directly to the river. This will allow more time to work up the current day's fish. Additional water may be added using the new upwelling valve that was added in December 2015.
   c) Following completion of that sample (i.e. empty trap), the main bypass gate will be closed and fish will be counted/evaluated according to normal protocol. The **crew will document the actual trap re-deployment time**, and enter the reduced sample-time into the FPC data link so the following days sample can be properly expanded into 24 hours (for example 21 or 22 hour sample time instead of 24) for the next day's sample. The FPC's SMP site is set up to receive reduced sample times, and provide an expanded estimate for a full 24 hour sample. This is important to maintain index sample consistency and the RI smolt numbers used in UW's Program RealTime run forecaster to predict smolt passage percentiles at RI Dam.
   d) This protocol will allow for minimal error (estimating a full count with only 2-3 hours of missing sample time rather than 12 hours) in achieving an expanded 24-hour trap count.

Bull Trout:

1) Columbia River bull trout are a **federally threatened species** and have federal protection under the **Endangered Species Act (ESA).** The US Fish and Wildlife Service (USFWS) issued a Biological Opinion on the effects to bull trout for incorporating Chelan's HCPs into the Rock Island Project license. The USFWS issued an annual incidental take (injure or kill) level of no more than 2% of the bull

trout passing through the juvenile fish bypass per year. In 2017, if a bull trout is incidentally captured during daily sampling at the Rock Island juvenile sampling facility, please follow these protocols:

2) ***Healthy bull trout:*** If you capture a bull trout during sampling, take a fork length measurement, document condition, scan for any PIT-tags; note the collection time and water temperature. In the event that a tag is detected it should be included in the appropriate days P4 file. After a bull trout is incidentally subjected to anesthesia and identified in the sorting trough, allow for normal recovery time in fresh water and then release the fish back to the pipe.
3) ***Sick or injured bull trout:*** If you capture a sick or injured bull trout during sampling operations, do not retain it unless you are *absolutely positive* that it is destined to die if released (for example, the fish is unable to right itself, is upside down and barely gilling, pupil is non-responsive). If the fish has a possible chance to survive, then follow directions in step 2 above.
4) ***Bull trout mortalities:*** If you encounter a bull trout mortality, please save, identify, and preserve (bag, identify and freeze) the fish, and ***inform Steve Hemstrom ext. 4281 following completion of the Index sampling that day***. Please document and communicate the circumstances in which the fish was found, and any apparent physical injury (including descale) you observe. Scan the fish for any possible PIT-tags and document any tags into that days P4 file. Make arrangements to deliver the specimen to the Fish and Wildlife building at headquarters.
5) ***Sub-adult bull trout PIT Tagging:*** No PIT tagging will occur in 2017.
6) ***Sub-adult bull trout tissue sample:*** No tissue samples will be taken in 2017.

Adult Lamprey:

1) ***Healthy adult lamprey:*** If you capture an adult lamprey in the bypass trap, take an overall measurement, an inner dorsal distance measurement (if possible), document condition, scan for any tags (1/2 and full duplex), and note the time and water temperature. After data is collected, transfer the lamprey and release in a calm spot on the Douglas county side of the forebay. In the event that a tag is detected it should be included in the appropriate days P4 file.
2) ***Sick or injured adult lamprey:*** If you capture a sick or injured adult lamprey during sampling operations, do not retain it unless you are absolutely positive that it is destined to die if released. If the fish has a possible chance to survive, then follow directions in step 1 above.
3) ***Adult lamprey mortalitites:*** If you encounter an adult lamprey mortality, please save, identify, and preserve. Please follow the same procedures as you would for bull trout mortalities.

Adult Steelhead:

1) ***Adult Steelhead:*** If you capture an adult steelhead in the bypass trap, try to determine if it is a kelt or an adult that is yet to spawn. If it is a kelt, record for daily catch info and release back into the fish ladder. If it is a healthy adult that has fallen back, then you may transfer and release it into the forebay in a calm spot upstream of the traveling screens.

White Sturgeon:

1) ***Healthy sturgeon:*** If you capture a sturgeon at R.I. bypass, take a fork length, weigh it if possible, scan for any tags, record condition and any applicable information about scutes (# and side of removed scutes). In the event that a tag is detected it should be included in the appropriate days P4 file. After data is collected, transfer the sturgeon and release in a calm spot on the Douglas county side of the forebay.
2) ***Sick or injured sturgeon:*** If you capture a sick or injured sturgeon during sampling operations, do not retain it unless you are absolutely positive that it is destined to die if released. If the fish has a possible chance to survive, then follow directions in step 1 above.
3) ***Sturgeon mortalities:*** If you encounter a sturgeon mortality, please save, identify, and preserve (if small enough), and **inform Lance Keller ext. 4299**. Please document and communicate the circumstances in which the fish was found, and any apparent physical injury you observe. If the specimen is small enough, take a fork length, weight, and scan for any tags. In the event that a tag is detected it should be included in the appropriate days P4 file. Also record any information regarding scutes (# and side of removed scutes). Arrange to deliver the specimen to the Fish and Wildlife building at headquarters when applicable.

Contingencies:

If, after start-up of the bypass system, we encounter any unforeseen problem(s) with fish collection, we will immediately work to correct the problem(s) and consult with the HCP Coordinating Committee.

C. Statement of BPA's involvement in the Project

The RISMP is a cooperative study between The District, Bonneville Power Administration (BPA), and the FPC. The District will provide supervisory costs for the project as it relates to District personnel, while BPA will pay for the remaining costs of the project. These costs include (but are not limited to) labor, benefits, transportation, miscellaneous materials and administrative overhead.

D. Time Schedule

Sampling will begin on 1 April 2017 and will be completed on 31 August 2017. Samples will be collected from 0900 hrs to 0900 hrs the following day throughout the sampling period.

E. Reporting Tasks

Fieldwork for this project occurs in the 6-month period between April and September. A final report on the 2017 Smolt Monitoring Program will be issued by 31 January 2018.

Place of Operations:

All sampling will take place at the Rock Island Dam Powerhouse No. 2, which is located 15 miles southeast of the city of Wenatchee, at Columbia River mile 453.

Personnel Involved:

The Senior Fisheries Biologist for Chelan County P.U.D. is Lance Keller. He can be reached at (509) 661-4299, fax (509) 661-8108, Email lance.keller@chelanpud.org or mail P.O. Box 1231, Wenatchee WA, 98807.

The Fisheries Biologist for Chelan County P.U.D. is Scott Hopkins. He can be reached at (509) 661-4763, fax (509) 661-8108, Email scott.hopkins@chelanpud.org or mail P.O. Box 1231, Wenatchee WA, 98807.

Fish &Wildlife Operations Superintendant for Chelan County P.U.D. is Todd West. He can be reached during normal working hours at (509) 661-4559, Email todd.west@chelanpud.org or mail P.O. Box 1231, Wenatchee WA, 98807.

The District crew working at Rock Island Dam will be supervised by a Fish & Wildlife Specialist/Foreman.

Fish and Wildlife Helpers who will be working on the project will be hired in the spring of 2017.

COMMENTS AND RECOMMENDATIONS PAGE FOR 2017 FIELD CREW

Appendix J
2017 Wenatchee Steelhead Release Plan
(Brood Year 2016)

Memorandum

Date: March 3, 2017

To: Rock Island and Rocky Reach HCP Hatchery Committees

From: Catherine Willard (CPUD), Scott Hopkins (CPUD), Chris Moran (WDFW), and Mclain Johnson (WDFW)

Re: 2017 Wenatchee Steelhead Release Plan (Brood Year 2016)

<u>Background</u>

Chelan PUD is required to produce 247,300 steelhead smolts for release into the Wenatchee River Basin in 2017 as part of the Rock Island and Rocky Reach HCP requirements. As of February approximately 267,035 Wenatchee summer steelhead (142,224 HxH and 124,811 WxW) are on station at the Facility. Beginning in winter 2011 the Chelan PUD Wenatchee River steelhead program was relocated to the Chiwawa Acclimation Facility ("Facility") (Figure 1) following significant upgrades to accommodate tributary based overwinter acclimation for the Wenatchee steelhead program. Steelhead are transferred from Eastbank Hatchery to the Facility in November and released in April through May. The Facility consists of three, in line circular, dual-drain tanks within an enclosed building and are operated on a partial water reuse system (RAS). The two outer tanks hold steelhead during rearing and the center tank is used solely for receiving fish that are allowed to move from the outer tanks to the center tank during release. Fish are not provided the opportunity to move to the center tank until gates are removed (typically April 20th). When the center tank contains a pre-determined number of fish for a release, fish are loaded into a hatchery truck and truck-planted at one of five release locations. This "screening" method has been used to differentiate between apparent active migrants (fish that move from the outer tanks to the center tank) from apparent non-active migrants (fish that do not move from the outer tank to the center tank).

In addition to the circular vessels, there are three traditional flow-through raceways (RCY) located outside. The smaller of the three, Raceway Three (RCY3), is used to rear steelhead when it is not needed for rearing "high ELISA" spring Chinook juveniles. Raceways One (RCY1) and Two (RCY2) are located adjacent to each other. The wall between the two raceways contains a gated opening that when removed, allows fish to move between the raceways. In addition to removing the gate, the water is lowered in the receiving pond (typically April 20th) to establish a directional flow that apparent active migrant fish may cue to. Similar to the RAS vessels, this set-up allows for a screening method that attempts to differentiate between apparent active- and apparent non-active migrants. When RCY1 contains the pre-determined number of fish suitable for release, fish are loaded into a transport truck and truck-planted at one of five release locations. Historically, this screening method has been termed a volitional release but is currently termed a screening method as this more accurately describes the end result of the action.

2017 Release Strategy Objectives

- Evaluate best hatchery management practices for hatchery releases to optimize homing fidelity, minimize residualism, maximize out-migration survival, and minimize negative ecological interactions (Draft NMFS Wenatchee River Steelhead Section 10 Permit).
- Assess hatchery release practices to inform development of a residualism baseline for the Wenatchee steelhead program consistent with the Draft NMFS Wenatchee River Steelhead Section 10 Permit DRAFT Steelhead Residual Management Plan.
- Utilize data collected from the 2017 Wenatchee River Steelhead release to assess applicable monitoring and evaluation objectives (i.e., Objectives 4 and 6) for the Wenatchee River summer steelhead hatchery program (Hillman et al. 2013).

Methods

The 2017 release strategy will evaluate the effectiveness of the screening method, and the role of rearing vessel (RAS versus RCY) and brood origin on fish performance (e.g., juvenile survival and adult returns). The 2017 release plan methodology will consist only of screened releases; release years 2015 and 2016 evaluated screened and non-screened releases. Additionally, 2,500 PIT tags will be applied to non-movers remaining in RCY2 at the end of the screened release period to increase the PIT sample size of non-movers to better understand their post release performance. As with previous years, the release numbers and locations identified in Table 1 are proportionally based on the spawning distributions in the respective streams.

- Cormack-Jolly–Seber survival probabilities to MCN will be calculated for each release group using recaptures of PIT-tagged fish.
- The percentage of PIT-tagged fish detected in the Wenatchee sub-basin after July 1 of the year of release will be calculated to estimate potential residualism for each release group.

Release Timing

In an effort to more closely align hatchery steelhead releases with the peak outmigration period for wild steelhead and potentially increase smolt to smolt survival, all fish located at the Facility will be released by May 8th; fish acclimated at Blackbird Island Pond will be allowed to volitionally move out of the pond through the end of June (after which time the pond outlet will be closed as in years past).

Release Location

Release locations in 2017 will be the same as the previous two years.

Pre-release Monitoring and Evaluation

Throughout acclimation and release, established sampling, transfer and release protocols will be followed (Hillman et al. 2013). Additionally, to gain an additional year of data for the RAS reared steelhead that are screened, assessment of smolt index and precocial maturation will be conducted via non-lethal sampling from the two screened RAS vessels (n=200 movers; n= 200 non-movers).

Table 1. Steelhead release numbers and locations, 2017.

Vessel	Origin[1]	Estimated Number Released[2]	Estimated # PIT-tagged	Destination	rkm	Movers or Non-movers
RAS3	WxW	11,971[3]	2,375	Nason	7.0	Movers
RCY1	Mixed	38,210	2,181	Nason	7.0	Movers
RAS1	WxW	11,720[3]	2,375	Nason	7.0	Movers
		61,901		**Total**		
RCY1	Mixed	78,299	4,469	U. Wenatchee	79.2	Movers
		78,299		**Total**		
RCY1	Mixed	73,379	4,188	Chiwawa	11.4	Movers
		73,379		**Total**		
RCY1	Mixed	Unknown	Unknown	L. Wenatchee	40.2	Non-movers
RAS1	WxW	Unknown	Unknown	L. Wenatchee	40.2	Non-movers
RAS3	WxW	Unknown	Unknown	L. Wenatchee	40.2	Non-movers
ELISA	HxH	24,952	2,500	Blackbird	40.5	Movers

[1]Mixed = HxH and WxW.
[2]Releases will occur April 20 - May 8; any remaining non-movers will be released by May 8th.
[3]Maximum estimated number of fish to be released; non-movers have not been subtracted from these totals.

Figure 1. Chiwawa Acclimation Facility site description.

REFERENCES

Hillman, T., T. Kahler, G. Mackey, J. Murauskas, A. Murdoch, K. Murdoch, T. Pearsons, and M. Tonseth. 2013b. Monitoring and evaluation plan for PUD Hatchery Programs, 2013 update. Report to the HCP and PRCC Hatchery Committees, Wenatchee, WA.

Appendix K
2017 Fish Spill Plan Rock Island and Rocky Reach Dams

2017 Fish Spill Plan

Rock Island and Rocky Reach Dams

Public Utility District No. 1 of Chelan County

Prepared By:

Thad Mosey
Fisheries Biologist

Public Utility District No. 1 of Chelan County
Wenatchee, Washington

Final
March 28, 2017

Introduction and Summary

In 2017, Public Utility No. 1 of Chelan County (Chelan PUD) will implement spill operations for fish passage at the Rock Island and Rocky Reach and projects. Spill timing and spill percentages are specified by the anadromous Habitat Conservation Plans (HCP) for each respective project. Chelan PUD conducted juvenile project survival studies from 2002 through 2011 at Rocky Reach and Rock Island under varying spill levels in order to achieve HCP survival standards. The Rock Island Project completed multiple survival studies over a nine year period (17 total studies) for spring migrating Plan Species (yearling Chinook, steelhead, sockeye), first using a 20 percent spill level, then a 10 percent spill level. Rock Island will continue to spill 10 percent of day average flow during the spring outmigration period through at least year 2020. Rocky Reach completed its suite of HCP survival studies for spring migrating Plan Species in 2011 (14 studies), under spill and no-spill operation at the dam. HCP juvenile survival standards were achieved for species tested with a no spill operation (yearling Chinook, steelhead, sockeye). Project spill levels are summarized in Tables 2 and 4 of this plan. Chelan PUD holds valid Incidental Take Statements (ITS) from National Oceanic and Atmospheric Administration Fisheries (NOAA) and the United States Fish and Wildlife Service (USFWS) for HCP fish spill operations at Rocky Reach and Rock Island dams.

For the 2017 juvenile outmigration, Chelan PUD will operate the Rocky Reach juvenile fish bypass system (JFBS) starting 1 April for the spring juvenile outmigration of yearling Chinook, steelhead, and sockeye. Spring spill at Rocky Reach Dam will consist of hydraulic spill for reservoir control only. HCP Project survival standards were achieved with bypass-only operations. During the subyearling Chinook outmigration in 2017, Rocky Reach will spill 9 percent of day average river flow for a duration covering 95 percent of subyearling outmigration past the dam.

At Rock Island Dam in 2017, Chelan PUD will operate the Project with a 10 percent day-average spill level for the spring outmigration period. Rock Island has also completed HCP spring Plan Species survival testing for all Plan Species with a 10 percent spill level at the dam and has achieved juvenile survival standards for yearling Chinook, steelhead and sockeye and combined adult-juvenile survival for all three species.

During the summer period in 2017, Rock Island Dam will spill 20 percent of the day-average river flow for the outmigration of subyearling (summer) Chinook. Spill is the primary means of juvenile salmon and steelhead passage at Rock Island per Section 5.4.1(a) of the Rock Island HCP. Spring and summer spill will cover 95 percent of the juvenile fish outmigration for yearling/subyearling Chinook, steelhead, and sockeye in 2017.

Rocky Reach Juvenile Fish Bypass Operations

Rocky Reach will operate its JFBS continuously through the spring outmigration period, beginning 1 April 2017. Daily index sampling (for steelhead, yearling Chinook, and sockeye) will be performed at the bypass sampling facility to estimate the outmigration percentiles for each species through the spring period. During "index sampling" each day, a total of four 30-minute samples (Table 1) will be taken beginning at the top of each hour, 0800 to 1100 hours. Spring spill for fish passage is not required at Rocky Reach in addition to the JFBS operation, but periods of forced spill may occur under high river flows. Some level of forced spill (river flow above 201 kcfs turbine capacity) normally occurs at Rocky Reach in the spring. Over the past 20 years, forced spill has occurred approximately 28 percent of all hours, April through June.

Sampling protocols at the Rocky Reach bypass system in 2017 will remain consistent with those used in 2004-2016. Daily sampling in spring and summer periods (Monday through Sunday) will use four 30-minute "index periods" at 0800, 0900, 1000, and 1100 hours (Table 1). The sample target for each 30-minute sample will be 350 smolts during the spring period (yearling Chinook, steelhead, and sockeye combined), and 125 smolts for summer period (subyearling Chinook). If the number of fish collected in the bypass sampling raceway is estimated to reach the maximum number prior to completion of the 30-minute sample, the sampling screen will be retracted from the bypass conduit, and the number of fish collected in the shortened sample period will be proportionately expanded to the entire 30-minute period.

Table 1. Index sampling times at the Rocky Reach juvenile fish bypass and the number of smolts per sample. Sample times and sample targets have remained consistent since 2004.

Time	Sample Duration	Number of Smolts	Day of Week
08:00-08:30	30 minutes*	350 (spring) 125 (summer)	Monday-Sunday
09:00-09:30	30 minutes*	350 (spring) 125 (summer)	Monday-Sunday
10:00-10:30	30 minutes*	350 (spring) 125 (summer)	Monday-Sunday
11:00-11:30	30 minutes*	350 (spring) 125 (summer)	Monday-Sunday

*Sample duration may be less than 30 minutes if smolt numbers are met prior to full 30 minute sample time

Rocky Reach 2017 Summer Spill Operations

Rocky Reach Dam will spill 9 percent of the estimated day average river flow for the subyearling Chinook outmigration (Table 2). Spill will commence in late May to early June upon arrival of subyearling Chinook smolts in the Rocky Reach bypass samples. Juvenile run-timing information at Rocky Reach will be used to estimate subyearling Chinook passage percentiles (from the University of Washington's Program RealTime run forecaster) and guide spill operations to cover 95 percent of the summer outmigration. Actual subyearling counts in combination with juvenile passage estimates from the University of Washington's Program RealTime run forecaster will determine start and stop dates for the summer spill program.

The HCP guidelines for starting and ending summer spill at Rocky Reach are as follows:

1. Summer spill will start at midnight no later than the day on which the estimated 1-percentile passage point is reached, as indicated by Program RealTime run-forecast model. Subyearling Chinook will be defined as any Chinook having a fork length from 76 to 150 mm.

2. Summer spill season will generally end no later than 15 August, but not until subyearling index counts from the juvenile bypass sampling facility are 0.3 percent or less of the cumulative run for three out of any five consecutive days (same protocol used 2004-2016) and Program RealTime is estimating that the 95th percentile passage point has been reached. In addition, spill operations must cover at least 95% of the subyearling outmigration

Diel Spill Shaping at Rocky Reach and Rock Island Dams

Daily spill volumes will be shaped within each 24-hour period at Rocky Reach Dam during the summer spill period, and at Rock Island Dam during both spring and summer spill periods (Tables 2 and 4).

Spill-shaping attempts to optimize spill water volume to maximize spill passage effectiveness for smolts. The diel spill shape functions to provide either higher or lower spill volume during periods of either higher or lower fish passage. Spill-shaping is based on the observed diel (24-hour) passage distributions of smolts at each project during spring and summer (Steig et al. 2009, Steig et al. 2010, Skalski et al. 2008, Skalski et al. 2010, Skalski et al. 2011, Skalski et al. 2012). The different spill percentages and time blocks are shaped such that the summation of water volume from all time blocks within the day equals the volume of water that would have been spilled under a constant, unshaped spill level (i.e. spill at 9 percent day-average river flow at Rocky Reach with no shaping). The hourly spill shape in 2017 will remain consistent with previous years, 2004-2016. Spill gates 2 through 8 will be used to meet daily spill percentage targets.

Table 2. Fish spill percentages and spill shape for the Rocky Reach spill program, 2017.

Project	Season	Daily Spill Average	Within-Day Spill Levels	Duration (# of hours each day)	Hourly Blocks of Spill	Spill Shape %
Rocky Reach	Spring	none	--	--	--	--
Rocky Reach	Summer*	9%	Med	1	0000-0100	9.0
			Low	6	0100-0700	6.0
			Med	2	0700-0900	9.0
			High	6	0900-1500	12.0
			Med	9	1500-2400	9.0

*Spill for subyearling Chinook

2017 Run-Timing Predictions

Chelan PUD contracts with the University of Washington (UW) to provide run-timing predictions and year-end observed values for spring and summer out-migrating percentiles for salmon and steelhead. UW's Program RealTime run-time forecasting model is used for this purpose. Program Real-Time provides daily forecasts and cumulative passage percentiles for steelhead, yearling/subyearling Chinook and sockeye at both Rocky Reach and Rock Island dams. This program enables Chelan PUD to better predict the time when a selected percentage of these species will arrive, and when a given percentage of any stock has passed. The program utilizes daily fish counts from the Rocky Reach bypass sampling facility and the juvenile fish bypass trap at Rock Island Dam. Estimates of passage percentiles are generated with the model's forecast error and are displayed with the daily predictions at:

http://www.cbr.washington.edu/crisprt/

Historic Run Timing

Estimated mean passage dates (first percentile to the 95th percentile) for each species at Rocky Reach and Rock Island dams are summarized in Table 3. Run-timing dates are estimated from daily index sample counts at the Rocky Reach JFBS (2004-2016), and from the Rock Island bypass trap, (2002-2016). At Rocky Reach Dam, the subyearling Chinook run generally begins the first week of June, with the one-percentile passage date on 31 May (mean date for years 2004-2016). Rocky Reach subyearling passage reaches the 95th percentile, on average, around 7 August (2004-2016, range: 21 July to 24 August).

Rock Island Dam juvenile salmon and steelhead sampling from the Smolt Monitoring Program (SMP; 2002-2016) indicates that the first percentile (one-percent passage) mean passage date for combined spring migrants (yearling Chinook, steelhead, and sockeye) occurs around 18 April (Table 3). The latest spring spill start date for Rock Island Dam per the HCP is 17 April. The summer outmigration of subyearling Chinook smolts at Rock Island Dam generally begins in early June (although fry are encountered earlier), and on average, reaches the 95th percentile passage point around 7 August (range: 22 July to 19 August, 2002-2016).

Table 3. Spill percentages, bypass operation dates, and mean passage percentile dates (2002-2016) for the 1st and 95th percentile passage points for HCP spring and summer outmigrants at Rocky Reach and Rock Island dams.

Rocky Reach	**steelhead**	**yearling Chinook**	**sockeye**	**subyearling Chinook**
Percent Spill	0% Spring	0% Spring	0% Spring	9% Summer
1st, 95th percentile Passage Dates	4/16, 5/30	4/15, 5/28	5/5, 5/24	5/31, 8/7
RR Bypass System Operation	4/1 – 8/31	4/1 – 8/31	4/1 – 8/31	4/1 – 8/31
Rock Island	**steelhead**	**yearling Chinook**	**sockeye**	**subyearling Chinook**
Percent Spill	10% Spring	10% Spring	10% Spring	20% Summer
1st, 95th percentile Passage Dates	4/22, 6/7	4/15, 6/2	4/16, 6/6	6/2, 8/7
RI Bypass Trap Operation	4/1 - 8/31	4/1 - 8/31	4/1 - 8/31	4/1 - 8/31

Source - Rock Island: http://www.cbr.washington.edu/crisprt/index_midcol2_pi.html

Source- Rocky Reach: http://www.cbr.washington.edu/crisprt/index_midcol2_che.html

Rock Island 2017 Spring Spill Operations

In 2017, Rock Island Dam will spill 10 percent of the estimated day average river flow starting no later than 17 April and will end spill after 95 percent of spring outmigrants have passed the dam (usually the first week of June), with spill being provided for at least 95% of the spring species outmigration. Spill volume will be shaped to maximize spill efficiency (Table 4). Chelan PUD personnel will operate the Rock Island bypass trap, an upper Columbia SMP site, continuously from 1 April through 31 August (seven days per week) to provide daily smolt counts. Index counts will provide the basis to determine the start and end of the spring and summer outmigration periods. The HCP guidelines to start and end the spring spill program at Rock Island Dam are as follows:

1. The Rock Island spring spill program will begin when the daily smolt passage index count exceeds 400 fish for more than 3 days (this corresponds to the approximately 5 percent passage date), or no later than 17-April, as outlined in Section 5.4.1. (a) of the Rock Island HCP.

2. Rock Island spring spill will end 1) following completion of the spring outmigration (95 percent passage point), and 2) when subyearling (summer) Chinook have arrived at the Project.

Operators will utilize the following spill gate sequence to meet daily spill percentage targets: 32, 31, 30, 1, 26, 16, 18, 24, 29, 17, 19, 20, 22, 25, 7, and 8.

Rock Island 2017 Summer Spill Operations

Rock Island will spill 20 percent of the estimated daily average river flow for a duration covering 95 percent of the summer outmigration of subyearling Chinook. Daily smolt counts from the Rock Island bypass trap will inform decisions on when to start and stop spill. The HCP guidelines to start and stop summer spill at Rock Island Dam are outlined as follows:

1. Rock Island summer spill in 2017 will begin immediately after completion of the spring spill. The summer spill level will be 20 percent of day average flow, shaped to increase spill efficiency. Spill will continue for a duration covering 95 percent of the subyearling Chinook outmigration.

2. Summer spill will generally end no later than 15 August, or when subyearling Chinook counts from the Rock Island trap are 0.3 percent or less of the cumulative run total for

three out of any five consecutive days, and UW's Program RealTime is estimating 95 percent run completion (same protocol used in 2004-2016).

Operators will utilize the following spill gate sequence to meet daily spill percentage targets: 32, 31, 30, 1, 26, 16, 18, 24, 29, 17, 19, 20, 22, 25, 7, and 8.

Table 4. Spill percentages and hourly spill shape for the Rock Island spring and summer fish spill program, 2017.

Project/Season	Daily Spill Average	With-in Day Spill Levels	Duration (# of hours each day)	Hourly Blocks of Spill	Spill Shape %
Rock Island Spring*	10%	High	4	0000-0400	12.5
		Med	3	0400-0700	10.0
		Low	5	0700-1200	6.0
		Med	8	1200-2000	10.0
		High	4	2000-2400	12.5
Rock Island Summer**	20%	High	1	0000-0100	23.0
		Med	1	0100-0200	19.0
		low	8	0200-1000	15.0
		Med	1	1000-1100	19.0
		High	13	1100-2400	23.0

*Spring spill for yearling Chinook, steelhead, and sockeye; **summer spill for subyearling Chinook.

Spill Program Communication

Chelan PUD's HCP representative will notify the HCPCC not less than once per week when fish passage numbers indicate that specific triggers for starting or stopping spill are likely to occur in the immediate future. Chelan PUD will notify the HCPCC regarding any unforeseen issues that pertain to the spill program as the season progresses. Communications with the HCPCC on spill information will generally be made by email, pre-scheduled conference calls, and HCPCC monthly meetings.

Literature Cited

Skalski, J.R., R.L. Townsend, T.W. Steig, and P.A. Nealson. 2012. Survival, Diel Passage, and Migration Dynamics of Yearling Chinook Salmon Smolts at Rocky Reach Dam in 2011. Prepared for Public Utility District of Chelan County, Wenatchee, WA. Columbia Basin Research School of Aquatic and Fishery Sciences, University of Washington. Final Report, January 2012.

Skalski, J.R., R.L. Townsend, T.W. Steig, and P.A. Nealson. 2011. Survival, Diel Passage, and Migration Dynamics of Yearling Chinook Salmon Smolts at Rocky Reach Dam in 2010. Prepared for Public Utility District No. 1 of Chelan County, Wenatchee, WA. Columbia Basin Research School of Aquatic and Fishery Sciences, University of Washington. Final Report, February, 2011.

Skalski, J.R., R.L. Townsend, T.W. Steig, and P.A. Nealson. 2010. Survival, Diel Passage, and Migration Dynamics of Sockeye Smolts at Rocky Reach Dam in 2009. Prepared for Public Utility District No. 1 of Chelan County, Wenatchee, WA. Columbia Basin Research School of Aquatic and Fishery Sciences, University of Washington. Final Report, January, 2010.

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Steig, T.W., P.A. Nealson, K.K. Kumagai, B.J. Rowdon, J.R. Selleck and C. Tunnicliffe. 2009. Route specific passage of juvenile Chinook, sockeye and steelhead salmon using acoustic tag methodologies at Rocky Reach and Rock Island Dams in 2009. Draft report for Chelan County Public Utility District No. 1, Wenatchee, WA, by Hydroacoustic Technology, Inc. Seattle, WA.

Steig, T.W., P.A. Nealson, K.K. Kumagai, B.J. Rowdon, J.R. Selleck and C. Tunnicliffe. 2010. Route specific passage of yearling Chinook and steelhead salmon using acoustic tag methodologies at Rocky Reach and Rock Island Dams in 2010. Draft report for Chelan County Public Utility District No. 1, Wenatchee, WA, by Hydroacoustic Technology, Inc. Seattle, WA.

Appendix L
2017 Rock Island and Rocky Reach HCP Action Plan

2017 Rocky Reach and Rock Island
HCP Action Plan - Final

COORDINATING COMMITTEE

Activity	Start	End
Deliver 2016 RR Bypass Evaluation Report	D (Feb 1)	F (Mar 15)
Deliver 2017 RR Bypass Operations Plan	D (Feb 1)	F (Mar 31)
Deliver 2016 RI Bypass Evaluation Report	D (Feb 1)	F (Mar 31)
Deliver 2017 RI Bypass Operations Plan	D (Feb 1)	F (Mar 15)
Pikeminnow long-line control programs	S (Feb 1)	C (Nov 30)
Pikeminnow angling control programs	S (May 1)	C (Oct 15)
Avian Predation programs	S (Apr 1)	C (Aug 31)
Piscivorous Bird Monitoring	S (Apr 1)	C (Dec 31)
Deliver 2017 RR/RI Spill Plan	D (Mar 1)	F (Apr 1)
Deliver 2017 RR/RI Spill Report	D (Sep 15)	F (Oct 15)
RR 9% Summer Spill	S (Jun 1)	C (Aug 15)
RI 10% Spring Spill	S (Apr 15)	C (Aug 15)
RI 20% Summer Spill	S (Jun 1)	C (Aug 15)
RR Juvenile Fish Bypass Operations	S (Apr 1)	C (Aug 31)
Coho Survival Standards SOA	D (Jan 1)	C (Apr 1)
RI Juvenile Bypass Trap Operations	S (Apr 1)	C (Aug 31)
2016 HCP Annual Report	D (Mar 1)	F (Apr 1)

HATCHERY COMMITTEE

Activity	Start	End
2016 Hatchery M & E Report	D (Jun 15)	F (Sep 1)
2018 Hatchery M & E work plans	D (Aug 1)	F (Oct 1)
Dryden Water Quality Monitoring (Year 6)	S (Mar 1)	C (May 1)
Coho NNI Mitigation	S (Apr 1)	F (Dec 31)
Chelan Falls Broodstock Collection Canal Trap Pilot	S (Jul 15)	C (Sep 30)
Chelan Hatchery Rehabilitation Feasibility	D (Jan 1)	
Pilot Outplant adult MetComp spr Chinook to Chewuch	S (Aug 15)	F (Sep 30)
Steelhead Residualism Plan - *Permit No. 18583*	D (Jan 1)	F (Sep 1)
Hatchery Program Broodstock Collection	S (May 1)	C (Dec 15)
Hatchery Releases	S (Apr 15)	C (May 1)
Receive Methow spring Chinook Permit		C (Mar 15)
Receive Wenatchee Steelhead Permit		C (Mar 15)

TRIBUTARY COMMITTEE

Activity	Start	End
RR and RI Plan Species Account Annual Deposit		C (Jan 31)
General Salmon Fund Approval	→ Ongoing	
General Salmon Fund Implementation	→ Ongoing	
Small Project Review and Approval	→ Ongoing	
Small Project Implementation	→ Ongoing	

D = Draft Document
F = Final Document

S = Start Project
C = Complete Project

Appendix M
Draft Upper Columbia River 2017 BY Salmon and 2018 BY Steelhead Hatchery Program Management Plan and Associated Protocols for Broodstock Collection, Rearing/Release, and Management of Adult Returns

STATE OF WASHINGTON
DEPARTMENT OF FISH AND WILDLIFE
Wenatchee Research Office
3515 Chelan Hwy 97-A Wenatchee, WA 98801 (509) 664-1227 FAX (509) 662-6606

April 7, 2017

To: HCP HC and PRCC HSC

From: Mike Tonseth, WDFW

Subject: **DRAFT UPPER COLUMBIA RIVER 2017 BY SALMON AND 2018 BY STEELHEAD HATCHERY PROGRAM MANAGEMENT PLAN AND ASSOCIATED PROTOCOLS FOR BROODSTOCK COLLECTION, REARING/RELEASE, AND MANAGEMENT OF ADULT RETURNS**

The attached protocol was developed for hatchery programs rearing spring Chinook salmon, summer Chinook salmon and summer steelhead associated with the mid-Columbia HCPs; spring Chinook salmon, summer Chinook salmon and steelhead programs associated with the 2008 Biological Opinion for the Priest Rapids Hydroelectric Project (FERC No. 2114); and fall Chinook salmon consistent with Grant County Public Utility District and Federal mitigation obligations associated with Priest Rapids and John Day dams (ACOE funded), respectively. These programs are funded by Chelan, Douglas, Grant County Public Utility Districts (PUDs), and ACOE and are operated by the Washington Department of Fish and Wildlife (WDFW), with the exception of the Omak Creek/Okanogan Basin steelhead broodstock collection, and acclimation/release of Omak Creek steelhead which is implemented by the Confederated Tribes of the Colville Reservation (CTCR).

This protocol is intended to be a guide for 2017 collection of salmon (2017BY) and steelhead (2018BY) broodstocks in the Methow, Okanogan, Wenatchee, and Columbia River basins. It is consistent with previously defined program objectives such as program operational intent (i.e., conservation and/or harvest augmentation), mitigation production levels (e.g., HCPs and Priest Rapids Salmon and Steelhead Settlement Agreement), changes to programs as approved by the HCP-HC and PRCC-HSC, and to comply with ESA permit provisions, USFWS consultation requirements.

Notable in this year's protocols are:

- Continuing for 2017, no age-2 or 3 males will be incorporated into spring or summer Chinook programs unless necessary to maintain effective population size (minimum female to male ratio of 1:0.75; conservation programs only).

- Use of ultrasonography to determine the sex of each fish retained for brood to ensure achieving the appropriate number of females for program production (does not include Priest Rapids Hatchery).

- Utilization of genetic sampling/assessment to differentiate Twisp River and Methow River Basin natural-origin spring Chinook adults collected at Wells Dam, and CWT interrogation during spawning of hatchery spring Chinook collected at the Twisp Weir and Methow FH to differentiate Twisp and Methow Composite hatchery fish for discrete management of Twisp and Methow Composite production components for the GPUD, CPUD and DPUD programs.

- Collection of only hatchery adult steelhead at Wells Dam/Hatchery for the Lower Methow safety-net (WFH/MFH), and Wells Hatchery Okanogan and mainstem Columbia safety-net programs.

- Collection of spring Chinook for the Nason Creek and Chiwawa programs using combination of Tumwater Dam and the Chiwawa Weir.

- Targeted collection of 100% of the Wenatchee summer Chinook and Wenatchee hatchery origin steelhead broodstock at Dryden Dam to reduce the number of activities that may contribute to delays in fish passage at Tumwater Dam (some adult collections at Tumwater may be necessary if sufficient adults cannot be acquired at Dryden Dam).

- Targeted collection of 100% of the natural origin steelhead broodstock at Tumwater Dam.

- Collection of summer Chinook broodstock from the Chelan Falls Canal Trap (CFCT), sufficient to meet the entire Chelan Falls yearling program of 576K. Summer Chinook collections at Entiat Hatchery may be used to support the Chelan Falls program if broodstock collection efforts at the CFCT fall short.

- Collection of surplus hatchery origin steelhead from the Twisp Weir (up to 25% of the required broodstock) to produce the 100K Methow safety-net on-station-released smolts (up to 17 adults). The remainder of the broodstock (51) will be WNFH returns collected at WNFH (or by angling/trapping for WNFH program) and/or Methow Hatchery and surplus to the WNFH program needs. Collection of Wells stock may be used if WNFH and Twisp returns are insufficient. The collection of adults will occur in spring of 2018.

- Summer Chinook collections at Wells Dam to support the CJH program may occur if CCT broodstock collection efforts fail to achieve broodstock collection objectives.

- Collection of ad-clipped only (no wire) spring Chinook adults (or possibly eggs identified through CWTs from ad-clipped +CWT CJH segregated returns)may occur from facilities in the Methow basin and/or Wells Dam. These alternative collection locations will only be used if CCT and USFWS broodstock collection efforts fail to achieve broodstock collection objectives for the CJH segregated program, or if conditions (e.g., spill at CJD, ladder/trap efficiency) appear unconducive to efficient collection of broodstock.

Collection will run concurrent with spring Chinook broodstock collection for Methow Hatchery.

- Collection from the Wells Hatchery volunteer channel of Wells summer Chinook to support the YN, Yakima River summer Chinook program.

- Targeted collection of 1,000 adipose present, non-coded wire tagged fall Chinook from the PRD OLAFT.

- Targeted collection of about 400 adipose present, non-coded wire tagged fall Chinook using hook and line efforts in the Hanford Reach.

These protocols may be adjusted in-season, based on actual run monitoring at mainstem dams and/or other sampling locations. Additional adaptive management actions as they relate to broodstock objectives may be implemented as determined by the HCP-HC or PRCC-HSC and within the boundaries of applicable permits.

Also included in the 2017 Broodstock Collection Protocols are:

Appendix A: 2017 BY Biological Assumptions for UCR Spring, Summer, and Fall Chinook and 2018 BY Summer Steelhead Hatchery Programs
Appendix B: Current Brood Year Juvenile Production Targets, Marking Methods, Release Locations
Appendix C: Return Year Adult Management Plans
Appendix D: Site Specific Trapping Operation Plans
Appendix E: Columbia River TAC Forecast
Appendix F: Annual Chelan, Douglas, and Grant County PUD RM&E Implementation Plans
Appendix G: DRAFT Hatchery Production Management Plan

Methow River Basin

Spring Chinook

Inclusion of natural-origin fish in the broodstock will be prioritized for the aggregate conservation program in the Methow Basin. Collections of natural-origin fish will not exceed 33% of the Methow Composite (i.e., non-Twisp) and Twisp natural-origin run escapement consistent with take provisions in Section 10 (a)(1)(A) Permits 18925 and 20533.

Hatchery-origin spring Chinook, if needed, will be collected in numbers excess to program production requirements to facilitate BKD management, comply with ESA Section 10 permit take provisions, and to meet programmed production shortfalls with natural origin fish. Based on historical Methow FH spring Chinook ELISA levels above 0.12, any hatchery origin spring Chinook broodstock collection will include hatchery origin spring Chinook in excess to broodstock requirements by approximately 33.3% (based upon the most recent 5-year mean

ELISA results for the Methow/Chewuch program; 11.8% for the Twisp program). For purposes of BKD management and to comply with maximum production levels and other take provisions specified in ESA Section 10 permits 18925 and 20533, culling will include the destruction of eggs from hatchery-origin females with ELISA levels greater than 0.12 and/or that number of hatchery origin eggs required to maintain production at 223,765 yearling smolts. Culling of eggs from natural-origin females will not occur unless their ELISA levels are determined by WDFW Fish Health to be a substantial risk to the program. Progeny of natural-origin females, with ELISA levels greater than 0.12, may be differentially tagged for evaluation purposes. Annual monitoring and evaluation of the prevalence and level of BKD and the efficacy of culling returning hatchery- and natural-origin spring Chinook will continue and will be reported in the annual monitoring and evaluation report for this program.

WDFW genetic assessment of natural-origin Methow spring Chinook (Small et al. 2007) indicated that Twisp natural-origin spring Chinook can be distinguished, via genetic analysis, from non-Twisp spring Chinook with a high degree of certainty. The Wells HCP Hatchery Committee accepted that Twisp-origin fish could be genetically assigned with sufficient confidence and that natural origin collections can occur at Wells Dam. Scale samples and non-lethal tissue samples (fin clips) for genetic/stock analysis will be obtained from adipose-present, non-CWT, non-ventral-clipped spring Chinook (suspected natural-origin spring Chinook) collected at Wells Dam, and origins assigned based on genetic analysis. Natural-origin fish retained for broodstock will be PIT tagged (pelvic girdle) for cross-referencing tissue samples/genetic analyses. Tissue samples will be preserved and sent to the WDFW genetics lab in Olympia Washington for genetic/stock analysis. Spring Chinook collected from Wells will be held until genetic analysis results are received (unless adult holding is not yet available due to the Wells modernization project, in which case fish will be held at Methow FH pending results), then transferred to and retained at Methow Hatchery and spawned for each program depending on results of DNA analysis. Brood collection of NORs at Wells will be based upon assignment of Twisp NORs to the Twisp program and non-Twisp NORs being used to support Methow and Chewuch River releases. Spring Chinook collected at Methow Hatchery will be held at MFH until genetic analysis results are received and then handled accordingly.

The number of natural-origin Twisp and Methow Composite (non-Twisp) spring Chinook retained will be dependent upon the number of natural-origin adults returning and the collection objective limiting extraction to no greater than 33% of the natural-origin spring Chinook return to the Methow Basin. Natural origin fish not assigning to the Twisp or Methow Composite will be released back into the Columbia River.

Weekly estimates of the passage of Wells Dam by natural-origin spring Chinook will be provided through stock-assessment and broodstock-collection activities. This information will facilitate in-season adjustments to collection composition so that extraction of natural-origin spring Chinook remains no more than 33%. Trapping at the Winthrop NFH will be included, if needed, in the event of broodstock shortfalls.

Pre-season run-escapement of Methow-origin spring Chinook to Wells Dam during 2017 is estimated at 3,265 spring Chinook, including 2,292 hatchery and 973 natural origin spring Chinook (Table 1 and Table 2). In-season estimates of natural-origin spring Chinook will be adjusted proportional to the estimated returns to Wells Dam at weekly intervals and may result in adjustments to the broodstock collection targets presented in this document.

The following broodstock collection protocol was developed based on BKD management strategies, projected return for BY 2017 Methow Basin spring Chinook at Wells Dam (Table 1 and Table 2), and assumptions listed in Appendix A.

The 2017 aggregate Methow spring Chinook broodstock collection will target up to 122 adult spring Chinook (18 Twisp, 104 Methow; Table 3). Based on the pre-season run forecast, Twisp fish are expected to represent about 5% of the CWT tagged hatchery adults and 18% of the natural origin spring Chinook passing above Wells Dam (Tables 1 and 2). Based on this proportional contribution and a collection objective to limit extraction to no greater than 33% of the age-4 and age-5 natural-origin spawning escapement to the Twisp, the 2017 Twisp origin broodstock collection will total 18 wild fish, representing 100% of the broodstock necessary to meet Twisp program production of 30,000 smolts. Methow Composite fish are expected to represent about 42% of the CWT tagged hatchery adults and 82% of the natural origin spring Chinook passing above Wells Dam (Tables 1 and 2). Based on this proportional contribution and a collection objective to limit extraction to no greater than 33% of the age-4 and age-5 natural-origin recruits, the 2017 aggregate Methow broodstock collection will total 104 natural origin spring Chinook. Broodstock collected for the aggregate Methow programs represents 100% of the broodstock necessary to meet the Methow programs production of 223,765 smolts. The Twisp River releases will be limited to releasing progeny of broodstock identified as wild Twisp and or known Twisp hatchery origin fish, per ESA Permit 18925. The MetComp releases will include progeny of broodstock identified as wild non-Twisp origin (or known Methow Composite hatchery origin if needed to meet shortfalls in the production goal) fish. Age-3 males ("jacks") will not be collected for broodstock.

Table 1. Brood year 2012-2014 age class-at-return projection for wild spring Chinook above Wells Dam, 2017.

Brood year	**Smolt Estimate**		**Age-at-return**										
			Twisp Basin					**Methow Basin**				
	Twisp[1]	Methow Basin[2]	Age-3	Age-4	Age-5	Total	SAR[3]	Age-3	Age-4	Age-5	Total	SAR[4]
2012	12,277	35,976	9	71	**11**	91	0.0074	47	615	**126**	788	0.0219
2013	24,605	36,242	19	**142**	21	182	0.0074	48	**619**	127	794	0.0219
2014	28,380	41,353	**21**	164	25	210	0.0074	**54**	707	145	906	0.0219
Estimated 2017 Return			**21**	**142**	**11**	**174**		**54**	**619**	**126**	**799**	

1 *Smolt estimate is based on sub-yearling and yearling emigration (Charlie Snow, personal communication).*
2 *Estimated Methow Basin smolt emigration based on Twisp Basin smolt emigration, proportional redd deposition in the Twisp River and Twisp Basin smolt production estimate.*
3 *Geometric mean Twisp NOR spring Chinook SAR to Wells Dam estimated using natural origin PIT tag returns (BY 2003-2009; David Grundy, personal communication).*
4 *Geometric mean Methow NOR spring Chinook SAR to Wells Dam estimated using natural origin PIT tag returns (BY 2003-2009; David Grundy, personal communication).*

Table 2. Brood year 2012-2014 age class and origin run escapement projection for UCR spring Chinook at Wells Dam, 2017.

	Projected Escapement											
	Origin								Total			
	Hatchery				Wild				Methow Basin			
Stock	**Age-3**	**Age-4**	**Age-5**	**Total**	**Age-3**	**Age-4**	**Age-5**	**Total**	**Age-3**	**Age-4**	**Age-5**	**Total**
MetComp	188	473	12	**673**	54	619	126	**799**	242	1,092	138	**1,472**
%Total				41.5%				82.1%				56.7%
Twisp	16	47	12	**75**	21	142	11	**174**	37	189	23	**249**
%Total				4.6%				17.9%				9.6%
Winthrop (MetComp)	324	1,189	31	**1,544**					324	1,189	31	**1,544**
%Total				53.9%								33.7%
Total	528	1,709	55	**2,292**	75	761	137	**973**	603	2,470	192	**3,265**

Table 3. Number of broodstock needed for the combined Methow spring Chinook conservation program production obligation of 223,765 smolts, collection location, and mating strategy.

By obligation	Production target	Number of Adults: Hatchery	Number of Adults: Wild	**Total**		
Chelan PUD	60,516		16F/16M	**32**		
Douglas PUD	29,123		8F/8M	**16**		
Grant PUD	134,126		37F/37/M	**74**		
Total	**223,765**		**61F/61/M**	**122**		
By program		Number of Adults: Hatchery	Number of Adults: Wild	**Total**	Collection location	Mating protocol
Twisp	**30,000**		**9F/9M**	**18**	Wells Dam/Twisp Weir	2x2 factorial
MetComp	**193,765**		**52F/52M**	**104**	Wells Dam/Methow Hatchery	2x2 factorial
Total	**223,765**		**61F/61M**	**122**		

Trapping at Wells Dam will occur at the East and West ladder traps beginning on May 1, or at such time as the first spring Chinook are observed passing Wells Dam, and continue through June 30, 2017 (collection quotas will be prioritized for the May 1-June 20 time frame). Spring Chinook broodstock collection and stock assessment sampling activities authorized through the 2017 Douglas PUD Hatchery M&E Implementation Plan will utilize a combination of trapping on the East and West ladders as per the detailed descriptions of the modified trapping operations for spring Chinook collection in Appendix D (pages 38 and 39). Natural origin spring Chinook will be retained from the run, consistent with spring Chinook run timing at Wells Dam (weekly collection quota). Collection goals will be developed by Wells M&E staff to identify the most appropriate spatial and temporal approach to achieving the overall brood target. All natural origin spring Chinook collected at Wells Dam for broodstock will initially be held at Wells FH (or immediately transferred to Methow FH taking into account the status of adult holding during the modernization project) pending genetic results and then transferred to Methow FH. Fish collected at MFH will remain at MFH or be transferred to WNFH.

Collection of ad-clipped only (no wire) spring Chinook adults (or possibly eggs identified through CWTs from ad-clipped +CWT CJH segregated returns) may occur from facilities in the Methow basin and/or Wells Dam. These alternative collection locations will only be used if CCT and USFWS broodstock collection efforts fail to achieve broodstock collection objectives for the CJH segregated program, or if conditions (e.g., spill at CJD, ladder/trap efficiency) appear unconducive to efficient collection of broodstock. Collection will run concurrent with spring Chinook broodstock collection for Methow Hatchery.

Trapping at the Twisp Weir for spring Chinook may begin May 1 or at such time as spring Chinook are observed passing Wells Dam and may continue through August 23. The trap may be operated up to seven days per week/16 hours per day (provided it is manned during active trapping).

However, trapping at the Methow Outfall trap may continue beyond the Twisp Weir operations as needed to meet basin wide PNI/pHOS objectives. Pending development of an adult management plan for spring Chinook in the Methow basin, hatchery-origin adults captured at the Methow Outfall (surplus to the Methow Hatchery program) will be: 1) used for adult out-planting to increase natural production (see Appendix for approved plan) and secondarily 2) transferred to the WNFH for incorporation into WNFH brood, or removed as surplus as supported by the HGMP's of both facilities.

Steelhead

Douglas PUD and Grant PUD steelhead mitigation programs above Wells Dam utilize adult broodstock collections from multiple sources and locations such as at Wells Dam, Twisp Weir, Methow Hatchery volunteer trap, WNFH volunteer traps, Omak Weir, Wild horse Creek box trap and angling in the Methow River and Okanagan River (Table 5). Generally incubation/rearing occur for the Methow safety net, Okanogan, and Columbia River release at Wells Fish Hatchery (FH) with incubation/early rearing at Methow Hatchery for the DPUD conservation program. Broodstock for the conservation programs (USFWS and DPUD) is achieved via hook-and-line in the Methow Basin and the Twisp Weir (as needed), respectively (these programs are under program design review and may composite the broodstock). Broodstock for the Methow safety net program is achieved primarily through returns to WNFH (including hook and line-caught HOR steelhead) and surplus fish removed at Methow Hatchery and the Twisp Weir.

Specific program brood sources are structured as follows:

Twisp River – Conservation Releases

Due to the recent increased concern for inbreeding depression risk (Ryman-Laikre) for the Twisp program as a result of low Ne and other confounding issues, the design of Twisp program is currently under review.

The HC and JFP are working to redefine the scope and nature of the 2017 brood and future Twisp program. Parties will complete this task no later than October 1 (or sooner) of the current year such that an approved plan can be implemented and in a manner that does not unnecessarily delay consultation on the Methow steelhead HGMPs.

Wells Hatchery – Methow River Release

The Wells Hatchery Methow River release (Methow safety net program) uses locally collected hatchery origin broodstock representative of the Twisp and WNFH conservation programs and as needed, the Methow safety-net program. Adults are collected in concert with adult management activities at the Twisp Weir, Methow Hatchery, WNFH, and through hatchery fish intercepted during natural-origin brood hook-and-line collection for the USWFS Winthrop conservation program. As a backup to potential collection shortfalls in the Methow safety-net program and as a result of uncertainties in spring collection efficiencies, a portion of the Methow program will be augmented with collection of hatchery origin adults (30) occurring in the fall at Wells Dam. These fall-collected fish will be considered surplus to any spring-collected Methow, and eggs and/or fry from these surplus broodstock may be utilized for other programs in the upper Columbia. At least through the 2017 releases, fish are released from the Methow Hatchery, but may be released at other locations in the lower Methow once the HC approves a plan for such releases.

Wells Hatchery-Columbia River Release

The Wells Hatchery Columbia River releases will use returns to Wells Hatchery and may be augmented with adult returns to the Methow Hatchery and Winthrop NFH if needed to fulfill the program. To ensure the safety-net programs (Methow and Okanogan) have broodstock, a portion of the broodstock requirement (60 adults) will be collected at Wells Dam in the fall of 2017, and held at Wells Hatchery (Table 5). These fall-collected fish will be considered surplus to the spring-collected Methow and Okanogan broodstock, and eggs and/or fry from these surplus broodstock may be utilized for other programs in the upper Columbia. Fish are released to the Columbia River, immediately downstream of Wells Dam.

Winthrop NFH – Methow River Release

The USFWS Methow River release will primarily use natural-origin fish collected through hook-and-line collection efforts in the Methow River each spring. In the event NO collection falls short of the target, WNFH hatchery-origin returns will be prioritized, followed by safety-net hatchery returns. Transfer of adult and/or gametes/eggs between program will be carefully choreographed to ensure fish are being utilized in the most efficient and effective manner. Fish may be released throughout the Methow basin.

Okanogan River releases

The Okanogan River uses a combination of natural and hatchery-origin adults collected in Omak Creek and elsewhere in the Okanogan Basin through CCT collection efforts. As a backup to potential collection shortfalls in the Okanogan, a portion of the Okanogan program may be augmented with Okanogan locally-adapted hatchery-origin adults identified at spawning from 30 back up adults collected in the fall at Wells Dam. If needed to supplement spring collections, only fish with positive CWT for Okanogan origin will be used for this safety net aspect of the program. These fall-collected fish will be considered surplus to any spring-collected Okanogan broodstock, and eggs and/or fry from these surplus broodstock will be utilized for other programs in the upper Columbia. Surplus fish will be surplussed at the earliest time when overages are apparent.

Steelhead programs located upstream of Wells Dam and at Wells Hatchery are presented in Table 4.

Table 4. 2018 brood year Steelhead Programs at Wells Hatchery and Upstream of Wells Dam

Program	Hatchery	Owner	Release Location	Release Target	Broodstock Collection Locations
DPUD Conservation[2]	TBD	Douglas PUD	TBD	48,000 (S_1)	TBD
Methow Safety-Net	Wells Hatchery	Douglas PUD	Methow Hatchery	100,000	HxH: Twisp Weir (up to 25%) + WNFH Hatchery (75%) or WNFH 1st, MFH 2nd to make up balance
Mainstem Columbia Safety-Net	Wells Hatchery	Douglas PUD	Wells Hatchery	160,000	HxH: Wells FH/Dam returns (1st option); Methow FH/WNFH (2nd option)
WNFH Conservation Program	WNFH	USFWS	WNFH or other locations as determined by the JFP	Up to 200,000 (S_2)	Maximize use of NOR, up to 55 pair captured by hook and line in the Methow River and Spring Creek Weir.
Okanogan[1]	Wells Hatchery/ St. Mary's Pond	Grant PUD/CCT	Okanogan tributaries	100,000[1]	Okanogan Basin, Wells Dam

[1] CCT received approval for the Okanogan steelhead HGMP as part of their Tribal Resource Management Plan in February, 2017. Omak Creek and Wells Fish Hatchery are no longer separate hatchery programs. Up to 58 broodstock (NOB or HOB) may be collected from throughout the Okanogan basin (or Wells Dam if necessary) to meet the 100k program.

2 The DPUD Twisp conservation program is currently under re-development after detection of inbreeding depression risk. The HC and JFP have committed to developing an approved plan in sufficient time for implementation and such that is doesn't negatively affect the consultations for Methow steelhead HGMPs.

The following broodstock collection protocol was developed based on mitigation program production objectives (Table 6), biological assumptions (Appendix A), and the probability that sufficient adult steelhead will return in 2017/2018 to meet production objectives absent a preseason forecast at the present time.

For the 2018 brood steelhead programs operating above Wells Dam, a total of 350 adults (152 natural origin and 198 hatchery origin adults) are estimated to be needed to fulfill the respective mitigation obligations (Table 6). To support these obligations and to ensure sufficient backup adults are on hand in the event tributary based collection efforts fall short of targets, trapping at Wells Dam and/or Wells FH will selectively retain up to 257 hatchery origin steelhead (west [and east, as necessary] ladder and volunteer trap collection; Table 5). As a note, all potential broodstock will be scanned for PIT tags at collection and PIT tagged fish will be returned to the river to meet their monitoring objective. Any adult determined to have been part of the Yakama Nations kelt reconditioning program will be released in the vicinity it was collected.

Twisp Conservation Program (DPUD)

Due to the increased concern for inbreeding depression risk (Ryman-Laikre) for the Twisp program as a result of low Ne and other confounding issues, the design of the Twisp program is currently under review.

The HC and JFP are working to redefine the scope and nature of the 2017 brood and future Twisp program. Parties will complete this task no later than October 1 (or sooner) of the current year such that an approved plan can be implemented and in a manner that does not unnecessarily delay consultation on the Methow steelhead HGMPs.

Methow Safety Net Program

Up to 14 surplus hatchery-origin Twisp-stock steelhead (to meet up to 25% of the 100K Methow Safety-Net release) will be targeted at the Twisp Weir and moved to Wells Hatchery for spawning. No less than 46 hatchery adults will be targeted at WNFH and through angling efforts, and if needed/available, Methow Hatchery volunteer traps to meet the balance of the program needs (Table 6). Up to 30 hatchery origin Wells stock collected and held at the Wells Hatchery will be used as a final option if broodstock collection at the Twisp Weir, and WNFH and MH traps/collection efforts are unsuccessful (Table 5). If needed, WNFH HO fish identified through PIT tag detections, collected at the MFH outfall may be transferred to WNFH for use in the Spawning Channel Evaluation Project rather than retained for broodstock. Coordination between USFWS and WDFW hatchery staff will occur during the season to determine prioritization.

Methow Conservation Program (USFWS)

Approximately 110 natural origin adults (55 pair) will be targeted for retention through hook–and-line collection efforts in the Methow River (Table 6). In the event of a shortage, excess hatchery steelhead from the Twisp Weir and volunteer returns to the WNFH (including angle-caught fish) will be utilized as needed to augment WNFH broodstock. Should there be inadequate surplus steelhead from these sources, excess hatchery steelhead (presumed Methow Safety-Net origin) captured at the Methow Hatchery volunteer trap will be used to fulfill the program. Natural-Origin females will be live-spawned and reconditioned.

Okanogan Hatchery/Endemic Program

Up to 58 adult steelhead will be targeted in the Okanogan Basin, including up to 100% natural-origin adults (dependent on run size and within the 33% natural origin extraction rate) (Table 5). Additionally, up to 30 hatchery adult steelhead will be targeted at Wells Dam/Hatchery as a back-up collection contingency due to unknown broodstock collection efficiencies in the Okanogan River Basin (Table 5).

Table 5. Broodstock collection locations, number, and origin by program.

Program	Number of Adults[1]		Primary collection location	Number of backup adults[2]	Backup collection location(s)	Total adult collection[1]	
	Hatchery	Wild				Hatchery	Wild
DPUD Columbia R.	108		Wells FH/Dam Wells Dam		Methow FH	108	
DPUD Methow R.	68		Twisp weir (14) Methow FH (46)	Up to 30	WNFH[3] Wells Dam	98	
DPUD Met. Conservation		24	Twisp weir	NA	NA		24
GPUD Okanogan R.	0-58[6]	0-58[7]	Omak Cr., Okanogan R. and tributaries.	Up to 30	Wells Dam, Wells FH[5]	0-88	0-58
USFWS Methow R.		110	Methow R. WNFH[4]	NA	Methow FH		110
Total **(PUD programs)**	**176-234**	**24-82**		**Up to 60**		**206-294**	**24-82**
Total **(All programs)**	**176-234**	**134-192**		**Up to 60**		**206-294**	**134-192**

[1] Assumes a 1:1 sex ratio (see table 6). Natural origin females will be live spawned and reconditioned.
[2] All backup broodstock are hatchery origin adults.
[3] May include hatchery origin adults collected via the USFWS hook and line efforts for natural origin fish in the Methow River and adult returns to WNFH.
[4] May also include excess hatchery origin adults collected via angling and at Methow FH and the Twisp Weir.
[5] Spring collection of hatchery origin steelhead as needed to meet program shortfall for the Okanogan Program.
[6] Dependent upon number of NOR broodstock collected in the Okanogan Basin, age structure and fecundity to achieve sufficient brood for a100k smolt program for the Okanogan.
[7] Depending upon NOR abundance and trapping efficiency

Table 6. Number of broodstock needed to produce approximately 608,000 smolts for the above Wells Dam 2018 brood summer steelhead programs. Includes primary collection location(s) and mating strategy. *Broodstock totals do not include additional fish that may be collected at other locations as a backup for shortfalls from primary collection sources*.

Program	Production target/request	Number of Adults		Total	Collection location	Mating protocol
		Hatchery	Wild			
DPUD[1] Columbia R.	160,000	54F/54M		**108**	Wells Dam/Twisp Weir/	1:1
DPUD[2] Methow R.	100,000	34F/34M		**68**[4]	Twisp Weir, MFH, WNFH, Wells Dam	1:1
DPUD Methow Conservation	48,000		12F/12M	**24**	TBD	2x2 Factorial
GPUD Okanogan R.[3]	100,000	14F/14M	15F/15M	**58**[5]	Okanogan R./Omak Creek	1:1/2x2[7]
USFWS	200,000		55F/55M	**110**[6]		2X2 Factorial
Total[4]	**608,000**	**109F/109M**	**75F/75M**	**368**		

[1] Mainstem Columbia releases at Wells Dam. Target HxH parental adults as the hatchery component.
[2] Methow hatchery release of HxH fish produced from either adults returning from the Winthrop conservation program, adults trapped at MFH, and/or surplus hatchery adults from the Twisp weir.
[3]CCT intends to achieve greater than 0.5 pNOB in both 2017 and 2018, but the actual number will be dependent upon run size and trap efficiency, per the HGMP. Numbers of hatchery and wild males and females in this table should not be taken as the goal or limit for any collection effort, as it could be up to 100% pNOB or pHOB.
[4] Up to an additional 30 hatchery adults will be collected at Wells FH as a fall back to shortfalls in collections for the Methow safety net.
[5] Up to an additional 30 hatchery origin adults will be collected at Wells Dam as backup to potential shortfalls in Okanogan Basin collection efforts.
[6] Collection priority: 1) hook and line, 2) adult returns to WNFH, 3) excess adult returns to Methow Hatchery.
[7] A 1:1 mating protocol will be used for all HxH/HxW crosses within the Okanogan. The Okanogan locally-adapted natural stock (WxW) will utilize a minimum 2x2 factorial mating to minimize potential negative effects associated with a small effective population size.

Overall collection for the PUD programs will be 294 fish (a combination of program specific and back-up adults; Table 5) and limited to no more than 33% of the entire run and/or 33% of the natural origin return. Hatchery and natural origin collections will be consistent with run-timing of hatchery and natural origin steelhead at Wells Dam and the Twisp Weir. Trapping at the Wells Dam ladders will occur between 01 August and 31 October, up to three days per week, and up to 16 hours per day, as required to meet broodstock objectives. Trapping will be concurrent with summer Chinook broodstocking efforts through 15 September on the west ladder (Appendix D). Operational criteria and dates for the Twisp Weir are still under construction.

Adult return composition including number, origin, age structure, and sex ratio will be assessed in-season at Priest Rapids and Wells dams. Broodstock collection adjustments may be made based on in-season monitoring and evaluation. If collection of adults from the east ladder trap is necessary, access will be coordinated with staff at Wells Dam due to the rotor rewind project.

Surplus UCR Juvenile Steelhead Management

In the event excess juvenile are produced from the over-collection efforts to support the Methow safety net and /or Okanogan programs which rely on spring adult collections, the parties agree that distribution of juveniles will follow the following priority matrix:

1. Used to support shortfalls in the WNFH production obligation provided fish health and/or marking requirements for the program can be met.

2. Used to support any shortfalls in the Wells Columbia River release provided fish health and/or marking requirements for the program can be met.

3. Used to support shortfalls in the Ringold SHD program provided fish health and/or marking requirements for the program can be met.

4. Out-planted to landlocked lakes within Okanogan County and/or Colville Reservation provided fish health requirements can be met or provided stocking allotments are not exceeded (as determined by WDFW, YN and CCT fishery managers, as applicable).

In addition, surplus fish, including broodstock, will be distributed at the earliest possible life-stage (e.g., prespawn adults, eyed-egg, fry) per WDFW policy.

Summer/fall Chinook

The summer/fall Chinook mitigation program in the Methow River utilizes adult broodstock collections at Wells Dam and incubation/rearing at Eastbank Fish Hatchery. The total production level target is 200,000 summer/fall Chinook smolts for acclimation and release from the Carlton Acclimation Facility.

The TAC 2017 Columbia River UCR summer Chinook return projection to the Columbia River (Appendix D) and BY 2012, 2013, and 2014 spawn escapement to tributaries above Wells Dam indicate sufficient summer Chinook will return past Wells Dam to achieve full broodstock collection for supplementation programs above Wells Dam. The following broodstock collection protocol for the Methow summer Chinook program was developed based on initial run expectations of summer Chinook to the Columbia River, program objectives, and program assumptions (Appendix A).

For 2017, up to 118 natural-origin summer Chinook at Wells Dam west (and east, if necessary) ladder(s), including 59 females for the Methow summer Chinook program (Table 7). Collection will be proportional to return timing between 01 July and 15 September. Summer Chinook stock assessment will run concurrent with summer Chinook broodstock collection at the west ladder trap. Trapping may occur up to 3-days/week, 16 hours/day (48 cumulative hours per week). Age-3 males ("jacks") will not be collected for broodstock.

Should use of Wells Dam be needed to meet any shortfalls in broodstock for summer/fall

Chinook programs occurring in the Okanogan Basin, the CCT will notify the HCP-HC and Wells HCP Coordinating Committee/PRCC-HSC and coordinate with Douglas PUD, Grant PUD, and WDFW to facilitate additional broodstock collection effort. Summer Chinook broodstock collection efforts at Wells Dam, should they be required to meet CJH program objectives, will be conducted concurrent with broodstock collection efforts for the Methow summer Chinook program and or steelhead collection efforts for steelhead programs above Wells Dam.
If the probability of achieving the broodstock goal is reduced based on passage at the west ladder or actual natural-origin escapement levels, broodstock collections may be expanded to the east ladder trap and/or origin composition will be adjusted to meet the broodstock collection objective. If collection of adults from the east ladder trap is necessary, access will be coordinated with staff at Wells Dam due to the rotor rewind project.

Table 7. Number of broodstock needed for Grant PUDs Methow summer Chinook production obligation of 200,000 smolts, collection location, and mating strategy.

Program	Production target	Number of Adults		**Total**	Collection location	Mating protocol
		Hatchery	Wild			
Methow	200,000		59F/59M	**118**	Wells Dam	1:1
Total	**200,000**		**118**	**118**		

Rearing – Early rearing growth will be modulated for a targeted size at release of approximately 18 fpp. Beginning on or about February 1, fish will be fed to satiation to maximize spring growth regardless of end size.

Release - The summer Chinook salmon acclimated at the Carlton Acclimation Facility will be forced released using the following criteria.

- all fish will be released during darkness (e.g., 9:00 PM or later),
- all fish will be released when Columbia River and Methow River flows are predicted to be satisfactory,
- all fish will be released no later than May 7 regardless of flow conditions,
- attempts will be made to have a steady release of fish to reduce collisions on the PIT antenna array.

Satisfactory flows in the Columbia occur when spilling flows are started and flows in the Methow River are satisfactory when flows are high and turbid. Releases will not occur until satisfactory flows in the Columbia occur, but could occur if Methow River flows are not satisfactory due to insufficient snow pack.

Columbia River Mainstem below Wells Dam

Summer/fall Chinook

Collection at the Wells FH volunteer channel will be used to collect the broodstock necessary for the Wells FH yearling (320,000) and sub-yearling (484,000) programs.
Because of CCT concerns about sufficient natural origin fish reaching spawning grounds and to ensure sufficient NOR's being available to meet the CCT summer Chinook program, incorporation of natural origin fish for the Wells program or programs with broodstock originating from the Wells volunteer channel, will be limited to fish collected in the Wells volunteer channel. The following broodstock collection protocol was developed based on mitigation objectives and program assumptions (Appendix A).

WDFW will target 494 run-at-large summer Chinook from the volunteer ladder trap at Wells Fish Hatchery outfall for the Wells sub-yearling and yearling programs, and up to 178 for the YN 275K-350K green egg request for the Yakima summer Chinook program (Table 8). Due to fish health concerns associated with the volunteer collection site (warming Columbia River water during late August), the volunteer collection will begin July 1 and terminate by August 31.

For 2017, broodstock collection for the Chelan Falls summer Chinook program will be prioritized at the Chelan Falls Canal Trap (CFCT) which was successfully piloted in 2016, beginning July 1 through September 15. Collection efforts in the EBO in 2015 and 2016 were insufficient to meet the adult requirements for the Chelan Falls program necessitating development of alternate collection locations/strategies. If shortfalls in adult needs are expected and the number of females needed to meet program has not been reached by August 15th, the HCP HC will discuss whether broodstock collection may default to surplus summer Chinook from the Entiat NFH or other HCP approved location to make up the difference. The 2017 broodstock target for the Chelan Falls program is 358 adults (Table 8). The total production level supported by this collection is up to 576,000 yearlings for the Chelan Falls program.

Table 8. Number of broodstock needed for the combined Chelan and Douglas PUD Columbia River below Wells summer Chinook production obligations of 1,380,000 smolts, collection location, and mating strategy. Also includes broodstock necessary for outside programs that rely on adult collection at Well Hatchery in 2017.

Program	Production target	Number of Adults[2]		Total	Collection location	Mating protocol
		Hatchery	Wild			
Wells 1+	320,000	94F/94M		**188**	Wells VC[3]	1:1
Wells 0+	484,000	153F/153M		**306**	Wells VC[3]	1:1
Chelan Falls 1+	576,000	179F/179M		**358**	CFCT[4]	1:1
Yakama Nation	350,000[1]	89F/89M		**178**	Wells VC[3]	NA
Total	**1,730,000**	**515F/515M**		**1,030**		

[1] The YN request is for between 275K and 350K green eggs to support the Yakima River summer Chinook program.
[2] The number of adults collected for these programs may indirectly incorporate natural origin fish; however, because they are volunteers, the

number is likely to be less than 10% of the total.
[3] Wells Hatchery volunteer channel trap.
[4] Chelan Falls Canal Trap

Wenatchee River Basin

In 2017 the Eastbank Fish Hatchery (FH) is expecting to rear spring Chinook salmon for the Chiwawa River and Nason Creek acclimation facilities located on the Chiwawa River and Nason Creek. The program production level target for the Chiwawa program (Chelan PUD obligation) in 2017 is 144,026 smolts, and based upon the biological assumptions (Appendix A) will require a total broodstock collection of about 74 natural origin spring Chinook (Table 10). The spring Chinook production obligation for Grant PUD in the Wenatchee Basin is 223,670 smolts (125,000 conservation and 98,670 safety net) and based upon the biological assumptions (Appendix A) will require a total broodstock collection of 142 adults (70 natural origin and 72 hatchery origin; Table 10).

Pre-season run-escapement of Wenatchee spring Chinook to Tumwater Dam during 2017 is estimated at 5,410 spring Chinook, including 4,637 hatchery and 773 natural origin spring Chinook (does not include age-3 males; Table 9). In-season estimates of natural-origin spring Chinook to Tumwater Dam will be provided through stock-assessment and broodstock-collection activities. This information will facilitate in-season adjustments to collection composition so that extraction of natural-origin spring Chinook remains no more than 33%.

Table 9. Age-4 and age-5 class return projection for wild and hatchery spring Chinook to Tumwater Dam during 2017.

	Chiwawa Basin			Nason Cr. Basin			Wenatchee Basin to Tumwater Dam		
	Age-4	Age-5	Total	Age-4	Age-5	Total	Age-4	Age-5	Total
Estimated wild return	418	108	**526**	123	32	**155**	614	159	**773**
Estimated hatchery return	3,238	63	**3,301**	1,336	0	**1,336**	4,574	63	**4,637**
Total	3,656	171	**3,827**	1,459	32	**1,491**	**5,188**	**222**	**5,410**

Table 10. Number of broodstock needed for the combined Wenatchee spring Chinook production obligation of 367,969 smolts, collection location, and mating strategy.

Program	Production target	Number of Adults		**Total**	Collection location	Mating protocol
		Hatchery	Wild			
Chiwawa Conservation	144,026	18F/18M	37F/37M	**74**[1]	Chiwawa Weir and Tumwater Dam[4]	2x2 factorial
Nason Conservation	125,000	0	35F/35M	**77**[2]	Tumwater Dam[4]	2x2 factorial

Nason Safety net	98,670	34F/34M[3]	0	**68**	Tumwater Dam	1:1
Total	**367,969**	**104**	**144**	**255**[2]		

[1] Includes 36 hatchery origin adults (represents ~50% of the adult target) to ensure the Chiwawa production goal is met if insufficient NO adults are collected).
[2] Includes ~10% additional NO fish for the Nason program to account for fish that may assign back to the White River spawning aggregate. No more than 70 NO fish will be retained for spawning.
[3] Chiwawa hatchery fish will only be collected to satisfy the Nason Cr. safety net program if in-season estimates of returning Nason conservation fish fall short of expectations.
[4] Collection of NO fish at Tumwater for the Chiwawa program will include previously PIT tagged adults (NO juveniles PIT tagged at the Chiwawa smolt trap).

Chiwawa River Conservation Program Broodstocking:

- Based upon estimates of returning previously PIT tagged NO fish to Tumwater Dam (Table 11), approximately 30 previously PIT-tagged NO spring Chinook from the Chiwawa River could be collected at TWD between June 1 and July 15, concurrent with Nason Creek brood stocking, adult management, RM&E, and the RRS Study.
- The balance of adults needed to meet the Chiwawa Conservation program (up to ~74 total or ~37 females) would be collected at the Chiwawa Weir.
    - Weir operations would be on a 24 hour up/24 hour down schedule from about June 1 through August 15 (not to exceed 15 cumulative trapping days). Timing of trap operation would be based on NO fish passage at TWD and would use estimated travel times (derived from PIT tags) to the lower Chiwawa PIT tag antenna array.
    - In the absence of adequate redd count data (i.e. until 2018) to calculate the 10% threshold, if after 15-days of weir operation, 67 bull trout encounters, or 15 August, the NO broodstock target is not reached, the balance of the mitigation obligation will be met through hatchery fish already retained for the Chiwawa program at TWD.
    - Over five years, the average number of bull trout captured during weir operation shall not exceed 70 individuals per year. Additionally, no more than 10 percent of the estimated mean number of adult bull trout in the Chiwawa Basin (using up to a rolling five year average derived from expanded redd counts) may be encountered during broodstock collection without concurrence from the USFWS. Sufficient redd data to calculate a full five year average is expected to be available as early as 2018.
    - To ensure the production target is met for the Chiwawa program, in the event that insufficient NO adults are collected for the conservation program, HO adults (presently estimated at 50% of the total broodstock requirement, however may be adjusted up or down depending on the run) would be collected at TWD to make up the shortfall (see Table 10) between June 1 and July 15.
    - Historic and in-season data for NO spring Chinook timing to the lower Chiwawa array from TWD will be used to determine optimal dates for collection.

- o Any bull trout that are caught at the Chiwawa trap will be immediately removed and released at a site ~10KM upstream of the weir to prevent fallback/impingement and to mitigate for potential delay. Handling and transport will be conducted by WDFW hatchery staff.
- o If a bull trout is killed during trapping, despite implementing conservation measures, trapping activities will cease and not continue until additional measures to minimize risks to bull trout can be discussed with the USFWS.

Table 11. PIT tagged natural origin adults to Tumwater Dam for the most recent 5-years (2012-2016) with conversion rates from Bonneville Dam.

	Detections at Bonneville Dam		Detections at Tumwater Dam			
Return year	Nason	Chiwawa	Nason	Conversion rate	Chiwawa	Conversion rate
2012	7	60	5	0.714	52	0.867
2013	2	29	2	1.000	22	0.759
2014	6	66	1	0.167	29	0.439
2015	9	42	6	0.667	28	0.667
2016	8	34	8	1.000	24	0.706
Mean	6.4	46.2	4.4	0.710	31.0	0.688
Geomean	5.7	44.0	3.4	0.603	29.5	0.671

Nason Creek Conservation Program Broodstocking:

- Up to ~77 NO spring Chinook (to allow for up to 10 percent of White River NO fish estimated to be encountered at Tumwater Dam MSA; Table 10) would be collected at TWD between June 1 and July 15.
  - o Only 70 NO adults (35 females) will be retained to produce the 125K Nason Conservation program.
  - o Collection of additional HO fish may occur in the event NO collection/retention falls short of expectation.
  - o Brood stock collection would run concurrent with adult management, RM&E, and the Spring Chinook Relative Reproductive Success Study. The GAPS microsatellite panel and existing GAPS plus WDFW spring Chinook Wenatchee baseline will be used for genotyping and GSI analyses similar to methods used in 2013.

- Decision Rules:
  - o Any fish that assigns to the White River with greater than 90% surety will be released in the White River.

  - Unassigned fish (individuals that can't be assigned to the Wenatchee Population or Leavenworth NFH), will be released upstream of Tumwater Dam.
  - In the event more fish assign to Nason or Chiwawa than are needed to meet the conservation program, the excess with the lowest assignment probabilities will be returned to the river upstream of Tumwater Dam.

Nason Creek Safety Net Program Broodstocking:

- Up to ~68 HO spring Chinook adults (from safety net program – identified by snout wire + body wire) would be targeted at TWD (Table 10) between June 1 and July 15, concurrent with NO brood stock collection, adult management, RM&E, and the Spring Chinook Relative Reproductive Success (RRS) Study.

Nason Creek spring Chinook Rearing/Release Strategy:

Rearing – Early rearing growth will be modulated for a targeted size at release of approximately 18 fpp. Beginning on or about February 1, fish will be fed to satiation to maximize spring growth regardless of end size.

Release - Spring Chinook salmon acclimated at the Nason Creek Acclimation Facility will be forced released using the following criteria.

- all fish will be released during darkness (e.g., 9:00 PM or later),

- all fish will be released when Columbia River and Nason Creek flows/conditions are predicted to be satisfactory,

- all fish will be released no later than May 7 regardless of flow conditions,

- attempts will be made to have a steady release of fish to reduce collisions on the PIT antenna array.

Satisfactory flows in the Columbia occur when spilling flows are started and flows in Nason Creek are satisfactory when flows are high and turbid. Releases will not occur until satisfactory flows in the Columbia occur, but could occur if Nason Creek flows are not satisfactory due to insufficient snow pack.

<u>*Steelhead*</u>

The steelhead mitigation program in the Wenatchee Basin uses broodstock collected at Dryden and Tumwater dams located on the Wenatchee River. Per ESA section 10 Permit 1395 provisions, broodstock collection will target adults necessary to meet a natural origin – conservation (WxW) oriented program, not to exceed 33% of the natural origin steelhead return to the Wenatchee Basin and a hatchery origin (HxH) – safety net program. The conservation and safety net programs each make up approximately half of the 247,300 production obligation. Based on these limitations and the assumptions listed in Appendix A, the following broodstock collection protocol was developed:

WDFW will retain a total of 140 mixed origin steelhead for broodstock for a smolt release objective of 247,300 smolts (Table 12). The 70 hatchery origin adults will be targeted at Dryden Dam and if necessary Tumwater dam. The 70 natural origin adults will be targeted for collection at Tumwater Dam. Collection will be proportional to return timing between 01 July and 14 November. Collection may also occur between 15 November and 5 December at both traps, concurrent with the Yakama Nation coho broodstock collection activities. Only adipose present coded wire tagged hatchery fish (or previously PIT tagged WxW hatchery progeny) will be retained for the safety net program. Adult return composition including number, origin, age structure, and sex ratio will be assessed in-season at Priest Rapids and at Dryden Dam. In-season broodstock collection adjustments may be made based on this monitoring and evaluation. To better ensure achieving the appropriate females equivalents for program production, the collection will include the use of ultrasonography to determine the sex of each fish retained for broodstock.

In the event steelhead collections fall substantially behind schedule, WDFW may initiate/coordinate adult steelhead collection in the mainstem Wenatchee River by hook and line. In addition to trapping and hook and line collection efforts, Tumwater and Dryden dams may be operated between February and early April the subsequent spring to supplement broodstock numbers if the fall trapping effort provides fewer than the required number of adults.

Table 12. Number of broodstock needed for the combined 2018 BY Wenatchee summer steelhead production obligation of 247,300 smolts, collection location, and mating strategy.

Program	Production target	Number of Adults		**Total**	Collection location	Mating protocol
		Hatchery	Wild			
Wenatchee Conservation[1]	123,650	0	35F/35M	**70**	TWD[3]/Dryden LBT-RBT[4]	2x2 factorial
Wenatchee Safety net[2]	123,650	35F/35M	0	**70**	Dryden LBT-RBT[4] /TWD[4]	1:1
Total	**247,300**	**70**	**70**	**140**		

[1] Broodstock collection for the conservation program will occur primarily at Tumwater Dam and will only fall back to Dryden Dam trapping facilities if a shortfall is expected.
[2] Broodstock collection for the safety net program will occur primarily at the Dryden Dam trapping facilities to minimize activities at TWD that could increase unintended delays on non-target fish. Collection at Tumwater Dam will only occur if shortfalls in broodstock are expected at Dryden Dam.
[3] TWD=Tumwater Dam.
[4] Dryden LBT-RBT= Dryden Dam left and right bank trapping facilities.

Summer/fall Chinook

Summer/fall Chinook mitigation programs in the Wenatchee River Basin utilize adult broodstock collections at Dryden and Tumwater dams, incubation/rearing at Eastbank Fish Hatchery (FH) and acclimation/release from the Dryden Acclimation Pond. The total production level target for BY 2017 is 500,001 smolts (181,816 GCPUD mitigation and 318,185 CCPUD mitigation).

The TAC 2017 Columbia River UCR summer Chinook return projection to the Columbia River (Appendix D) and BY 2012, 2013 and 2014 spawner escapement to the Wenatchee River indicate sufficient summer Chinook will return to the Wenatchee River to achieve full broodstock collection for the Wenatchee River summer Chinook supplementation program. Review of recent summer/fall Chinook run-timing past Dryden and Tumwater dam indicates that previous broodstock collection activities have omitted the early returning summer/fall Chinook, primarily due to limitations imposed by ESA Section 10 Permit 1347 to minimize impacts to listed spring Chinook. In an effort to incorporate broodstock that better represent the summer/fall Chinook run timing in the Wenatchee Basin, the broodstock collection will front-load the collection to account for the disproportionate collection timing. Approximately 43% of the summer/fall Chinook destined for the upper Basin (above Tumwater Dam) occurs prior to the end of the first week of July; therefore, the collection will provide 43% of the objective by the end of the first week of July. Weekly collection after the first week of July will be consistent with run timing of summer/fall Chinook during the remainder of the trapping period. With concurrence from NMFS, summer Chinook collections at Dryden Dam may begin up to one week earlier. Based on these limitations and the assumptions listed in Appendix A, the following broodstock collection protocol was developed:

WDFW will retain up to 262 natural-origin, summer Chinook at Dryden and/or Tumwater dams, including 131 females (Table 13). To better ensure achieving the appropriate females for program production, the collection will implement the draft Production Management Plan, including ultrasonography to determine the sex of each fish retained for broodstock. Trapping at Dryden Dam may begin 27 June and terminate no later than 15 September and operate up to 7-days/week, 24-hours/day. Trapping at Tumwater Dam if needed may begin 15 July and terminate no later than 15 September and operate up to 48 hours per week for broodstock related activities.

Table 13. Number of broodstock needed for the combined 2017 BY Chelan and Grant PUD Wenatchee summer Chinook production obligations of 500,001 smolts, collection location, and mating strategy.

Program	Production target	Number of Adults		Total	Collection location	Mating protocol
		Hatchery	Wild			
Chelan PUD	318,185		83F/83M	**172**		
Grant PUD	181,816		48F/48M	**98**		
Total	**500,001**		**131F/131M**	**262**	Dryden LBT-RBT[1] /TWD[2]	1:1

[1] Dryden LBT-RBT= Dryden Dam left and right bank trapping facilities.
[2] TWD=Tumwater Dam.

Priest Rapids Fall Chinook

Collection of fall Chinook broodstock at Priest Rapids Hatchery (PRH) will generally begin in early September and continue through about mid-November. Juvenile release objectives specific to Grant PUD (5,599,504 sub-yearlings), and Federal (1,700,000 sub-yearlings at PRH + 3,500,000 smolts at Ringold Springs Hatchery – collection of broodstock for the federal programs are conditional upon having contracts in place with the ACOE), mitigation commitments. Biological assumptions are detailed in Appendix A. For the Ringold Springs production, adult collection, holding, spawning and incubation occurs at PRH until the eyed-egg stage. Eyed eggs are transferred to Bonneville Hatchery until they are transferred for spring acclimation and release at Ringold Springs.

For 2017 up to 1,000 adipose present, non-coded wire tagged (high proportion of natural origin) fall Chinook adults will be targeted at the OLAFT). Additional NO adults targeted as a continued pilot evaluation through hook-and-line angling efforts in the Hanford Reach to increase the proportion of natural origin adults in the broodstock to meet integration of the hatchery program will also be incorporated into the program. It is estimated that approximately 400 adults may be collected through the hook-and-line efforts. Close coordination between broodstock collections at the volunteer channel, the OLAFT and through hook-and-line efforts in the Hanford Reach will need to occur so over collection is minimized. Fish surplus to production needs will be culled at the earliest possible life-stage (e.g, brood collected, brood spawned, eggs). Presumed NOR's collected and spawned from either hook-and-line caught broodstock or OLAFT collections will be prioritized for PRH programs (i.e. OLAFT and Hanford Reach angler caught fish will be externally marked, held in a separate pond from volunteer collected fish, spawned first each week, and to the extent possible segregated and reserved for the GPUD program).

Grant PUD staff will work closely with WDFW hatchery and M&E staff to maintain separation of gametes/progeny of OLAFT and angling collected adults at spawning and through incubation/early rearing.

Based upon the biological assumptions in Appendix A, an estimated 4,219 females will need to be collected (3,536 spawned) to meet the 10,799,054 smolts required to meet the current three up-river bright (URB) programs which rely on adults collected at the Priest Rapids Hatchery volunteer channel trap, hook-and-line efforts on the Hanford Reach, and/or the Priest Rapids Dam off ladder trap (OLAFT; Table 14).

To increase the probability of incorporating a higher percentage of NOR's from the volunteer channel, adipose present, non-CWT males and females will be prioritized for retention and males older than 3 will be prioritized. In addition, preliminary information suggests that the pNORs is higher in the later part of the trapping period than the earlier period. As data become available, the PRCC-HSC may choose, in-season, to retain a disproportionately high number of broodstock from the latter half of the returns to the volunteer trap.

<u>Implementation Assumptions</u>

1) Broodstock may be collected at any or all of the following locations/means: the PRD off ladder trap (OLAFT – operated 4-days per week/8 hrs/day to collect up to 1,000 presumed NOR's), hook-and-line angling (ABC) in the Hanford Reach (actual numbers collected are uncertain but will contribute to the overall brood program and pNOB), and the Priest Rapids Hatchery volunteer channel trap.

2) Assumptions used to determine egg/adult needs is based upon current program performance metrics.

3) Broodstock retained from the volunteer channel will exclude to the degree possible, age-2 and 3 males (using length at age; i.e. retain males ≥ 75 cm) to address genetic risks/concerns of younger age-at-maturity males producing offspring which return at a younger age (decreased age-at-maturity) and also decrease the probability of using hatchery origin fish in the broodstock that are skewed towards earlier ages at maturity.

4) Only adipose present, non-CWT males and females will be retained for broodstock from volunteer channel collected broodstock unless a shortage is expected.

5) Only progeny of adipose present, non-wired fish encountered through hook-and-line angling and at the OLAFT will be prioritized for retention into the program.

6) Broodstock collected from the OLAFT and by hook-and-line will exclude age-2 and to the degree possible age-3 fish (<75 cm) to minimize genetic risks/concerns of younger age-at-maturity males producing offspring which return at a younger age (decreased age-at-maturity) and to ensure the highest proportion of NOR's in the collection (e.g. collection of 1 in 5 age-3 fish for broodstock from the OLAFT).

7) All gametes of fish spawned from hook-and-line broodstocking efforts and/or OLAFT collections will be incorporated into the PRH based programs.

8) Real time otolith reading and an alternative mating strategy will be implemented in 2017 similar to 2015 and 2016 unless the PRCC-HSC agrees that the PNI objective in 2017 can be met without implementing 1x4 matings. Otoliths from males from the OLAFT and ABC collections will be collected during the peak spawning week and read prior to spawning. If the male is natural origin, then it will be spawned with 4 females, otherwise it will be spawned with two females or the milt discarded if it is a known hatchery male and there are sufficient numbers of unknown males available for spawning.

9) All eggs or juveniles leaving PRH (including surplus) will have a unique otolith mark so that returning adults can be identified. Exceptions to this could occur if there are guarantees of a suitable mark/tag from a receiving hatchery.

10) Natural origin broodstock collection at the volunteer trap will be prioritized for the GPUD program by collecting fish when the probability of encountering natural origin fish is highest and balancing run-time representation.

Table 14. Number of broodstock needed for the combined Grant PUD and ACOE fall Chinook production obligations of 10,799,504 sub-yearling smolts at Priest Rapids and Ringold Springs hatcheries, collection location, and mating strategy.

Program	Production target	Number of Adults	**Total**	Collection location	Mating protocol
Grant PUD	5,599,504	2,234F/1,145M	**3,379**		
ACOE-PRH	1,700,000	681F/350M	**1,031**		
ACOE – Ringold[1]	3,500,000	1,397F/716M	**2,113**		
Total	**10,799,504**	**4,312F/2,211M**	**6,523**		

Collection location	Estimated number of adults		Total		
	Hatchery	Wild			
Priest Rapids Hatchery	**3,266F/1,683M**	**119F/55M**	**5,123**	PRH volunteer trap	1:2
OLAFT[2]	**307F/153M**	**360F/180M**	**1,000**	PRD off-ladder trap	1:2, 1:4
ABC[3]	**23F/45M**	**113F/219M**	**400**	Hanford Reach	1:2, 1:4
Total	**3,596F/1,881M** (5,477; 84.0%)	**592F/454M** (1,046; 16.0%)	**6,523**		

[1] As of brood year 2009, Priest Rapids Hatchery is taking sufficient eggs to meet the 3,500,000 sub-yearling smolt release at Ringold-Meseberg Hatchery funded by the ACOE – late incubation of this program occurs at Bonneville.
[2] Estimated number of fall Chinook females and males to be acquired from the OLAFT in 2017. F/M ratios were derived through run at large data. Estimates of H/W were derived through otolith results.
[3] ABC fish are adults collected from hook and line collection efforts on the Hanford Reach. Estimates of F/M were derived through 2012-2014 spawn numbers. Estimates of and H/W were derived through otolith results from 2012 and 2014.

Appendix A

2017 Biological Assumptions for UCR spring, summer, and Fall Chinook and Summer Steelhead Hatchery Programs

Program	Mean Values for 2012-2016								Mean Values 2010-2014 Brood
	ELISAs		Fecundity		Prespawn Survival				
	H	W			H		W		
	≥ 0.12	≥ 0.2	H	W	M	F	M	F	G-E-R Survival[1]
Methow SPC	0.170	0.052	3,563	4,197	0.986	0.993	0.978	0.983	0.913
Twisp SPC	0.105	0.059	3,413	4,144	1.000	1.000	1.000	0.971	0.913
Twisp SHD	[redacted]	[redacted]	[redacted]	5,323	[redacted]	[redacted]	1.000	1.000	0.76
Wells SHD	[redacted]	[redacted]	5,619	5,957	0.971	0.938	0.900	0.820	0.61
Okanogan SHD	[redacted]	[redacted]	5,483	[redacted]	[redacted]	1.000	[redacted]	[redacted]	0.80
Wells SUC 1+	0.021	0.000	4,099	4,604	0.976	0.982	0.992	0.989	0.87
Wells SUC 0+	0.021	0.000	4,099	4,604	0.976	0.982	0.992	0.989	0.80
YN Green Eggs	0.021	0.000	4,099	4,604	0.976	0.982	0.992	0.989	NA
Methow SUC	0.000	0.024	[redacted]	4,569	[redacted]	[redacted]	0.977	0.973	0.783
Chelan Falls 1+	0.022	[redacted]	4,072	[redacted]	0.988	0.982	[redacted]	[redacted]	0.825
Wenatchee SUC	0.000	0.033	[redacted]	4,834	[redacted]	[redacted]	0.975	0.954	0.856
Wenatchee SHD	[redacted]	[redacted]	5,672	5,691	1.000	0.994	0.981	0.952	0.657
Nason SPC	0.123	0.041	[redacted]	4,441	[redacted]	[redacted]	0.989	0.977	0.870
Chiwawa SPC	0.123	0.015	3,847	4,696	0.993	0.985	0.994	0.971	0.882
Priest Rapids FAC 0+	[redacted]	[redacted]	3,703	[redacted]	0.824	0.845	[redacted]	[redacted]	0.817
ACOE @PRH	[redacted]	[redacted]	3,703	[redacted]	0.824	0.845	[redacted]	[redacted]	0.817
ACOE @Ringold	[redacted]	[redacted]	3,703	[redacted]	0.824	0.845	[redacted]	[redacted]	0.768

[1] Green egg to release survival.

Appendix B

Projected Brood Year Juvenile Production Targets, Marking Methods, Release Locations, Release Size, Release Type

Brood Year	Production Group	Program Size	Marks/Tags[3]	Additional Tags	Release Location	Release Year	Release Size (fpp)	Release Type
Summer Chinook								
2017	Methow SUC 1+ (GPUD)	200,000	Ad +CWT	5,000 PIT minimum	Methow River at CAF	2019	13-18	Forced
2017	Wells SUC 0+ (DPUD)	480,000	Ad + CWT	3K-5K PIT	Columbia R. at Wells Dam	2018	50	Forced
2017	Wells SUC 1+ (DPUD)	320,000	Ad + CWT		Columbia R. at Wells Dam	2019	10	Volitional
2017	Chelan Falls SUC 1+ (CPUD)	576,000	Ad + CWT	10,000 PIT	Columbia R. at CFAF	2019	13	Forced
2017	Wenatchee SUC 1+ (CPUD/GPUD)	500,001	Ad + CWT	5,000 PIT minimum	Wenatchee R. at DAF	2019	15-18	Volitional
2017	CJH SUS 1+	500,000	Ad + 100K CWT	5,000 PIT	CJH	2019	10	Volitional
2017	CJH SUS 0+	400,000	Ad + 100K CWT	5,000 PIT	CJH	2018	50	Volitional
2017	Okanogan SUS 1+	266,666	Ad + CWT	5,000 PIT	Omak Pond	2019	10	Volitional
2017	Okanogan SUS 1+	266,666	Ad + CWT		Riverside Pond	2019	10	Volitional
2017	Okanogan SUS 1+	266,666	Ad + CWT		Similkameen Pond	2019	10	Volitional
2017	Okanogan SUS 0+	300,000	Ad + CWT	5,000 PIT	Omak Pond	2018	50	Forced
Spring Chinook								
2017	Methow SPC (PUD)	108,249	CWT only	5,000 PIT	Methow R. at MFH	2019	15	Volitional
2017	Methow SPC (PUD)	25,000[1]	CWT only	7,000 PIT	Methow R. at GWP (YN)	2019	15	Volitional
2017	Methow SPC (PUD)	60,516	CWT only	5,000	Chewuch R. at CAF	2019	15	Volitional
2017	Twisp SPC (PUD)	30,000	CWT only	5,000 PIT	Twisp R. at TAF	2019	15	Volitional
2017	Methow SPC (USFWS)	400,000	Ad + CWT	20,000 PIT	Methow River at WNFH	2019	17	Forced (2-day)

2017	Okanogan SPC[4] (CCT)	200,000	CWT only	5,000 PIT	Okanogan R. at Tonasket Pond	2019	15	Volitional
2017	Chief Joe SPC[5] (CCT)	700,000	Ad + 200K CWT	5,000 PIT	Columbia R. at CJH	2019	15	Forced
2017	Chiwawa R. SPC (CPUD) (conservation)	144,026	CWT only	5,000 PIT minimum	Chiwawa River at CPD	2019	18	Short term volitional
2017	Nason Cr. SPC (GPUD) (conservation)	125,000	CWT body tag	5,000 PIT	Nason Cr. at NAF	2019	18	Forced
2017	Nason Cr. SPC (GPUD) (safety net)	98,670	Ad + CWT		Nason Cr. at NAF[9]	2019	18	Forced
Fall Chinook								
2017	Priest Rapids FAC 0+ (ACOE)	1.7M	Ad + Oto	Approximately 43,000 spread across the fish released from PRH	Columbia River at PRH	2018	50	Forced
2017	Priest Rapids FAC 0+ (GPUD)	600,000	Ad+CWT+ Oto		Columbia River at PRH	2018	50	Forced
2017	Priest Rapids FAC 0+ (GPUD)	600,000	CWT + Oto		Columbia River at PRH	2018	50	Forced
2017	Priest Rapids FAC 0+ (GPUD)	1M[2]	Ad + Oto		Columbia River at PRH	2018	50	Forced
2017	Priest Rapids FAC 0+ (GPUD)	3.4M	Oto only		Columbia River at PRH	2018	50	Forced
2017	Ringold Springs FAC 0+ (ACOE)	3.5M	Ad + Oto		Columbia River at RSH	2018	50	Forced
Steelhead								
2018	Wenatchee Mixed (HxH/WxW) (CPUD)	66,771	Ad + CWT (HxH) CWT only (WxW)	Estimated 5,400 PIT[7]	Nason Cr. direct release	2019	6	Forced/Volitional
2018	Wenatchee Mixed (HxH/WxW) (CPUD)	53,170	Ad + CWT (HxH) CWT only (WxW)	Estimated 4,300 PIT[7]	Chiwawa R. direct release	2019	6	Forced/Volitional
2018	Wenatchee Mixed (HxH/WxW) (CPUD)	102,359	Ad + CWT (HxH) CWT only (WxW)	Estimated 8,278 PIT[7]	Wenatchee R. direct release	2019	6	Forced/Volitional

2018	Wenatchee HxH (CPUD)	25,000	Ad + CWT	Estimated 2,022 PIT[7]	Wenatchee R. at BBP	2019	6	Volitional
2018	Twisp Conservation (DPUD)[11]	48,000	CWT only	TBD	Twisp River at Buttermilk Bridge/TBD	2019	6	Direct Plant
2018	Wells HxH (DPUD)	100,000	Ad only	5,000 PIT	Methow River at MFH	2019	6	Volitional
2018	Wells HxH (DPUD)	160,000	Ad only	5,000 PIT	Columbia R. at Wells Dam	2019	6	Volitional
2018	MetComp WxW (USFWS)	200,000	Ad + CWT	20,000 PIT	Methow R. at WNFH or other locations TBD	2019	4-6	Volitional/Direct Plant
2018	Okanogan HxH/HxW (CCT/GPUD)	Up to 100K [6]	Ad /CWT snout	Up to 20,000 PIT [7,9]	Okanogan/Similkameen Omak, Salmon, Wildhorse Ck.,, other tribs. (TBD)	2019	5-8	Volitional capture Wells; dropped planted in Salmon Creek, Similkameen R., and possibly other tributaries, TBD by fall of 2018.
2018	Okanogan WxW (CCT/GPUD)	Up to 100K [6]	Body and snout CWT[8]	Up to 20,000 PIT [7,9]	Okanogan/Similkameen Omak, Salmon, Wildhorse Ck.,, other tribs. (TBD)	2019	5-8	Volitional from St. Mary's pond. The numbers going to Omak Creek and other tributaries will be determined by fall of 2018.

[1] Release of fish at the Goat Wall Pond remote acclimation site operated by the YN is conditional upon HC and HSC approval.
[2] Externally marking of this group is presently funded by WDFW. Marking of this 1M fish is contingent on *US v. Oregon* Policy Committee approval for 2017.
[3] Presently all CWT's are applied to the snout.
[4] The Okanogan SPC program derives its juveniles from a 200K transfer of Methow SPC from WNFH as part of a reintroduction effort. Fish are released into the Okanogan Basin.
[5] The Chief Joe Hatchery SPC program presently receives surplus adults from the Leavenworth NFH. Juveniles are released on station from CJH.
[6] Total Okanogan release not to exceed 100K + 10%.
[7] PIT number s to each release site are estimated and not actual.
[8] The Okanogan steelhead HGMP and NOAA's BiOp for the TRMP state that WxW progeny will receive a unique internal tag (CWT or PIT) and/or receive an alternative fin clip. At this time, CCT does not intend to use an alternative fin clip until/unless a high proportion of the released fish have WxW parents and there is an acceptable survival risk/benefit of the alternative fin clip.

[9] Total PIT tag release in the Okanogan 20,000
[10] Beginning with the 2017 brood, adult returns from the Nason conservation program will be utilized to meet the Nason safety net program and will receive a supplemental body tag (blank wire either at the base of the adipose or the caudal peduncle) in addition to the adipose clip.
[11] With the recent detection inbreeding depression effects in the Twisp conservation program, parties are currently working on developing a new plan for the program. Once developed and agreed to, this table will be updated to reflect any changes.

Appendix C

Return Year Adult Management Plans

At a gross scale, adult management plans will include all actions that *may* be taken within the current run year to address surplus hatchery fish (if any). At the time of submission for this document, spring Chinook will probably be the only group where a reasonable pre-season forecast may be available to lay out what the expected surplus is, how many can be expected to be removed through each action, etc. Preseason forecasts for steelhead will be available in September.

Wenatchee Spring Chinook

Pre-season estimates for age-4 and age-5 adults project a total of 5,410 (773 natural origin [14.3%] and 4,637 hatchery origin [85.7%]) spring Chinook back to Tumwater Dam in the Wenatchee Basin. Approximately 3,827 Chiwawa and 1,491 Nason spring Chinook are to reach Tumwater Dam in 2017, of which about 681 (12.8%) and 4,637 fish (87.2%) are expected to be natural and hatchery origin spring Chinook, respectively. The balance of about 92 natural origin spring Chinook expected back are destined to the remaining spawning aggregates (Table 1). In-season assessment of the magnitude and origin composition of the spring Chinook return above Tumwater Dam will be used to provide in-season adjustments to hatchery/wild composition and total broodstock collection, consistent with ESA Section 10 Permits 18118 and 18121.

Table 1. Age-4 and age-5 class return projection for wild and hatchery spring Chinook to Tumwater Dam during 2017.

	Chiwawa Basin[1]			Nason Cr. Basin[1]			Wenatchee Basin to Tumwater Dam[2]		
	Age-4	Age-5	Total	Age-4	Age-5	Total	Age-4	Age-5	Total
Estimated wild return	418	108	**526**	123	32	**155**	614	159	**773**
Estimated hatchery return	3,238	63	**3,301**	1,336	0	**1,336**	4,574	63	**4,637**
Total	3,656	171	**3,827**	1,459	32	**1,491**	**5,188**	**222**	**5,410**

[1] Reflects NOR estimates to Tumwater Dam and has not been adjusted for pre-spawn mortality.
[2] Wenatchee Basin to Tumwater Dam total includes NORs to the White, Little Wenatchee, and Chiwawa rivers and Nason Creek.

Absent conservation fisheries or adult removal at Tumwater Dam (TWD), the expected number of age-4 and age-5 Hatchery Origin Returns (HOR) for the upper Wenatchee River Basin as a whole is estimated to be approximately six times the expected number of Natural Origin Returns (NORs; 6.3 times the number of NOR’s in the Chiwawa River and 8.6 times the number of NOR’s in Nason Creek). The combined HO and NO returns will represent about 4.2 times the number of adults needed to meet the interim Chiwawa run escapement to TWD of 900 fish indicating a disproportionate number of hatchery origin spring Chinook will be on the spawning grounds in the fall of 2017 (Table 2). The combined HO and NO returns will represent about 3 times the number of adults needed to meet the interim Nason run escapement to TWD of 500 fish indicating a disproportionate number of hatchery origin spring Chinook will be on the spawning grounds in the fall of 2017 (Table 3).

Additional Adult Management

2017 adult management actions are intended to provide for near 100% removal of age-3 hatchery males (jacks), and unknown hatchery origin adults (ad-/cwt-) and up to about 93% of the age-4 and age-5 hatchery origin adults (about 1,717 males and 1,288 females according to current models, Table 2). In addition, approximately 68 HO and 144 NO adults will be removed between TWD and the Chiwawa Weir and retained for broodstock to support meeting the combined Grant and Chelan PUD Wenatchee spring Chinook obligation, the balance will be surplused at TWD and used for tribal and/or food bank disbursements or nutrient enhancement projects.

Table 2. Run escapement and spawning escapement of Chiwawa River hatchery and natural origin fish to Tumwater Dam and the Chiwawa River in 2017.

	To Tumwater Dam		To Chiwawa River		Adults surplused at TWD[3]	Total Chiwawa spawners
	Wild	Hatchery	Wild[1,2]	Hatchery[2]		
Females[4]	305	1,850	228	73	1,717	**301**
Males[4]	221	1,388	156	55	1,288	**211**
Sub-total	526	3,238	384	128	3,005	**512**
Pre-spawn survival[6]			0.85	0.55		
Expected PNI						**0.80**
Expected pHOS						**0.25**

[1] Wild broodstock needs of 74 wild NO fish (37 females/37 males) for the Chiwawa conservation program have already been accounted for in this total as well as pre-spawn mortality.
[2] Adjusted for pre-spawn mortality.
[3] Does not include age-3 hatchery males "jacks" removed during adult management activities at TWD or through a conservation fishery.
[4] Age-4 and age-5 fish only. Gender proportions were made based upon a 5-year average sex ratio for hatchery and wild fish of the same age class.
[5] This should result in approximately 301 redds in the Chiwawa Basin under the assumption that each female produces only one redd.
[6] Estimated survival from Tumwater to spawn.

Table 3. Run escapement and spawning escapement of Nason Creek hatchery and natural origin fish to Tumwater Dam and Nason Creek in 2017.

	To Tumwater Dam		To Nason Creek		Adults surplused at TWD[3]	Total Nason spawners
	Wild	Hatchery	Wild[1,2]	Hatchery[2]		
Females[4]	90	763	47	159	440	**206**
Males[4]	65	573	26	120	321	**146**
Sub-total	155	1,336	73	279	761	**352**
Pre-spawn survival[6]			0.85	0.55		
Expected PNI						**0.56**

Expected pHOS	**0.79**

[1] Wild broodstock needs of 70 wild NO fish (35 females/35 males) for the Nason conservation program have already been accounted for in this total as well as pre-spawn mortality.
[2] Adjusted for pre-spawn mortality and HO broodstock needs of 68 fish (34 females/34 males).
[3] Does not include age-3 hatchery males "jacks" removed during adult management activities at TWD or through a conservation fishery.
[4] Age-4 and age-5 fish only. Gender proportions were made based upon a 5-year average sex ratio for hatchery and wild fish of the same age class.
[5] This should result in approximately 206 redds in Nason Creek under the assumption that each female produces only one redd.
[6] Estimated survival from Tumwater to spawn.

Wenatchee Summer Steelhead

Depending on the outcome of preseason and in-season estimates of hatchery and natural origin steelhead to the Wenatchee Basin during the annual run cycle monitoring at the Priest Rapids Dam Off Ladder Trap (OLAFT), removal of surplus adult steelhead may occur at Tumwater Dam or in combination with a conservation fishery.

A more detailed run forecast will be available in September 2017. Adult management plans will be finalized then and appended to this document.

Methow Spring Chinook

Pre-season estimates project a total of 3,265 (973 natural origin [29.8%] and 2,292 hatchery origin [70.2%]) spring Chinook back to Methow Basin. Of the 2,292 hatchery returns, about 748 are estimated to be from the conservation program with the balance of 1,544 from the WNFH safety net program (Table 5).

Table 5. Brood year 2012-2014 age class and origin run escapement projection for UCR spring Chinook at Wells Dam, 2017.

	Projected Escapement											
	Origin								**Total**			
	Hatchery				**Wild**				**Methow Basin**			
Stock	**Age-3**	**Age-4**	**Age-5**	**Total**	**Age-3**	**Age-4**	**Age-5**	**Total**	**Age-3**	**Age-4**	**Age-5**	**Total**
MetComp	188	473	12	**673**	54	619	126	**799**	242	1,092	138	**1,472**
%Total				41.5%				82.1%				56.7%
Twisp	16	47	12	**75**	21	142	11	**174**	37	189	23	**249**
%Total				4.6%				17.9%				9.6%
Winthrop (MetComp)	324	1,189	31	**1,544**					324	1,189	31	**1,544**
%Total				53.9%								33.7%
Total	528	1,709	55	**2,292**	75	761	137	**973**	603	2,470	192	**3,265**

Some level of adult management will be required to limit the number of hatchery spring Chinook on the spawning grounds. Because a conservation fishery is not yet possible under current permit limitations, adult management will need to occur through operation of the volunteer channel traps located at both the Methow Hatchery (MH) and Winthrop NFH (WNFH).

Presently hatchery fish from MH are prioritized to: a) contribute to the supplementation of the natural populations (up to either the escapement objectives or PNI/pHOS goal), b) make up shortfalls in natural-origin brood for the MH conservation program, and c) to support the 400K safety-net program at WNFH. As such WNFH will operate volunteer hatchery ladder to support removal of excess safety-net and conservation fish (when needed) fish. MH will operate its volunteer trap and will provide surplus hatchery adults (in excess to the MH and conservation needs) to WNFH to support the safety-net program, to support removal of excess safety-net and conservation fish, or retain adults to facilitate testing translocation of conservation fish to under-seeded spawning areas as approved by the HCP HC and PRCC HSC. The translocation of conservation program adults will be prioritized over their use as broodstock for the safety net program as long as both programs can meet full production. The intention of adult translocation is to increase natural production which is the primary function of the Methow Hatchery.

Specific actions are as follows:

Adult management actions will be used to support achieving hatchery production levels and escapement/sliding-scale PNI targets identified in the Methow Spring Chinook BiOp (2017) and Permits #18925, #18927 and #20533. Adult management removal targets identified in this document may be revised based on best available inseason run estimates.

Twisp River Spring Chinook: spring Chinook in the Twisp River will be managed separately from the rest of the basin.

a. Adipose-clipped fish encountered at the Twisp Weir will be removed (putative WNFH returns or strays from outside of the basin).
b. Age-3 hatchery males will be removed and euthanized or transported to WNFH.
c. Adult management will be performed to maintain pHOS ≤0.50. pNOB will be >0.50 and may be allowed to fluctuate between 0.50 and 1.0 in order to achieve a pHOS ≤0.50.
d. Wild fish will be collected as broodstock – up to ~18 individuals, but not to exceed 33% of the wild run. Hatchery fish may be collected as broodstock dependent on collection success of wild fish and provided that Twisp-program pNOB may not be less than 0.50.
e. The Twisp Weir will be fished for the duration of the broodstock collection, only, in 2017. Adult management activities will be incidental to broodstock collection. Once broodstock collection is completed, the weir will be opened to fish passage to limit delay/trapping effects on bull trout. Tentatively, during broodstock collection, the weir will be fished from 6:00 AM to 9:00 PM on a daily basis. Deviation from this schedule may be implemented based on the run size and catch efficiency for broodstock.

Methow River (MFH and WNFH) and Chewuch River Spring Chinook (MetComp):

a. Stock assessment will be performed at Wells Dam during the spring Chinook broodstock collection. This information on stock, hatchery:wild, and male:female composition in conjunction with fish counts at Wells Dam will be used to adjust in-season adult management targets.

b. MetComp returns will be managed by removing volunteers at WNFH and Methow Hatchery using the outfall traps at these facilities.

   i. All hatchery-origin age-3 males will be removed

      1. Gender identified by ultrasound.

   ii. The Methow and Winthrop FH volunteer traps will be fished continuously (24 h per day/7 d per week) throughout the run and fish removed at least once daily (depending on specific facility limitations), or as often as needed when fish are present. Adjustments to the operation of the trapping facilities will be made based upon capture/extraction rates as well as bull trout encounters and take limitations.

   iii. Trapping will cease at Methow Hatchery if:

      1. Removal of MFH and WNFH origin adults meets the targets established (in this document and as adjusted in-season), or

      2. If overall hatchery bull trout take is likely to be exceeded. However, in-season adjustment may be made to reduce the likelihood of bull trout encounters including, but not limited to: limiting 1) the time of day trap is fished, 2) hours per day fished, 3) days per week fished.

   iv. Trapping will cease at Winthrop NFH if:

      1. Removal of WNFH and MFH origin adults meets the targets established (in this document and as adjusted in-season), or

      2. If overall hatchery bull trout take is likely to be exceeded. However, in-season adjustment may be made to reduce the likelihood of bull trout encounters including, but not limited to: limiting 1) the time of day trap is fished, 2) hours per day fished, 3) days per week fished.

   v. All adipose clipped returns encountered at WNFH and MFH volunteer traps will be removed.

      1. Returns to WNFH will be retained at WNFH for broodstock (WNFH safety net and Okanogan 10(j) programs) or surplusing.

      2. Returns to MFH will be transferred to WNFH for broodstock (WNFH safety net and Okanogan 10(j) programs) or surplusing.

   vi. Conservation program returns may also be transported to specific reaches of the Methow and/or Chewuch Rivers to meet the minimum spawning escapement objective or to experimentally augment spawner distribution (such an action will require an approved study or implementation plan by the HCP HC and PRCC HSC, and be permissible under current ESA permits).

Based on the preseason forecast for wild and hatchery spring Chinook to the Methow Basin, once NO broodstock requirements are fulfilled and accounting for an estimated prespawn mortality for NO fish of 50% (42% for HO fish), there will be approximately 426 NO spawners. Based upon the sliding PNI scale for NO run sizes >300 fish, the initial goal for 2017 will be to manage for a minimum spawning escapement of 548 spawners; to achieve this, an estimated 67.4% of the hatchery returns (1,862 HO fish) will need to be removed (Table 6). This will result in approximately 122 hatchery origin spawners on the spawning grounds after accounting for prespawn mortality.

Table 6. Calculated targets and projected adult management results for Methow spring Chinook in 2017.

Wild Spawning Escapement	pNOB[2]	pHOS	PNI Target[3]	Allowable Hatchery Spawners	Hatchery surplus	Hatchery Broodstock (WNFH + 10j)	Proportion of Hatchery Fish to Remove	Total spawning escapement
426[1]	1.00	0.223	0.82	122	0 MH	472	0.674[4]	548
					1,544 WNFH			
				Adjusted for Pre-spawn loss	Total Surplus			
				290	1,390			

[1] Adjusted for prespawn mortality. Includes about 78 NO fish expected to go into the Twisp River basin.
[2] pNOB of conservation program only.
[3] Based on 3-pop model and assumes a minimum of 75% conservation program adults for WNFH broodstock.
[4] Assumes a 90% conversion of hatchery fish to hatchery outfalls. Value includes hatchery adults needed to meet WNFH and Okanogan 10(j) production components.

In-season assessment of the magnitude and origin composition of the spring Chinook return above Wells Dam will be used to provide in-season adjustments to hatchery/wild composition and total broodstock collection, consistent with ESA Section 10 Permits 18925, 18927, and 20533.

Methow Summer Steelhead

Depending on the outcome of preseason and in-season estimates of hatchery and natural origin steelhead to the Methow Basin during the annual run cycle monitoring at the Priest Rapids Dam Off Ladder Trap (OLAFT), removal of surplus adult steelhead may occur at the Twisp Weir (primarily as an action related to the steelhead RSS to meet a 1:1 hatchery:wild spawning composition upstream of the weir), the Wells Hatchery Volunteer Channel, volunteer returns to the Methow Hatchery and Winthrop NFH, or in combination with a conservation fishery.

A more detailed run forecast will be available in September 2017. Adult management plans will be finalized then and appended to this document.

Okanogan Summer Steelhead

Depending on the outcome of preseason and in-season estimates of hatchery and natural origin steelhead to the Okanogan Basin during the annual run cycle monitoring at the Priest Rapids Dam Off Ladder Trap (OLAFT), removal of surplus adult steelhead may utilize a conservation fishery or in combination with removal through spring Okanogan tributary weir operations.

A more detailed run forecast will be available in September 2017. Adult management plans will be finalized then and appended to this document.

Appendix D

Site Specific Trapping Operation Plans

Tumwater Dam

For 2017, WDFW and Chelan PUD are proposing the following plan (a summary of activities by month for Tumwater Dam is summarized in Table 1):

1) **Real-time monitoring and trap operations:** Throughout all trapping activities described in this plan, the two PIT tag antennae arrays within the Tumwater Dam ladder (weir 15 and 18 see Appendix 2), will be monitored by WDFW and Chelan PUD and detections of previously PIT tagged fish will be evaluated to determine the median passage time of fish between first detection at weir 15 and last detection at weir 15 or weir 18. Median passage estimates will be updated with every 10 PIT-tagged fish encountering weir 15. If the median passage time is greater than 48 hours, trapping will cease and fish will be allowed to exit via the ladder (i.e., bypass the trap). If trapping has been stopped, PIT tag passage monitoring will continue and trapping will resume if and when the median passage time is less than 24 hours. In summary, real-time PIT tag monitoring will occur both when the trap is operational and when fish are bypassed. This will provide an opportunity to evaluate trapping effects versus baseline passage rates through the ladder for future operations.

2) **Improved Fish Handling Efficiency**: Several infrastructure improvements at Tumwater allow WDFW and other operators to cycle through sampled fish more quickly. These improvements consist of an additional holding tank and an improved conveyance system between the trap and holding tank. The facility improvements and additional staffing by WDFW (3 operators instead of 2) during peak spring Chinook and sockeye passage (i.e. June 1 and July 15), will ensure that the trapping denil is operated constantly allowing unimpeded passage through the trap. Historically, the trapping denil has been periodically shut down while fish were being processed.

3) **Enhanced effort for Tumwater trapping operations from June 1 and July 15**: The Tumwater trap will be operated in an active-manned trapping condition (the ladder bypass will not be used however, fish may still ascend the denil [steep pass] unimpeded). The trap will be checked a minimum of 1x per day. More frequent trap checks will be made as fish numbers increase. Between June 16 and July 15 the Tumwater trap will be actively manned 24 hours/day 7 days/week utilizing two- three person crews (two people will sample fish and the third will maintain operation of the steep pass so that it will not be closed to passage). This represents an additional person to keep the denil operating

constantly. If during this period staff are not available (due to logistical, funding, or other issues) to keep the denil operating continuously, the trap will be opened to allow for nighttime passage (this is in addition to passage required under a detected delay event).

4) **Enhanced effort and limited Tumwater trapping operations from July 16 to August 31**: The trap will be operated 3 days/week for up to 16 hours/day (not to exceed 48 hours per week) to support broodstock collection activities for summer Chinook and sockeye run composition sampling (CRITFC) and sockeye spawner escapement PIT tagging. Video enumeration and full passage will occur when trapping is not occurring.

5) **Planned Tumwater trapping operations from September 1 until mid-December:** The trap will return to a 24 hours/7days/week manned or unmanned active trapping for steelhead and Coho broodstock collection and adult steelhead management. During this time period bull trout are rare and spring Chinook are not present at Tumwater. For this trapping period, real-time monitoring will continue to be implemented.

6) **Operations at Tumwater from mid-December until about mid-February:** During this period the trapping facility is not operated due to having been winterized. Only video enumeration and full passage are available during this period.

7) **Planned Tumwater trapping operations from mid-February through May:** The trap will return to a 24 hours/7days/week manned or unmanned active trapping for adult steelhead management and spawner escapement tagging. Beginning on or about May 1, limited spring Chinook broodstocking, run comp sampling, etc. may also occur. For this trapping period, real-time monitoring will continue to be implemented.

8) **Limitation in staffing or other unforeseen problems**: If WDFW staff are not available to operate the trapping facility (according to this plan) for any reason, then full passage will be allowed (fish will be allowed to bypass the trap and exit the ladder directly), until staff are able to return.

9) **Unforeseen scenarios and in season observations**: If during the trapping period, observations from field staff warrant reconsideration of any part of the plan as described above, WDFW and Chelan PUD will alert the Hatchery Committee and work cooperatively with the Services to determine whether changes are needed to further minimize incidental take or otherwise ensure that take is maintained at the manner and extent previously approved by the Services

Table 1. Summary of broodstock collection, spawner escapement tagging, adult management, run composition sampling, and reproductive success activities anticipated to be conducted at Tumwater Dam in 2017. Blue denotes steelhead, brown spring Chinook, orange sockeye, pink summer Chinook, and green Coho.

Activity	Month											
	Jan	Feb	Mar	Apr	May	June	Jul	Aug	Sep	Oct	Nov	Dec
SHD pHOS mgt[1]		15 Feb				15 June			1 Sep			15 Dec
Su. SHD BS collection[2]									1 Sep		15 Nov	
Su. SHD Spawner Esc. tagging[3]		15 Feb				15 June			1 Sep			15 Dec
Spring Chinook RSS[4]					1 May		15 Jul					
Sp Chinook run comp[5]					1 May		15 Jul					
Sp Chinook pHOS mgt[6]					1 May		15 Jul					
Sp Chin stray mgt[7]					1 May		15 Jul					
Sockeye run comp[8]							15 Jul	15 Aug				
Sockeye spawner esc tagging[9]							15 Jul	15 Aug				
Su. Chin BS collection[10]							1 Jul		15 Sep			
Coho BS collection[11]									1 Sep		30 Nov	

[1] Adult management of the 2017 brood will end in June 2017. However it is anticipated that adult management will occur for the 2018 brood beginning 1 September or earlier if conducted in conjunction with broodstock collection activities at Tumwater Dam for other species.
[2] Summer steelhead broodstock collection will be prioritized at Dryden Dam traps. However if broodstock objectives cannot be met at Dryden then trapping may occur at Tumwater concurrent with other activities.
[3] SHD spawner composition tagging at Tumwater Dam will run concurrent with SHD adult management and other (broodstock) activities at Tumwater Dam.
[4] The spring Chinook RSS will run from 1 May through about 15 July or at such time or at such time the sockeye return develops at Tumwater Dam.
[5] Spring Chinook run composition sampling will run concurrent with the RSS.
[6] Spring Chinook pHOS management will end in July consistent with the arrival of the sockeye return and run concurrent with RSS activities.
[7] Removal of unknown hatchery origin spring Chinook strays at Tumwater Dam will run concurrent with the RSS.
[8] Sockeye run composition sampling will occur at Tumwater Dam beginning no earlier than 15 July. Trapping at Tumwater Dam for run composition sampling will follow a 3d/week, 16hrs/d (48 hrs/week) trapping schedule consistent with permit 1347.
[9] Sockeye spawner escapement sampling will occur at Tumwater Dam beginning no earlier than 15 July. Trapping at Tumwater Dam for spawner escapement tagging will follow a 3d/week, 16hrs/d (48 hrs/week) trapping schedule consistent with permit 1347.
[10] Summer Chinook broodstock collection will be prioritized at Dryden Dam. However if broodstock objectives cannot be met at Dryden Dam then trapping may occur at Tumwater Dam. Trapping at Tumwater Dam for summer Chinook broodstock will follow a 3d/week 16hr/day (48 hrs/week) trapping schedule and may run concurrent with other broodstock collection, run sampling, or adult management activities.
[11] Coho trapping will be conducted at both Dryden and Tumwater Dams. Trapping at Tumwater Dam for Coho broodstock will follow a 3d/week 16hr/day (48 hrs/week) trapping schedule and may run concurrent with other broodstock collection, run sampling, or adult management activities. Collection is permitted through December 7 of each year but typically ceases by the end of November.

Dryden Dam

For 2017, WDFW and Chelan PUD are proposing the following plan (a summary of activities by month for the right and left bank Dryden Dam traps is summarized in Table 2):

The Dryden Dam left and right bank trapping facilities will operate up to five days per week, 24 hours per day beginning July 1 and continue until as late as November 15. Both traps, if operated, will do so on concurrent days and will be checked and cleared every 24 hours, or sooner if it appears that run contribution to the facilities exceeds reasonable limits for adult holding.

If daily river temperatures meet or exceed 21° C (69.8° F) trapping activities and fish handling will cease until temperatures drop below this threshold. This may require reducing trap operation to only nighttime hours with early morning traps checks to ensure the safety of the fish.

Table 2. Summary of broodstock collection, spawner escapement tagging, adult management, run composition sampling, and/or reproductive success activities anticipated to be conducted at Dryden Dam trapping facilities in 2017. Blue denotes steelhead, pink summer Chinook, and green Coho.

Activity	Month											
	Jan	Feb	Mar	Apr	May	June	Jul	Aug	Sep	Oct	Nov	Dec
Left Bank												
Su. SHD BS collection[1]							1 Jul				15 Nov	
Su. SHD Run Comp.							1 Jul				15 Nov	
Su. SHD spawner esc. Tagging[2]							1 Jul				15 Nov	
Su. Chinook run comp							1 Jul		15 Sep			
Su. Chin BS collection[3]							1 Jul		15 Sep			
Coho BS collection									1 Sep		30 Nov	
Right Bank												
Su. SHD BS collection[1]							1 Jul				15 Nov	
Su. SHD Run Comp.							1 Jul					
Su. SHD spawner esc. Tagging2							1 Jul				15 Nov	
Su. Chinook run comp							1 Jul		15 Sep			
Su. Chin BS collection[3]							1 Jul		15 Sep			
Coho BS collection[4]									1 Sep		30Nov	

[1] Summer steelhead broodstock collection will be prioritized at Dryden Dam traps. However if broodstock objectives cannot be met at Dryden then trapping may occur at Tumwater concurrent with other activities.
[2] SHD spawner composition tagging at Dryden Dam will run concurrent with other (broodstock or M&E) activities at Dryden Dam.
[3] Summer Chinook broodstock collection will be prioritized at Dryden Dam. However if broodstock objectives cannot be met at Dryden Dam then trapping may occur at Tumwater Dam. Trapping at Dryden Dam for summer Chinook broodstock will follow an up to 5d/week 24hr/day trapping schedule and may run concurrent with other broodstock collection, run sampling, or adult management activities.
[4] Coho trapping will be conducted at both Dryden and Tumwater Dams. Trapping at Dryden Dam for Coho broodstock will follow an up to 5d/week 24hr/day trapping schedule and may run concurrent with other broodstock collection, run sampling, or adult management activities. Collection is permitted through December 7 of each year but typically ceases by the end of November.

Wells Dam Ladder and Hatchery Volunteer Traps

For 2017, WDFW and Douglas PUD are proposing the following plan (A summary of activities by month for the Wells Dam East/West ladder and Wells FH volunteer traps is summarized in Table 3):

1). **East Ladder Trap:**

The East ladder trap will only be operated as needed to meet broodstock collection objectives and other management activities if they cannot be adequately fulfilled through the West ladder and Wells FH volunteer trap operations or if construction activities on the hatchery modernization preclude use of either the West ladder or volunteer traps.

If the East ladder trap is used, it may begin as early as May 1 and, with two exceptions, will operate under a maximum 3-day per week/16 hours per day or 48 cumulative hours per week and will run concurrent with any trapping activities occurring at the West ladder trap. The first exception to the above is that for spring Chinook between May 1 and June 20, the trap may operate a maximum of 5-days per week (but no more than three consecutive days)/16 hours per day and will run concurrent with any trapping activities occurring at the West ladder trap. The second exception is for coho trapping after September 26. Anticipated trap operation is not expected to go beyond November 15.

For coho trapping, the East ladder trap may be operated, concurrent with the West ladder trap, 5 days per week/ 9 hours per day September 27 through October 9, and 7 days per week/16 hours per day beginning October 10. Trap operators will bypass Chinook, steelhead, and sockeye during coho trapping. Anticipated trap operation is not expected to go beyond November 15.

The CRITFC will also trap sockeye at Wells Dam for tagging and stock assessment. They have not yet submitted a specific request for trapping in 2017, but their preference in past years has been to use the East ladder, and to begin the last week of June and end the third week of August.

If daily river temperatures meet or exceed 21º C (69.8º F) trapping activities and fish handling will cease until temperatures drop below this threshold. This may require reducing trap operation to only nighttime hours with early morning traps checks to ensure the safety of the fish.

2). **West Ladder Trap:**

The West ladder may begin as early as May 1 for spring Chinook broodstock collection and, with two exceptions, will operate under a maximum 3-day per week/16 hours per day or 48 cumulative hours per week. The first exception to the above is that for spring Chinook between May 1 and June 20, the trap may operate under a maximum 5-days per week (but no more than three consecutive days)/16 hours per day and will run concurrent with any trapping activities occurring at the East ladder trap. The second exception is for coho trapping after September 26. Anticipated trap operation is not expected to go beyond November 15.

For coho trapping, the West ladder trap may be operated 5 days per week/ 9 hours per day September 27 through October 9, and 7 days per week/16 hours per day beginning October 10. Trap operators will bypass Chinook, steelhead, and sockeye during coho trapping. Anticipated trap operation is not expected to go beyond November 15.

The CRITFC will also trap sockeye at Wells Dam for tagging and stock assessment. They have not yet submitted a specific request for trapping in 2017, but their preference in past years has been to use the East ladder, but they also use the West ladder in some years. CRITFC trapping generally begins the last week of June and end the third week of August.

If daily river temperatures meet or exceed 21° C (69.8° F) trapping activities and fish handling will cease until temperatures drop below this threshold. This may require reducing trap operation to only nighttime hours with early morning traps checks to ensure the safety of the fish.

3). **Wells FH Volunteer Trap:** The Wells FH volunteer trap may begin as early as July 1 for summer Chinook broodstock collection and operate through mid-June of the following year for steelhead broodstock collection and adult management if needed. The trap may operate up to seven days per week/24 hours per day to facilitate broodstock collection and adult management actions.

If daily river temperatures meet or exceed 21° C (69.8° F) trapping activities and fish handling will cease until temperatures drop below this threshold. This may require reducing trap operation to only nighttime hours with early morning traps checks to ensure the safety of the fish.

Table 3. Summary of broodstock collection, spawner escapement tagging, adult management, run composition sampling, and/or reproductive success activities anticipated to be conducted at Wells Dam in 2017. Blue denotes steelhead, brown spring Chinook, pink summer Chinook, orange sockeye, and green Coho.

Activity	Month											
	Jan	Feb	Mar	Apr	May	June	Jul	Aug	Sep	Oct	Nov	Dec
East/West Ladders												
Su. SHD BS collection[1]									1 Sep		15 Nov	
Su. SHD run comp.									1 Sep		15 Nov	
Su. SHD Spawner Esc. Tagging[2]									1 Sep		15 Nov	
Sp Chinook BS collection					1 May	30 Jun						
Sp Chinook run comp					1 May		15 Jul					
Sockeye SA tagging[3]						26 June		18 Aug				
Su. Chin BS collection[4]							1 Jul		15 Sep			
Coho BS collection[5]									15 Sep		15 Nov	
Wells Volunteer Trap												
Su. SHD BS collection[1]									1 Sep		15 Nov	
SHD pHOS mgt.[6]		15 Feb				15 June			1 Sep			15 Dec
Su. Chin BS collection[7]							1 Jul		15 Sep			
Su. Chin Surplussing							1 Jul			30 Oct		

[1] Summer steelhead broodstock collection will be prioritized at West ladder and volunteer traps. However if broodstock objectives cannot be met at either of those two locations then trapping may occur at the East ladder concurrent with other activities.
[2] SHD spawner composition tagging at Wells Dam will run concurrent with other (broodstock or M&E) activities at Wells Dam.
[3] Summer Chinook broodstock collection for the Methow (Carlton) program will be prioritized at the West ladder trap. However if broodstock objectives cannot be met at the West ladder then trapping may occur at the East ladder. Trapping at the west and/or East ladders for summer

Chinook broodstock will follow an up to 3d/week 16hr/day (48 cumulative hours) trapping schedule and may run concurrent with other broodstock collection, run sampling, or adult management activities.

[4] CRITFC trapping of sockeye for stock assessment and tagging typically begins the last week of June and extends through the third week of August, following an up to 3d/week 16hr/day (48 cumulative hours) coordinated with WDFW spring or summer Chinook and steelhead broodstock collection and stock assessment trapping, preferring to trap on the East ladder.

[5] Coho trapping may be conducted at both East and/or West ladders. Trapping at Wells Dam ladder traps for Coho broodstock will follow an up to 3d/week 16hr/day trapping schedule and may run concurrent with other broodstock collection, run sampling, or adult management activities. Trapping at the Wells Dam ladder will cease no later than November 15.

[6] Adult management of the 2017 brood will end in June 2017. However it is anticipated that adult management will occur for the 2018 brood beginning 1 September or earlier if conducted in conjunction with broodstock collection activities at the Wells Hatchery volunteer channel for other species.

[7] Summer Chinook broodstock collection for the Wells Hatchery programs will be prioritized at the Wells Hatchery volunteer trap. Trapping at the volunteer channel may occur up to 7 days per week, 24 hours per day and may include broodstock collection and/or adult management.

Methow Hatchery Volunteer and Twisp Weir Traps

For 2017, WDFW and Douglas PUD propose the following plan (A summary of activities by month for Methow Hatchery volunteer trap and the Twisp Weir is summarized in Table 4):

Specific operation details for the Methow Hatchery volunteer trap and Twisp Weir are still being worked through. Once those details have been fleshed out more thoroughly, this section will be updated.

If daily river temperatures meet or exceed 21º C (69.8º F) trapping activities and fish handling will cease until temperatures drop below this threshold. This may require reducing trap operation to only nighttime hours with early morning traps checks to ensure the safety of the fish.

Table 4. Summary of broodstock collection, spawner escapement tagging, adult management, run composition sampling, and/or reproductive success activities anticipated to be conducted at Methow Hatchery and the Twisp Weir in 2017. Blue denotes steelhead and brown spring Chinook.

Activity	Month											
	Jan	Feb	Mar	Apr	May	June	Jul	Aug	Sep	Oct	Nov	Dec
Methow Hatchery[1]												
SHD pHOS mgt.			1 Mar			15 Jun			1 Sep		15 Nov	
Sp. Chinook BS collection					1 May			30 Aug				
Sp. Chinook pHOS mgt.[2]					1 May			30 Aug				
Twisp Weir[3]												
Steelhead RSS			1 Mar		30 May							
Su. SHD BS collection				1-30 Apr								
SHD pHOS mgt.			1 Mar		30 May							
Sp. Chinook BS collection						1 June		15 Aug				
Sp. Chinook pHOS mgt.						1 June		22 Aug				

[1] Specific details on how operation of the Methow Hatchery volunteer trap will work for SHD adult management are still being worked out at this time.

[2] Adult management for spring Chinook at the Methow Hatchery volunteer trap will run concurrent with broodstock collection.

[3] Specific details on how operation of the Twisp Weir will work for 2017 to include the steelhead RSS, broodstock collection, and adult management and spring Chinook broodstock collection and adult management is still being worked out at this time.

Priest Rapids Dam Off-Ladder-Adult-Fish-Trap (OLAFT)

Table 5. Summary of broodstock collection, VSP monitoring, and/or run composition sampling activities anticipated to be conducted at the Priest Rapids Dam Off-Ladder-Adult-Fish-Trap (OLAFT) in 2017. Blue denotes steelhead, purple fall Chinook, and orange sockeye.

Activity	Month											
	Jan	Feb	Mar	Apr	May	June	Jul	Aug	Sep	Oct	Nov	Dec
SHD VSP Monitoring[1]							1 Jul				15 Nov	
Fall Chin. BS collection[2]									1 Sep		15 Nov	
Fall Chinook Run Comp.[3]									1 Sep		15 Nov	
Sockeye BS Collection[4]						22 Jun	10 Jul					

[1] Steelhead VSP monitoring targets up to 15% of the annual return over Priest Rapids Dam. Presently that requires operation of the OLAFT up to 3 days/ week, 8 hours per day. The trap is opened to passage each night.
[2] To acquire the target 1,000 adipose present, non-CWT adult fall Chinook for broodstock, the OLAFT is operated up to 5 days per week, 8 hours per day. Three of the five days are concurrent with the SHD VSP monitoring. The trap is opened to passage each night.
[3] Fall Chinook run composition runs concurrent with SHD VSP monitoring and/or fall Chinook broodstock collection activities.
[4] Sockeye broodstock collection to support YN reintroduction efforts in the Yakima is based upon abundance based sliding scale. Depending on the strength of the return and allowable allocation, the trap may be operated up to 5 days per week, 8 hours per day beginning about 22 June and running through about 10 July. The trap is opened to passage each night.

Appendix E

Columbia River TAC Forecast

Table 1. 2017 Columbia River at mouth salmon and steelhead returns – actual and forecast.

***Columbia River Adult Salmon Returns: Actual and Forecasted** a*				
		2016 Forecast	**2016 Return**	**2017 Forecast**
Spring Chinook	***Upriver Total***	**188,800**	**187,816**	**160,400**
Upper Columbia (total)		27,600	26,632	19,300
Upper Columbia wild		*5,000*	*na*	*3,700*
Snake River Spring/Summer (total) b		124,800	116,282	95,800
Snake River wild b		*23,700*	*24,840*	*15,100*
Summer Chinook	***Upper Columbia***	**93,300**	**91,048**	**63,100**
Sockeye	***Total***	**101,600**	**354,466**	**198,500**
Wenatchee		57,800	c	54,200
Okanogan		41,700	c	137,900
Yakima		na	c	4,000
Deschutes		na	c	1,000
Snake River b		*2,100*	c	*1,400*
a/ Numbers may not sum due to rounding				
b/ 2016 return is based on TAC run reconstruction methodology c/ TAC is still evaluating post-season distribution to individual tributaries				
Provided by the *U.S. v Oregon* Technical Advisory Committee (TAC)				

Appendix F

Annual Chelan, Douglas, and Grant County PUD RM&E Implementation Plans

Chelan PUD

The Final 2017 Chelan Hatchery Monitoring and Evaluation Implementation Plan (PDF) is available at the HCP Hatchery Committees Extranet Homepage. Please use the following procedure:

* Visit: https://extranet.dcpud.net/sites/nr/hcphc/
* Login using "Forms Authentication" (for non-Douglas PUD employees)

Douglas PUD

The Final 2017 DCPUD ME Implementation Plan (PDF) is available at the HCP Hatchery Committees Extranet Homepage. Please use the following procedure:

* Visit: https://extranet.dcpud.net/sites/nr/hcphc/
* Login using "Forms Authentication" (for non-Douglas PUD employees)

Grant PUD

2017 GPUD Hatchery ME Implementation Plan for the Wenatchee Basin and Methow Summer Chinook Salmon
https://partner.gcpud.org/sites/ResCom/PRCCHatchery/Final/2016%20GPUD%20Hatchery%20ME%20Implementation%20Plan%20for%20the%20Wenatchee%20Basin_FINAL.pdf?Web=1

2017 Priest Rapids Hatchery Implementation Plan
https://partner.gcpud.org/sites/ResCom/PRCCHatchery/Final/PRH%20ME%202016-17%20Implementation%20plan%20final.pdf?Web=1

Appendix G

DRAFT

Hatchery Production Management Plan

The following management plan is intended to provide life-stage-appropriate management options for Upper Columbia River (UCR) PUD salmon and steelhead mitigation programs. Consistent, significant over-production or under-production risks the PUD's not meeting the production objectives required by FERC and overages in excess of 110% of program release goals violates the terms and conditions set forth for the implementation of programs under ESA and poses potentially significant ecological risks to natural origin salmon communities.

Under RCW 77.95.210 (Appendix A) as established by House Bill 1286, the Washington Department of Fish and Wildlife has limited latitude in disposing of salmon and steelhead eggs/fry/fish. While this RCW speaks more specifically to the sale of fish and/or eggs WDFW takes a broader application of this statute to include any surplus fish and/or eggs irrespective of being sold or transferred.

We propose implementing specific measures during the different life-history stages to both improve the accuracy of production levels and make adjustments if over-production occurs. These measures include (1) Improved Fecundity Estimates, (2) Adult Collection Adjustments, (3) Within-Hatchery Program Adjustments, and (4) Culling at the earliest life-stage.

<u>Improved Fecundity Estimates</u>

A) Develop broodstock collection protocols based upon the most recent 5-year mean in-hatchery performance values for female to spawn, fecundity, green egg to eye, and green egg to release.
B) Use portable ultrasound units to confirm gender of broodstock collected (broodstock collection protocols assume a 1:1 male-to-female ratio). Ultrasonography, when used by properly trained staff will ensure the 1:1 assumption is met (or that the female equivalents needed to meet production objective are collected). Spawning matrices can be developed such that if broodstock for any given program are male limited sufficient gametes are available to spawn with the females.

<u>Adult Collection Adjustments</u>

C) Make in-season adjustments to adult collections based upon a fecundity-at-length regression model for each population/program and origin composition need (hatchery/wild). This method is intended to make in-season allowances for the age structure of the return (i.e. age-5 fish are larger and therefore more fecund than age-4 fish), but will also make allowances for age-4 fish that experienced more growth through better ocean conditions compared to an age-5 fish that reared in poorer ocean conditions.

Within-Hatchery Program Adjustments

D) At the eyed egg inventory (first trued inventory), after adjustments have been made for culling to meet BKD management objectives, the over production will be managed in one or more of the following actions as approved by the HCP-HC or PRCC-HSC:
   - Voluntary cooperative salmon culture programs under the supervision of the department under chapter 77.100 RCW;
   - Regional fisheries enhancement group salmon culture programs under the supervision of the department under this chapter;
   - Salmon culture programs requested by lead entities and approved by the salmon funding recovery board under chapter 77.85 RCW;
   - Hatcheries of federally approved tribes in Washington to whom eggs are moved, not sold, under the interlocal cooperation act, chapter 39.34 RCW; and
   - Governmental hatcheries in Washington, Oregon, and Idaho; or
   - Culling for diseases such as BKD and IHN, consistent with the Salmonid Disease Control Policy of the Fisheries Co-managers of Washington State; or
   - Distribution to approved organizations/projects for research.

E) At tagging (second inventory correction) fish will be tagged up to 110% of production level at that life stage. If the balance of the population combined with the tagged population amounts to more than 110% of the total release number allowed by Section 10 permits then the excess will be distributed in one or more of the following actions as approved by the HCP-HC or PRCC-HSC:
   - Voluntary cooperative salmon culture programs under the supervision of the department under chapter 77.100 RCW;
   - Regional fisheries enhancement group salmon culture programs under the supervision of the department under this chapter;
   - Salmon culture programs requested by lead entities and approved by the salmon recovery funding board under chapter 77.85 RCW;
   - Hatcheries of federally approved tribes in Washington to whom eggs are moved, not sold, under the interlocal cooperation act, chapter 39.34 RCW; and
   - Transfer to another resource manager program such as CCT, YN, or USFWS program;
   - Governmental hatcheries in Washington, Oregon, and Idaho;
   - Placement of fish into a resident fishery (lake) zone, provided disease risks are within acceptable guidelines; or
   - Culling for diseases such as BKD and IHN, consistent with the Salmonid Disease Control Policy of the Fisheries Co-managers of Washington State; or
   - Distribution to approved organizations/projects for research.

F) In the event that a production overage occurs after the above actions have been implemented or considered, and deemed non-viable for fish health reasons in accordance with agency aquaculture disease control regulations (i.e. either a pathogen is detected in a population that may pose jeopardy to the remaining population or other programs if retained or could introduce a pathogen to a watershed where it had not previously been detected) then culling of those fish may be considered.

All, provisions, distributions, or transfers shall be consistent with the department's egg transfer and aquaculture disease control regulations as now existing or hereafter amended. Prior to department determination that eggs of a salmon stock are surplus and available for sale, the department shall assess the productivity of each watershed that is suitable for receiving eggs.

Appendix N
Chelan County PUD Hatchery Monitoring and Evaluation Implementation Plan 2018

Chelan County PUD Hatchery Monitoring and Evaluation Implementation Plan 2018

Prepared by:

Catherine Willard

July 2017

Contents

1. INTRODUCTION 1
2. AQUACULTURE MONITORING 4
   - 2.1 Broodstock Collection and Stock Assessment 5
   - 2.2 In-Hatchery Monitoring 5
   - 2.3 Release Monitoring 6
3. JUVENILE MONITORING 8
   - 3.1 Freshwater productivity of Supplemented Stocks 8
   - 3.2 Tributary Evaluations 9
4. ADULT MONITORING 10
   - 4.1 Spawning Escapement Estimates 12
   - Wenatchee Steelhead 12
   - Chiwawa and Methow Spring Chinook 12
   - Wenatchee Summer Chinook 13
   - 4.2 Harvest Reporting 13
5. DATA MANAGEMENT , ANALYSIS, AND REPORTING 14
   - 5.1 Data Management 14
   - 5.2 Data Analysis 14
   - 5.3 Reporting 14

6. Lake Wenatchee Sockeye Salmon 14
   - 6.1 Juvenile Monitoring 15
   - 6.2 Adult Monitoring 15

Appendix A 20

1. INTRODUCTION

The Habitat Conservation Plan (HCP) specifies that a monitoring and evaluation plan will be developed for the hatchery program. The approach to monitoring the hatchery programs was guided by the "*Monitoring and Evaluation Plan for PUD Hatchery Programs: 2013 Update*" (Hillman et al. 2013) and the "*Conceptual Approach to Monitoring and Evaluating the Chelan County Public Utility District Programs*" (Murdoch and Peven 2005).

The purpose of this document is to define the tasks associated with the approved scope of work to implement Chelan PUD's (CPUD's) hatchery monitoring and evaluation (M&E) plan for 2018. Additionally, monitoring and evaluation activities for Lake Wenatchee sockeye in 2018 are included in this document. As monitoring tasks are completed in 2017 and are evaluated for their efficacy, methodologies to accomplish the tasks defined in the 2018 Implementation Plan may be modified [with Habitat Conservation Plan's Hatchery Committee (HCP-HC) approval].

The work described in this plan has Endangered Species Act (ESA) coverage provided by NFMS Section 10(a)(1)(A) permits 18121 and 1395 and Section 10(a)(1)(B) permit 1347. All activities conducted under this Implementation Plan shall adhere to all terms and conditions as specified in the referenced permits. These permits allow for changes to monitoring or research protocols with the caveat that such modifications are approved by NMFS prior to implementing those changes. Terms and conditions relevant to monitoring and evaluating the hatchery programs have been used to inform the various measurements below and associated scopes of work with entities performing the work. A report summarizing compliance with the terms and conditions set forth under the above-references permits is required for submittal to NMFS; a copy of this completed report will be provided to the HCP HC.

The Implementation Plan includes all four components of the hatchery M&E Program including: (1) aquaculture monitoring; (2) juvenile monitoring; (3) adult monitoring; and (4) data, analysis and reporting. Under each component are study design elements that will be used to inform the overarching program components. Figure 1 illustrates the relationship of the components and study design elements used to address each component. Table 1 depicts which study design element is being performed by entity, and the associated objectives for each study design element as referred to in Hillman et al. 2013. For Lake Wenatchee sockeye salmon, the proposed M&E activities cover juvenile and adult life history stages and provide the data necessary to track or estimate viable salmonid population parameters (VSP) and is described in Section 6.0.

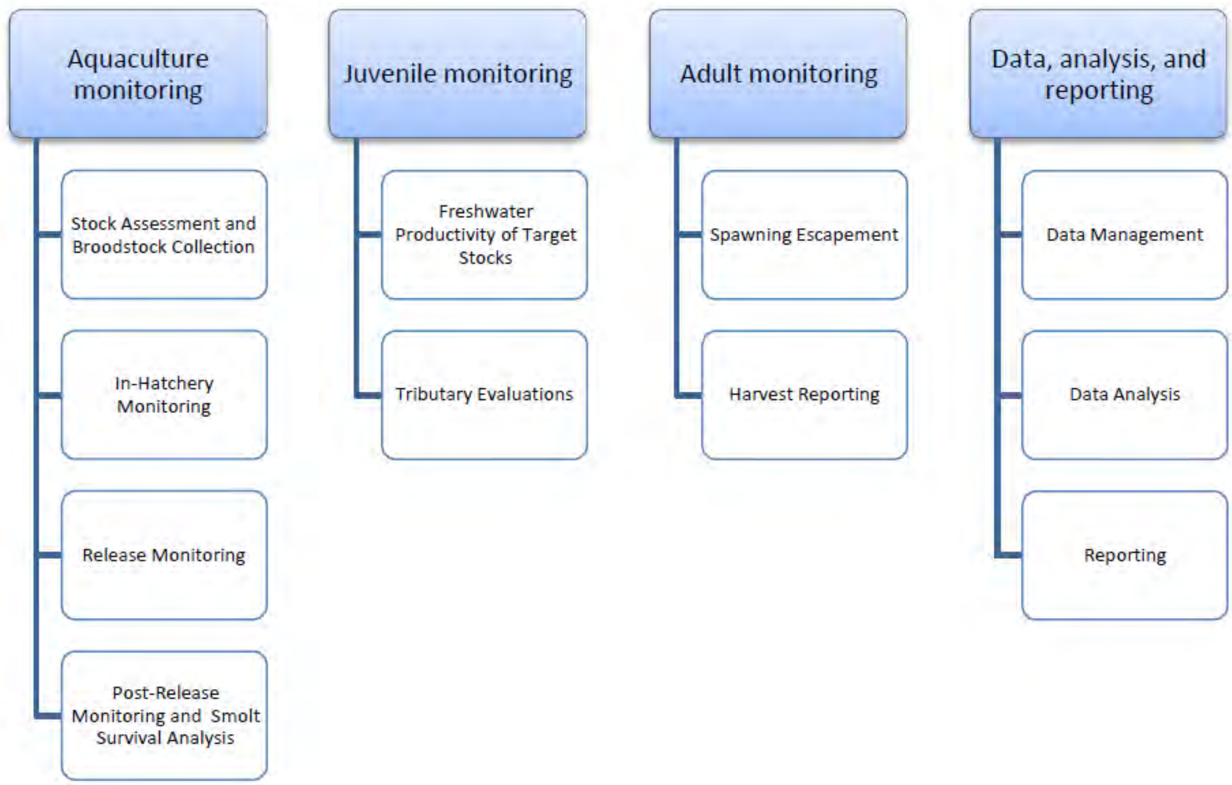

Figure 1. The four components of the hatchery monitoring and evaluation program and the study design elements within each component.

Table 1. Study design elements performed by entity, and the associated objectives for each study design element as referred to in Hillman et al. 2013.

Monitoring and evaluation component	Objectives[1]	Study Design Elements	Chiwawa spring Chinook	Wenatchee summer Chinook	Methow spring Chinook[4]	Chelan Falls summer Chinook[5]	Wenatchee Steelhead
Aquaculture Monitoring	3,5,8	Stock assessment and broodstock collection	WDFW	WDFW	WDFW	WDFW	WDFW
	5, 8	In-hatchery monitoring	WDFW CPUD[2]	WDFW CPUD[2]	WDFW Biomark[3]	WDFW CPUD[2]	WDFW CPUD[2]
	9	Release monitoring	WDFW	WDFW	WDFW	WDFW	WDFW
	9	Post-release monitoring and smolt survival analysis	WDFW	WDFW	WDFW	WDFW	WDFW
Juvenile monitoring	2	Freshwater productivity of stocks	WDFW	WDFW	WDFW	NA	WDFW
		Tributary evaluations	WDFW	WDFW	WDFW	NA	WDFW
Adult monitoring	1,2,3,4,5,6, 8,10	Spawning escapement	CPUD	WDFW	WDFW	BioAnalysts	WDFW
	8	Harvest reporting	WDFW	WDFW	WDFW	WDFW	WDFW
Data, analysis, and reporting	All	Data management	WDFW CPUD BioAnalysts	WDFW BioAnalysts	WDFW	WDFW BioAnalysts	WDFW BioAnalysts
		Data analysis	WDFW CPUD BioAnalysts	WDFW BioAnalysts	WDFW	WDFW BioAnalysts	WDFW BioAnalysts
		Reporting	WDFW CPUD BioAnalysts	WDFW BioAnalysts	WDFW	WDFW BioAnalysts	WDFW BioAnalysts

[1] Monitoring questions relative to Objective 7 will be addressed at the next 10 year HCP check-in.
[2]CPUD crews will PIT tag in-hatchery fish.
[3]Biomark will PIT tag in-hatchery fish.
[4]In 2018, monitoring and evaluation for the Methow spring Chinook program is described in “Implementation of Comprehensive Monitoring and Evaluation of Wells Hatchery Complex Programs”.
[5]Because the Chelan summer Chinook program is primarily an augmentation program, monitoring and evaluation efforts focus on straying, release characteristics, and harvest.

2. AQUACULTURE MONITORING

The aquaculture monitoring component is comprised of two basic elements: (1) stock assessment and broodstock collection at adult trapping locations and (2) in-hatchery monitoring including spawning, rearing, and release of juveniles. Data collected during these elements primarily support monitoring questions 5.1.1, 5.2.1, 8.1.1, 8.2.1, 8.3.1, 8.3.2, 8.4.1, 9.1.1, 9.2.1, 9.3.1 and 9.4.1, but also contribute data to monitoring questions 3.2.1, and 3.2.2 (Hillman et al. 2013). Table 2 below provides a summary of the variables to be measured in 2018 under the aquaculture monitoring component and what objective the measure(s) supports. The text that follows in this section further describes the activities.

Table 2. Monitoring and Evaluation Plan (Hillman et al. 2013) objectives and the associated measured variables for the aquaculture monitoring component.

Objectives	**Measured Variables** *(Applicable Study Component(s))*
<u>Objective 3:</u> Determine if the hatchery adult-to adult survival (i.e., hatchery replacement rate, HRR) is greater than the natural adult-to adult survival (i.e., natural replacement rate, NRR) and the target hatchery survival rate.	• Number of hatchery and naturally produced fish collected for broodstock (*Broodstock Collection and Stock Assessment*) • Number of broodstock used by brood year (hatchery and naturally produced fish) (*Broodstock Collection and Stock Assessment*)
<u>Objective 5:</u> Determine if the run timing, spawn timing, and spawning distribution of the hatchery component is similar to the natural component of the target population or is meeting program-specific objectives.	• Ages of hatchery and naturally produced fish sampled via PIT tags or stock assessment monitoring (*Broodstock Collection and Stock Assessment*) • Time (Julian date) of ripeness of hatchery and natural origin steelhead captured for broodstock (*Broodstock Collection and Stock Assessment*)
<u>Objective 8:</u> Determine if hatchery programs have caused changes in phenotypic characteristics of the natural populations.	• Size (length), gender, and total/salt age of broodstock (*Broodstock Collection and Stock Assessment*) • Assess age of fish (*Broodstock Collection and Stock Assessment*) • Length, weight, and age (covariate) of hatchery and natural-origin broodstock after eggs have been removed (*Broodstock Collection and Stock Assessment*) • Number and weight of eggs (*Broodstock Collection and Stock Assessment*)
<u>Objective 9:</u> Determine if hatchery fish were released at the programmed size and number.	• Fork length and weights of random samples of hatchery juveniles at release (*Release Monitoring*) • Monthly individual lengths and weights of random samples of hatchery juveniles (*In-Hatchery Monitoring*) • Numbers of smolts released from the hatchery (*Release Monitoring*)

2.1 Broodstock Collection and Stock Assessment

Broodstock collection and stock assessment for Wenatchee summer steelhead, Wenatchee summer Chinook, Methow spring Chinook, Chelan Falls summer Chinook, and Chiwawa River spring Chinook, hatchery programs will, in most instances, occur concurrent to and consistent with the Broodstock Collection Protocol approved annually by the HCP-HC and relevant permits. Data collection during broodstock collection will be consistent with Murdoch and Peven (2005). A representative sample of fish trapped throughout the entire run, either collected for broodstock or released back to the river, will be sampled for origin, age, sex, size, and migration timing. Biological sampling of all fish trapped will include presence of internal (CWT or PIT) and external (VIE) tags or marks, scales, length, and sex (determined by ultrasound). PIT tags will be injected into all target species (Chinook and steelhead), whether collected for broodstock or released back to the river to monitor for potential fallbacks. All non-target species will be enumerated daily. Measures of central tendency and spread will be calculated and reported for each metric.

2.2 In-Hatchery Monitoring

The in-hatchery monitoring component will begin when adult fish are collected and retained for broodstock and ends when juvenile fish are released. Life stage specific in-hatchery survival and growth rates, disease monitoring, and an estimate of the number of fish released will be collected and analyzed according to Murdoch and Peven (2005). Additional data to be collected includes individual lengths and weights of juveniles during monthly sampling, and the weight of gonadal mass and body of spawned broodstock. Measures of the central tendency and spread will be calculated and reported for each metric.

Fish Marking

All of Chelan PUD's hatchery fish will be coded-wire tagged (CWT) and externally marked or marked as otherwise agreed to by the HCP HC. A comprehensive marking strategy will be developed by the HCP-HC and included as an Addendum to this Plan. The identification of these hatchery-produced fish is needed for a suite of adult metrics and may be used for adult management and/or fisheries as contemplated by the co-managers.

Using methods described in Keller and Murauskas (2012), hatchery fish will be PIT-tagged (Table 3) at Eastbank Hatchery approximately two to four weeks before the fish are transferred to acclimation ponds or in the spring prior to release. Additional PIT-tagging may occur for program specific studies/comparisons as approved by the HCP-HC. The data collected from the PIT-tags will assist in release monitoring, migration timing, juvenile survival, and smolt-to-adult survival. For all fish marking, quality control check will be performed during and immediately following tagging and prior to release.

Table 3. Chelan PUD's hatchery program release goals and recommended number of fish PIT tagged.

Program	Release goals	Number of fish PIT tagged[1]	PIT tag rate (%)
Chiwawa spring Chinook	144,026	10,000	6.9
Wenatchee steelhead	247,300	20,000	8.0
Wenatchee summer Chinook	318,816 (CPUD Program) 181,184 (GPUD Program)	20,600	4.1
Methow spring Chinook	60,156	5,000	8.3
Chelan Falls summer Chinook	576,000	10,000	1.7

[1] Additional PIT tagging may take place for Chelan PUD approved studies and/or comparisons.

2.3 Release Monitoring

Hatchery fish will be released during smoltification in the spring, typically between 15 April and 1 June. Whenever possible, the exact release dates will coincide with environmental conditions that promote a rapid emigration that minimizes both the potential negative ecological interactions of hatchery fish with naturally produced fish and predation on hatchery fish by avian or other predators. The default release method will incorporate a volitional approach, as approved by the HCP HC, unless it can be demonstrated other approaches are better. The monitoring data collected for each stock are described below.

Chiwawa and Methow Spring Chinook

Pre-release sampling data will be conducted consistent with Murdoch and Peven (2005), including individual weights to the nearest 0.1 gram. Data collected will support monitoring questions 9.1, 9.2, 9.3 and 9.4 in the updated monitoring and evaluation plan (Hillman et al. 2013). PIT tag monitoring of spring Chinook released in the Chiwawa River will occur during the release period (April). Juvenile Chinook will pass through two 92-cm diameter PIT-tag antennas connected to Allflex 310 readers and Quantitative Sampling Technologies (QST) QuBE data logger. The release location and type (i.e., volitional, forced, or trucked) are recorded for each observation file created and uploaded to the PTAGIS database maintained by the Pacific States Marine Fisheries Commission after each year of release. PIT-tagged fish in each observation (release) file are assumed to represent untagged fish. Observation files contain the PIT tags associated with the original tag files and will be used for analysis (see Post-release Monitoring Section). The total number of fish released will be based on the population size at CWT tagging (100%), subtracting mortality enumerated by hatchery staff that occurred from tagging to release.

Wenatchee Summer Steelhead–

Pre-release sampling will be conducted consistent with Murdoch and Peven (2005), including individual weights to the nearest 0.1 gram. Data collected will support monitoring questions 9.1, 9.2, 9.3 and 9.4 in the updated monitoring and evaluation plan. Monitoring of steelhead released in the Wenatchee River sub-basin will occur during loading of fish into transport trucks, unless fish are released directly into the Chiwawa River. Steelhead will pass through a series of PIT-tag antennas, each connected to a data logger, thereby allowing the creation of a PIT-tag observation file for each truckload of steelhead consisting of unique tag records. The release location (stream and rkm), release type (volitional or forced), and hatchery group (HxH or WxW) will be recorded for each tag file created. PIT-tagged fish in each observation (release) file are assumed to represent untagged fish. However, because PIT-detection efficiency during loading will not be 100%, the number of fish in each truckload will be estimated using volumetric displacement. Observation files contain the PIT tags associated with the original tag files and will be used for analysis (see Post-release Monitoring Section). The total number of fish released will be based on the population size at CWT tagging (100%), subtracting mortality enumerated by hatchery staff that occurred from tagging to release.

Wenatchee and Chelan Falls Summer Chinook

Pre-release sampling will be conducted consistent with Murdoch and Peven (2005), including individual weights to the nearest 0.1 gram. Data collected will support monitoring questions 9.1, 9.2, 9.3 and 9.4 in the updated monitoring and evaluation plan. Should PIT tagging occur, a monitored release strategy consistent with other Chinook stocks (i.e., Chiwawa Spring Chinook) will be implemented. The total number of fish released will be based on the population size at CWT tagging (100%), subtracting mortality enumerated by hatchery staff that occurred from tagging to release.

2.4 Post-Release Monitoring and Survival Analysis

Data will be collected during rearing, acclimation, release, and the emigration period that may prove valuable in explaining variability in adult survival (Murdoch and Peven 2005). Rearing densities have been reported to influence the survival of hatchery fish (Martin and Wertheimer 1989; Banks 1994) and may also be linked to disease prevalence during rearing (Banks 1994; Ogut and Reno 2004). Acclimation of hatchery fish before release has been found to increase survival and reduce stray rates when the duration of the acclimation period is sufficient (Clarke et al. 2010, 2012; Rosenberger et al. 2013). These metrics (i.e., rearing density and acclimation period) will be collected annually to determine their influence on fish survival.

PIT-tagged groups of hatchery fish will be used to estimate survival during their emigration. Variation in survival during the emigration period may also inform observed adult survival rates. Survival during emigration and travel will be estimated using interrogation or release files and the standard Cormack-Jolly-Seber (CJS) estimator. CJS estimates are termed apparent survival estimates because it is unknown whether fish suffered mortality (e.g., size or time of release) or simply failed to emigrate (i.e., residualized or were precocial males). In the latter case, the proportion of PIT-tagged fish detected in the Methow sub-basin, Wenatchee or Columbia rivers after the emigration period is complete may explain variation in smolt survival rates. The post-release performance of PIT-tag groups will be estimated and monitored annually, consistent

with methods in Murdoch and Peven (2005). Additionally, precocity of hatchery releases will be evaluated by examining the proportion of PIT tag releases detected in adult fish ladders and tributaries within the same year as release.

3. JUVENILE MONITORING

Data collected during these elements primarily support monitoring questions 2.1.1 and 2.2.1. and the monitoring objectives described in Table 4 (Hillman et al. 2013). Table 4 below provides a summary of the variables to be measured in 2018 under the juvenile monitoring component and what objective the measure supports. The text that follows in this section further describes the activities.

Table 4. Monitoring and Evaluation Plan (Hillman et al. 2013) objectives and the associated measured variables for the juvenile monitoring component.

Objective	Measured Variables *(Applicable Study Component(s))*
Objective 2: Determine if the proportion of hatchery fish on the spawning grounds affects the freshwater productivity of supplemented stocks.	• Number of juveniles (smolts, parr [where appropriate], and emigrants) (*Freshwater Productivity of Supplemented Stocks*)

3.1 Freshwater productivity of Supplemented Stocks

Steelhead, Spring Chinook, and Summer Chinook

The freshwater productivity of supplemented stocks in the Wenatchee sub-basin will be monitored using smolt traps in the Chiwawa River and the lower Wenatchee River consistent with historical trapping efforts. Additionally, a newly derived analytical method which uses PIT-tag mark-recapture data will be utilized that reduces bias and increases precision by including estimates of emigration during the winter non-trapping periods. Up to 3,000 parr will be PIT tagged in the Chiwawa River in the fall, based on the spatial distribution and abundance estimated during parr snorkel surveys, to generate estimates of migration during the non-trapping periods. A random sample of a minimum of 10 percent of fish per remote site will be held in a live box for 24 hours to evaluate tag loss and delayed mortality. Using PIT tagged parr detections at the lower Chiwawa PIT array during the non-trapping period, the total number of PIT-tagged parr that emigrated will be estimated, and then expanded by the tag rate. Overwinter mortality of PIT-tagged parr is assumed to be the same as non-PIT-tagged parr. Overwinter survival estimates of Chiwawa River parr will be derived by estimating survival to the lower Wenatchee PIT tag array and analyses with the TribPit Survival software program and/or estimating survival of fall parr and spring smolts to McNary. PIT-tag mark-recapture trials conducted during the trapping period in the fall will also be used to estimate detection probabilities of the PIT-tag array at a given discharge level. Abundance and variance will be estimated using the same methods as those used in the smolt trap estimate. The estimated abundance and variance from each method and time period (trapping and non-trapping

periods) will be summed to estimate a total production estimate. Under the proposed methodology, unbiased estimates of abundance during the entire migration period will be generated with relatively high precision (PSE < 15%), which is consistent with NOAA Fisheries' recommendations (Crawford and Rumsey 2011). Historical estimates will be revised using the new estimation techniques.

Specific actions to monitor the freshwater productivity of supplemented spring Chinook salmon in the Methow sub-basin have yet to be determined. As these become available, the plan will be amended and presented to the HC by December.

3.2 Tributary Evaluations

Chiwawa River

Snorkel surveys will be utilized to estimate parr abundance within the Chiwawa subwatershed during the summer. This approach has been used in the Chiwawa subwatershed since 1992. In parallel to addressing Objective 2, additional juvenile data can help to assess the habitat carrying capacity in each tributary. This information can add value to the overall M&E plans and help inform management decisions.

Sampling will follow a stratified random sampling design. Landscape classification will be used to stratify streams in the Chiwawa subwatershed that support juvenile Chinook salmon. In the Chiwawa subwatershed, WDFW found that classification "explained" most of the variability in fish numbers caused by geology, land type, valley bottom type, stream state condition, and habitat type (Hillman 2013). The same classification method was used to identify sections of the Little Wenatchee River (reference area) that corresponded to discrete reaches in the supplemented subwatersheds, but that had no release of hatchery Chinook. Consistent with previous efforts, habitat types within each land-class or reach will be identified and quantified annually. At least three units of each habitat type within each reach will be randomly selected for estimating densities of salmon and trout. Thus, overall sampling consists of a stratified- random sampling design, which increases the accuracy and precision of population estimates.

Densities of salmon and trout will be estimated in August and September by direct underwater observation within the randomly-selected habitat units. Underwater methods will follow those described by Thurow (1994), Dolloff et al. (1996), and O'Neal (2007). Habitat surface areas and volumes will be estimated during fish sampling. Numbers of fish counted will be adjusted for detection probabilities using the models published in Hillman et al. (1992). For each habitat type within a state type and reach stratum, the mean density of salmon and trout will be calculated as the ratio of mean numbers to mean area or volume sampled (Cochran 1977). Total numbers of fish will be estimated per habitat type within a state type and reach stratum as the product of mean density of fish in a given habitat type, times total area or volume of that habitat type within the stratum (Cochran 1977). Total numbers of fish within the supplemented subwatershed will be estimated as the sum of all population numbers per habitat type in state type/reach strata. Bootstrapping methods will be utilized to estimate variance and percent errors (based on 95% confidence interval) for total numbers of fish.

4. ADULT MONITORING

The adult monitoring component is comprised of two basic elements: (1) estimating spawning escapement and (2) harvest monitoring. Data collected during these elements primarily support monitoring questions 1.1.1, 1.2.1, 2.1.1, 2.2.1, 3.2.1, 3.2.2, 4.1.1, 5.1.1, 5.2.1, 5.3.1, 5.3.2, 6.3.1, but also contribute data to monitoring questions 6.1.1, 6.2.1, 8.1.1, 8.2.1, 8.4.1, 10.1.1, 10.1.2, 10.1.3 and 10.1.4. Table 5 below provides a summary of the variables to be measured in 2018 under the adult monitoring component and what objective the measure(s) supports. The text that follows in this section further describes the activities.

Table 5. Monitoring and Evaluation Plan (Hillman et al. 2013) objectives and the associated measured variables for the adult monitoring component.

Objective	**Measured Variables** *(Applicable Study Component(s))*
Objective 1: Determine if conservation programs have increased the number of naturally spawning and naturally produced adults of the target population and if the program has reduced the natural replacement rate (NRR) of the supplemented population.	• Number of hatchery and naturally produced fish on spawning grounds *(Spawning Escapement Estimates)* • Number of hatchery and naturally produced fish taken for broodstock (*Broodstock Collection and Stock Assessment*) • Number of hatchery and naturally produced fish taken in harvest (if recruitment is to the Columbia) *(Harvest Reporting)*
Objective 2: Determine if the proportion of hatchery fish on the spawning grounds affects the freshwater productivity of supplemented stocks.	• Number of hatchery and naturally produced fish on the spawning grounds (*Spawning Escapement Estimates*) • Number of redds *(Spawning Escapement Estimates)*
Objective 3: Determine if the hatchery adult-to-adult survival (i.e., hatchery replacement rate, HRR) is greater than the natural adult-to-adult survival (i.e., natural replacement rate, NRR) and the target hatchery survival rate.	• Number of hatchery and naturally produced fish on spawning grounds *(Spawning Escapement Estimates)* • Number of hatchery and naturally produced fish harvested *(Harvest Reporting)*
Objective 4: Determine if the proportion of hatchery-origin spawners (pHOS or PNI) is meeting management target.	• Number of hatchery and naturally produced fish on spawning grounds *(Spawning Escapement Estimates)*
Objective 5: Determine if the run timing, spawn timing, and spawning distribution of the hatchery component is similar to the natural component of the target population or is meeting program-specific objectives.	• Time (Julian date) of hatchery and naturally produced salmon carcasses or marked steelhead detected on spawning grounds within defined reaches *(Spawning Escapement Estimates)* • Time (Julian date) of arrival at mainstem projects and within tributaries (e.g., traps, PIT arrays) with

Objective	Measured Variables *(Applicable Study Component(s))*
	the intent to identify biologically significant differences *(Spawning Escapement Estimates)* • Location (GPS coordinates) of female salmon carcasses observed on spawning grounds *(Spawning Escapement Estimates)*
<u>Objective 6:</u> Determine if stray rate of hatchery fish is below the acceptable levels to maintain genetic variation among stocks.	• Number of hatchery fish collected for broodstock (*Broodstock Collection and Stock Assessment*) • Number of hatchery fish taken in fishery (*Harvest Reporting*) • Locations of live and dead strays (used to tease out overshoot) *(Spawning Escapement Estimates)* • Number of hatchery carcasses (PIT-tagged and/or CWT) found in non-target and target spawning areas or number of returning spawners counted via PIT-tag detection or at weirs in close temporal proximity to spawning areas (stray data into the Entiat sub-basin will be obtained from USFWS Fisheries Resource Office-Leavenworth) *(Spawning Escapement Estimates)*
<u>Objective 8:</u> Determine if hatchery programs have caused changes in phenotypic characteristics of natural populations.	• Total and salt (ocean) age and gender of hatchery and naturally produced salmon carcasses collected on spawning grounds *(Spawning Escapement Estimates)* • Whenever possible, age at maturity and sex ratio will be measured at weirs or dams near the spawning stream to avoid the size-related carcass recovery bias on spawning grounds (carcass sampling or ultrasound on live fish) *(Spawning Escapement Estimates)* • Assess age of fish, including harvested fish *(Spawning Escapement Estimates and Harvest Reporting)*
<u>Objective 10:</u> Determine if appropriate harvest rates have been applied to conservation, safety-net, and segregated harvest programs to meet the HCP/SSSA goal of providing harvest opportunities while also contributing to population management and minimizing risk to natural populations.	• Numbers of hatchery fish taken in harvest *(Harvest Reporting)* • Numbers of natural-origin fish taken in harvest *(Harvest Reporting)*

4.1 Spawning Escapement Estimates

Chelan Summer/Fall Chinook

Chinook spawning ground surveys will be conducted in the Chelan River and (see Appendix A for survey reaches). Spawning ground surveys will be conducted via foot or raft beginning late September and continuing until spawning has ended (usually mid-November). Frequency of surveys will vary depending on method.

Summer Chinook carcass surveys will be conducted in the Chelan River beginning in September and ending in November consistent with methods described in Murdoch and Peven (2005). A representative sample (i.e., 20%) of spawners as determined by spawner abundance and distribution (typically 100% of the carcasses encountered in the Chelan River) will be sampled. Biological data will include collection of scale samples for age analysis, length measurements (POH and FKL), gender, egg voidance, and a check for tags or marks. DNA samples (five-hole punches from operculum) will be collected as needed to address different objectives. These data will be used to assess length-at-age, size-at-age, egg voidance, origin (hatchery or naturally produced), stray rates, and genetics. All carcass surveys will be conducted within the historical reaches.

Wenatchee Steelhead

The number of hatchery and naturally produced steelhead returning to the Wenatchee sub- basin will be estimated using a PIT tag mark recapture model. The estimated spawner abundance for the Wenatchee steelhead population will be a combination of PIT tag-based tributary and redd-based mainstem Wenatchee River estimates. Steelhead redd counts will be conducted weekly in all major spawning areas in the mainstem Wenatchee River (see Appendix A for survey reaches); minor spawning areas in the mainstem Wenatchee River will be surveyed once, based on the spawn timing in adjacent major spawning areas, to estimate redd abundance at peak spawning. The estimated total number of redds in the Wenatchee River mainstem will be expanded by the sex ratio of the population to estimate spawner abundance. Spawner abundance in tributaries of the Wenatchee River will be estimated using a PIT tag mark recapture model.

Chiwawa Spring Chinook

Chiwawa spring Chinook spawning escapement will be estimated based on the total number of redds found in each tributary (Murdoch et al. 2010) using methods described in Murdoch and Peven (2005). Weekly redd and carcass surveys will be conducted simultaneously from the first week of August through September (see Appendix A for survey reaches). Redd-based estimates assume that each female constructs one redd, which WDFW has found to be appropriate for this population (Murdoch et al. 2009). The total number of redds in each reach will be estimated using methods described in Millar et al. (2012) and using the observer efficiency model currently under development by WDFW. Redd counts will be expanded and the number of hatchery and naturally produced fish will be estimated using methods in Murdoch et al. (2010). Carcasses encountered during surveys will be sampled according to methods outlined in Murdoch and Peven (2005). All CWTs (i.e., snout or adipose) from carcasses will be read and the data entered into the Regional Mark Processing Center database within one year of collection.

Additionally, all redds and female carcasses will be geo-referenced using hand-held GPS devices. Carcass recovery bias has been detected in the Chiwawa spring Chinook population (Murdoch et al. 2010) and if not corrected will bias estimates of hatchery and naturally produced fish on the spawning grounds. While it may be appropriate to correct for carcass recovery bias for some monitoring questions (e.g., 2.2), when comparisons to reference populations are made in monitoring questions 1.1.and 1.2, carcass bias will not be corrected because other monitoring programs have not corrected for a similar bias.

Wenatchee Summer Chinook
Wenatchee summer Chinook spawning ground counts will begin the first week in September and continue through the end of spawning in November (see Appendix A for survey reaches). Total census redd counts will be conducted by foot or raft depending on stream size, flow, and density of spawners within the stream reach (see Appendix A for survey reaches). All stream reaches will be surveyed once per week. Redd data will be collected using methods described in Murdoch and Peven (2005). The total number of redds in each reach will be estimated using methods described in Millar et al. (2012) and using the observer efficiency model currently under development by WDFW. Weekly ground-based census counts and the true number of redds (determined via intensive surveys) will be compared in order to generate observer efficiency. River characteristics (e.g., channel width, water depth, discharge, visibility, and habitat complexity), observer experience, and survey effort will be incorporated into a model to predict observer efficiency in all river reaches. Predicted redd generate observer efficiency for each river reach will be used to adjust ground-based redd counts to estimate the total reach redd count. Ground-based surveys will also be used to estimate redd life for each river reach. The estimated spawner abundance in the Wenatchee River and an associated level of precision will be calculated using the estimated total redd count for each reach, mean redd life, and the sex ratio of the population similar to methods described in Millar et al. (2012). Salmon carcass data collected during spawning ground surveys will be consistent with Murdoch and Peven (2005). All CWTs (i.e., snout or adipose) from carcasses will be sent to the WDFW lab in Olympia. The CWT lab will extract and read CWTs and submit all required information to RMIS within one year of collection.

4.2 Harvest Reporting
In years when the expected hatchery adult returns are in excess of the levels needed to meet the hatchery program goals (i.e., broodstock and/or escapement), surplus fish may be available for harvest. Harvesting or removal of surplus hatchery fish may have benefits to the natural populations by reducing potential negative ecological and genetic impacts (e.g., density dependent effects, loss of fitness, and loss of genetic variation). The contribution of hatchery fish to fisheries will be monitored using CWT recoveries on a brood-year basis supporting Objective 10.

To obtain the necessary data to determine if the harvest rates are meeting objectives, a statistically valid creel program will be designed and implemented for all sport and/or conservation fisheries in the Upper Columbia River to estimate harvest of hatchery fish from

both Chelan and Grant County PUD funded hatchery programs (Murdoch and Peven 2005). Information collected during creel surveys are an integral component to calculating the HRR (Objective 3), particularly given most CWT recoveries for PUD mitigation programs occur in the Upper Columbia River and its tributaries, with the exception of summer Chinook where most CWT recoveries occur in ocean fisheries. Because of considerable time lags in reporting of CWT's to the Regional Marking Information System (RMIS) database, it requires an ongoing query of recovery data until the number of estimated fish does not change.

5. Data Management , Analysis, and Reporting

5.1 Data Management

A Microsoft Access database maintained by WDFW will contain all the monitoring data collected for hatchery evaluations. The database will contain and manage all data associated with aquaculture monitoring, juvenile monitoring, and adult monitoring.

All data entered into the database are evaluated for quality control and quality assurance by WDFW. Quality control checks using analyses such as modified Z-scores, boxplots, and the Generalized Extreme Studentized Deviate Procedure (Iglewicz and Hoaglin 1993) will be conducted for all data entry. In the event outliers are identified, discussion will occur on whether identified outliers are true data points or transcription errors. This process ensures that the data used to test statistical hypotheses are correct and accurate.

5.2 Data Analysis

The analyses proposed are consistent with the Monitoring and Evaluation Plan for PUD Hatchery Programs: 2013 Update (Hillman et al. 2013). Each of the objectives will be addressed using the appropriate statistical tests, as well as graphic analyses that convey relevant information.

5.3 Reporting

An annual M&E report will be generated following the completion of each calendar year and will be available for HCP-HC review by June 1 of the following year. Additionally, monthly progress reports will be made available to the HCP-HC.

6. Lake Wenatchee Sockeye Salmon

The Chelan PUD will conduct monitoring and evaluation (M&E) activities to track key population attributes related to Lake Wenatchee sockeye salmon in 2018(Table 6). In the absence of a sockeye hatchery program, M&E activities are no longer rooted in the context of evaluating the effects of sockeye salmon supplementation, but instead focus directly on the performance of the natural population, which is a unique departure from historic monitoring obligations. Broadly, the proposed M&E activities cover juvenile and adult life history stages and provide the data necessary to track or estimate viable salmonid population parameters (VSP): abundance, productivity, spatial structure and diversity (McElhaney et al. 2000). The data collected may also have utility in future hatchery compensation recalculation efforts.

Chelan PUD is conducting these M&E activities to support commitments made under the 2011 hatchery recalculation effort, which also included a steelhead production commitment for a sockeye species swap (SOA 2011). This section of the implementation plan describes the specific commitments by juvenile and adult life history stages.

6.1 Juvenile Monitoring

Chelan PUD will conduct or fund activities to monitor and evaluate the temporal distribution and age/size of out-migrating smolts, and estimate smolt production (Table 6). Smolt production will be estimated from data collected at the lower Wenatchee smolt trap and via back calculations based on collected adult return data (i.e., age-at-return estimates, SARs, and adult escapement to the tributaries). Collectively, these activities include: (1) funding of the lower Wenatchee River smolt trap concurrent with efforts aimed at evaluating Chelan PUD funded supplemented populations in the Wenatchee River sub-basin; (2) tagging up to 5,000 PIT tags for natural-origin juveniles encountered during smolt trapping activities and collecting scale samples at this location; and (3) estimating adult escapement estimates to the tributaries, and collection of adult return data at Tumwater (see the *Adult Monitoring* section for details) to back-calculate smolt production.

The monitoring data obtained will provide a useful set of tools for evaluating the performance of natural origin sockeye salmon within the sub-basin and downstream and also support the evaluation of VSP parameters [e.g., outmigration timing and size (diversity); and PIT tagging juveniles for SAR estimates (productivity)].

6.2 Adult Monitoring

Several M&E activities associated with adult returns of Lake Wenatchee sockeye salmon will be conducted and/or funded by Chelan PUD (Table 6). These efforts include (1) continuation of accurate adult counts at Rock Island, Rocky Reach, and Tumwater dams; (2) sampling of scales for age distribution, sex ratio determination, and returns of PIT-tagged adults at Tumwater Dam; (3) reach-specific conversion estimates between Rock Island Dam and spawning grounds in the White and Little Wenatchee rivers (i.e., Rock Island to Tumwater Dam to spawning tributaries); and (4) providing between 250 to 1,000 PIT tags to estimate adult spawning escapement in the Little Wenatchee and White rivers utilizing PIT tags and mark-recapture techniques (the software program Sample Size 2.0.7, developed by the University of Washington School of Aquatic and Fisheries Science (P. Westhagen, J. Lady, and J. Skalski) was used to determine the minimum number of tags required (i.e., 250) to estimate adult sockeye escapement at a +/- 7 percent confidence interval). Chelan PUD will adjust the number of PIT-tagged individuals in order to maintain precision in estimates at the lowest rate of interference to migrating populations, if it is warranted due to annual changes in escapement and detection probabilities. In an effort to PIT tag the run at large, adults will be PIT tagged at Tumwater consistent with the Tumwater Operations Protocol, daily throughout the run.

Collectively, these data will provide reliable metrics of adult returns and spawning escapement (abundance), recruits-per-spawner (productivity), distribution of spawners among tributaries (spatial structure), and run-timing and age structure for adult immigrants (diversity).

Table 6. Chelan PUD's proposed Lake Wenatchee sockeye salmon monitoring and evaluation activities.

Life History Stage	M&E Activity	Entity Performing the Activity	Related analysis	VSP parameter addressed
Juvenile	Concurrent operation of the lower Wenatchee smolt trap to collect juvenile outmigration data	WDFW	Generate distribution of outmigration timing, estimate smolt production and determine average smolt size.	Diversity and productivity
Juvenile	PIT tagging smolts at lower Wenatchee smolt trap (up to 5,000 fish annually) and collecting/aging scale samples	WDFW	Estimate smolt-to-adult returns.	Productivity
Juvenile	Develop adult return based smolt production estimates	WDFW	Use collected data (i.e., adult age-at-return data, SARs, adult escapement to the tributaries) to back-calculate smolt production.	Productivity
Adult	Rock Island and Rocky Reach Dam adult counts	CPUD	Initial spawner abundance (Okanogan stock separation)	Abundance and spatial structure
Adult	PIT tag subsample (250 adults) of returning adults at Tumwater Dam to support mark-recapture evaluation	WDFW	Calculate spawner abundance and relative distribution among ~~in~~ tributaries	Abundance and spatial structure
Adult	Collect and age scales[1] and determine sex via ultrasound from returning adults at Tumwater Dam	WDFW	Estimate age-at-return, sex ratio, and relative productivity of contributing spawner cohorts	Productivity and diversity
Adult	Tumwater Dam adult counts	WDFW	Estimate potential spawner abundance (pre Lake-Wenatchee harvest), potential productivity (recruits/spawner), and run timing distribution	Abundance and diversity
Adult	Operate PIT detection arrays on Little Wenatchee and White River	WDFW	Calculate spawner abundance (post-Lake Wenatchee harvest and other mortality), actual productivity (recruits/spawner), and entry-to-spawning-habitat timing distribution, and spatial spawner distribution among tributaries	Abundance, productivity, spatial structure, and diversity
All	Data management, analysis, and reporting	BioAnalysts CPUD	------	NA

[1] Scales would be collected concurrently from adults that are PIT tagged at Tumwater Dam.

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Appendix A

Designated survey reaches for Methow subbasin summer Chinook spawning ground surveys.

River	Reach	Code	RM
Methow	Mouth to Methow Bridge	M1	0.0-14.78
	Methow Bridge to Carlton Bridge	M2	14.78-27.17
	Carlton Bridge to Twisp Bridge	M3	27.17-39.55
	Twisp Bridge to MVID	M4	39.55-44.85
	MVID to Winthrop Bridge	M5	44.85-49.80
	Winthrop Bridge to Hatchery Dam	M6	49.80-51.55

Designated survey reaches for Wenatchee River basin summer Chinook spawning grounds surveys. Asterisks denotes reaches where redd observer efficiency will be assessed.

Reach Code	Reach Section	River Mile
W10	Lake Wenatchee to Bridge	54.20-53.58
	Bridge to Swamp *	53.58-52.66
	Swamp to Chiwawa River	52.66-48.39
W9	Chiwawa River to Schugart Flats	48.39-47.93
	Schugart Flats to Old Plain Bridge	47.93-46.21
	Old Plain Bridge to RR Bridge	46.21-41.91
	RR Bridge to RR Tunnel	41.91-39.28
	RR Tunnel to Swing Pool *	39.28-36.67
	Swing Pool to Tumwater Br	36.67-35.55
W8	Tumwater Br to Swiftwater Campground *	35.55-33.50
	Swiftwater Campground to Unimproved Campground	33.50-33.08
	Unimproved Campground to Tumwater Dam	33.08-30.91
W7	Tumwater Dam to Penstock Br	30.91-28.66
	Penstock Br to Icicle Road Br *	28.66-26.43
W6	Icicle Road Br to Icicle Mouth	26.43-25.61
	Icicle Mouth to Boat Takeout *	25.61-24.49
	Boat Takeout to Leavenworth Br	24.49-23.90
W5	Leavenworth Br to Irrigation Flume *	23.90-22.77
	Irrigation Flume to Peshastin Br	22.77-20.00
W4	Peshastin Br to Dryden Dam *	20.00-17.76
W3	Dryden Dam to Williams Canyon	17.76-15.54
	Williams Canyon to Upper Cashmere Br	15.54-10.22
	Upper Cashmere Br to Lower Cashmere Br	10.22-9.49
W2	Lower Cashmere Br to Old Monitor Br *	9.49-7.12
	Old Monitor Br to Sleepy Hollow Br	7.12-3.27
W1	Sleepy Hollow Br to River Bend *	3.27-1.73
	River Bend to Siphon	1.73-1.29
	Siphon to Mouth	1.29-0.45

Designated survey reaches for Wenatchee Basin spring Chinook spawning grounds surveys.

Reach Code	Reach Section	River Mile
Chiwawa River and Tributaries (Rock and Chikamin)		
C7	Buck Cr to Phelps Cr	36.39-33.46
C6	Phelps Cr (Trinity) to Maple Cr Br	33.46-29.64
C5	Maple Cr Br to Atkinson Flats	29.64-26.59
C4	Atkinson Flats to Schaefer Cr	26.59-24.24
C3	Schaefer Cr to Rock Cr Campground	24.24-22.97
R1 - Rock	Mouth to Chiwawa River Road Bridge	0.00-1.05
C2	Rock Cr Campground to Grouse Cr	22.97-12.27
K1 - Chikamin	Mouth to Chiwawa River Road Bridge	0.00-0.68
C1	Grouse Cr to Mouth	12.27-0.00
Nason Creek		
N4	White Pine Creek to Lower R.R. Bridge	16.09-13.68
N3	Lower R.R. Bridge to Hwy 2 Bridge	13.68-9.13
N2	Hwy 2 Bridge to Kahler Cr	9.13-4.46
N1	Kahler Cr to Mouth	4.46-0.00
White River and Tributaries (Panther and Napeaqua)		
H4	Falls to Grasshopper Meadows	21.16-19.78
T1 - Panther	Boulder field to Mouth	0.43-0.00
H3	Grasshopper Meadows to Napeaqua River	19.78-17.59
Q1 - Napeaqua	Take out to Mouth	0.91-0.00
H2	Napeequa River to Sears Cr Bridge	17.59-11.97
H1	Sears Cr Bridge to Mouth	11.97-0.00
Little Wenatchee River		
L3	Rainy Cr to Lost Cr	10.78-6.74
L2	Lost Cr to Old Fish Weir	6.74-2.13
L1	Old Fish Weir to Mouth	2.13-0.00
Upper Wenatchee River		
W10	Lake Wenatchee to Chiwawa River	54.20-48.39
Chiwaukum Creek		
U1	Metal bridge to Mouth	1.0 – 0.0
Icicle River		
I1	Hatchery to Mouth	3.02-0.00
Peshastin Creek and Tributaries (Ingalls Creek)		
D1 - Ingalls	Trailhead to mouth	0.64-0.00
P2	Ingalls Creek to Camas Cr	9.14-5.63
P1	Camas Cr to Mouth	5.63-0.00

Designated survey reaches for Wenatchee River basin steelhead spawning grounds surveys. Asterisks denote index reaches. Spawning escapements in tributaries will be estimates using PIT-tag arrays.

Reach Code	Reach Section	River Mile
W10	Lake Wenatchee to Chiwawa River*	54.20-48.39
W9	Chiwawa River to Tumwater Bridge*	48.39-35.55
W8	Tumwater Br to Swiftwater Campground	35.55-33.50
	Swiftwater Campground to Unimproved Campground*	33.50-33.08
	Unimproved Campground to Tumwater Dam	33.08-30.91
W7	Tumwater Dam to Icicle Road Bridge	30.91-26.43
W6	Icicle Road Br to Leavenworth boat ramp*	26.43-24.49
	Boat Takeout to Leavenworth Bridge	24.49-23.90
W5	Leavenworth Bridge to Peshastin Bridge	23.90-20.00
W4	Peshastin Bridge to Dryden Dam	20.00-17.76
W3	Dryden Dam to Lower Cashmere Bridge	17.76-9.49
W2	Lower Cashmere Bridge to Sleepy Hollow Bridge *	9.49-3.27
W1	Sleepy Hollow Bridge to Mouth	3.27-0.45

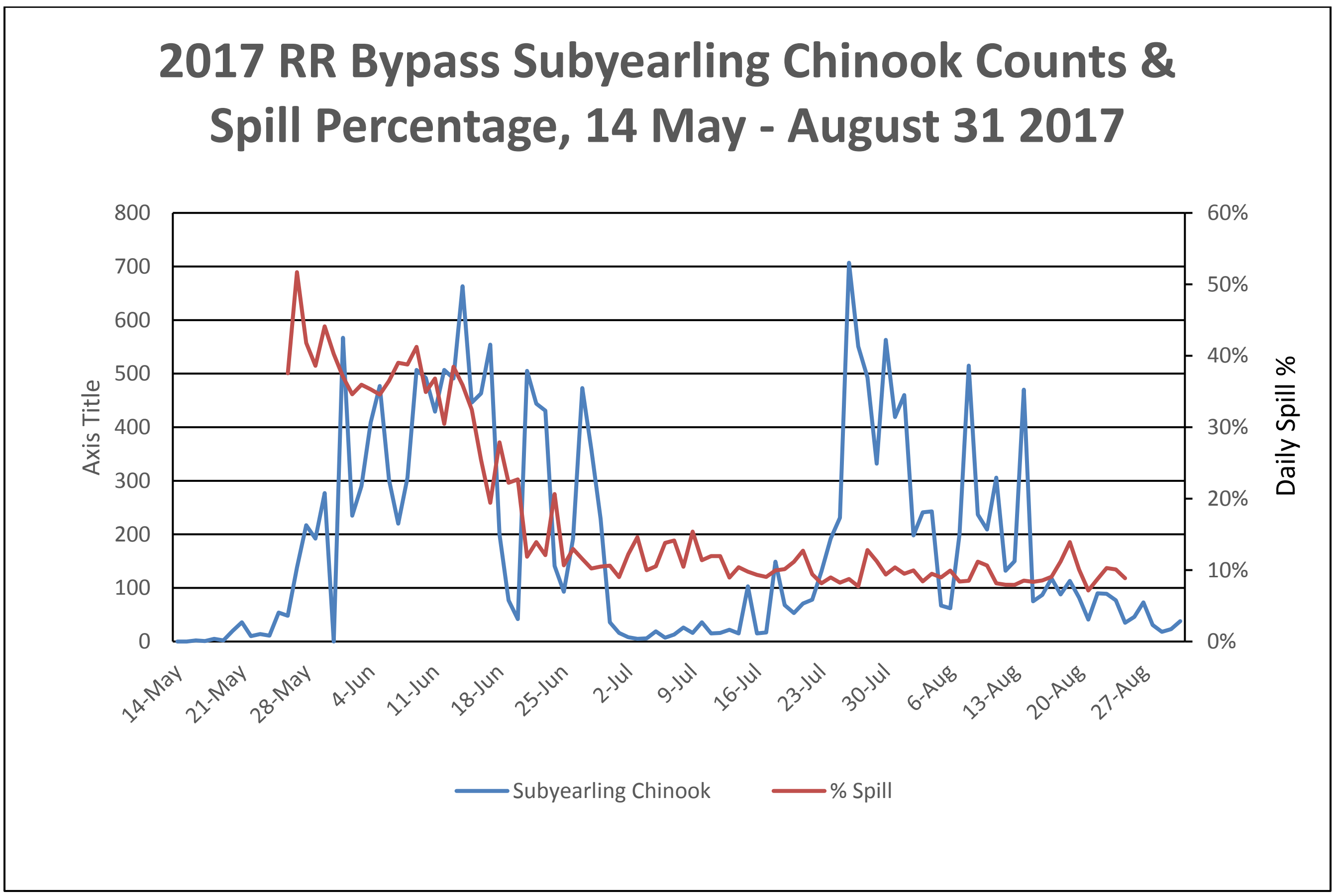
Tributary	River mile of PIT tag array
Mission Creek	0.54
Peshastin Creek	1.91
Chumstick Creek	0.31
Icicle River	0.26
Chiwaukum Creek	0.24
Chiwawa River	0.58
Nason Creek	0.52
Little Wenatchee River	1.74
White River	1.65

Appendix O
Chelan PUD Rocky Reach and Rock Island HCPs Final 2017 Fish Spill Report

Chelan PUD
Rocky Reach and Rock Island HCPs
Final 2017 Fish Spill Report

2017 ROCKY REACH
Summer Spill

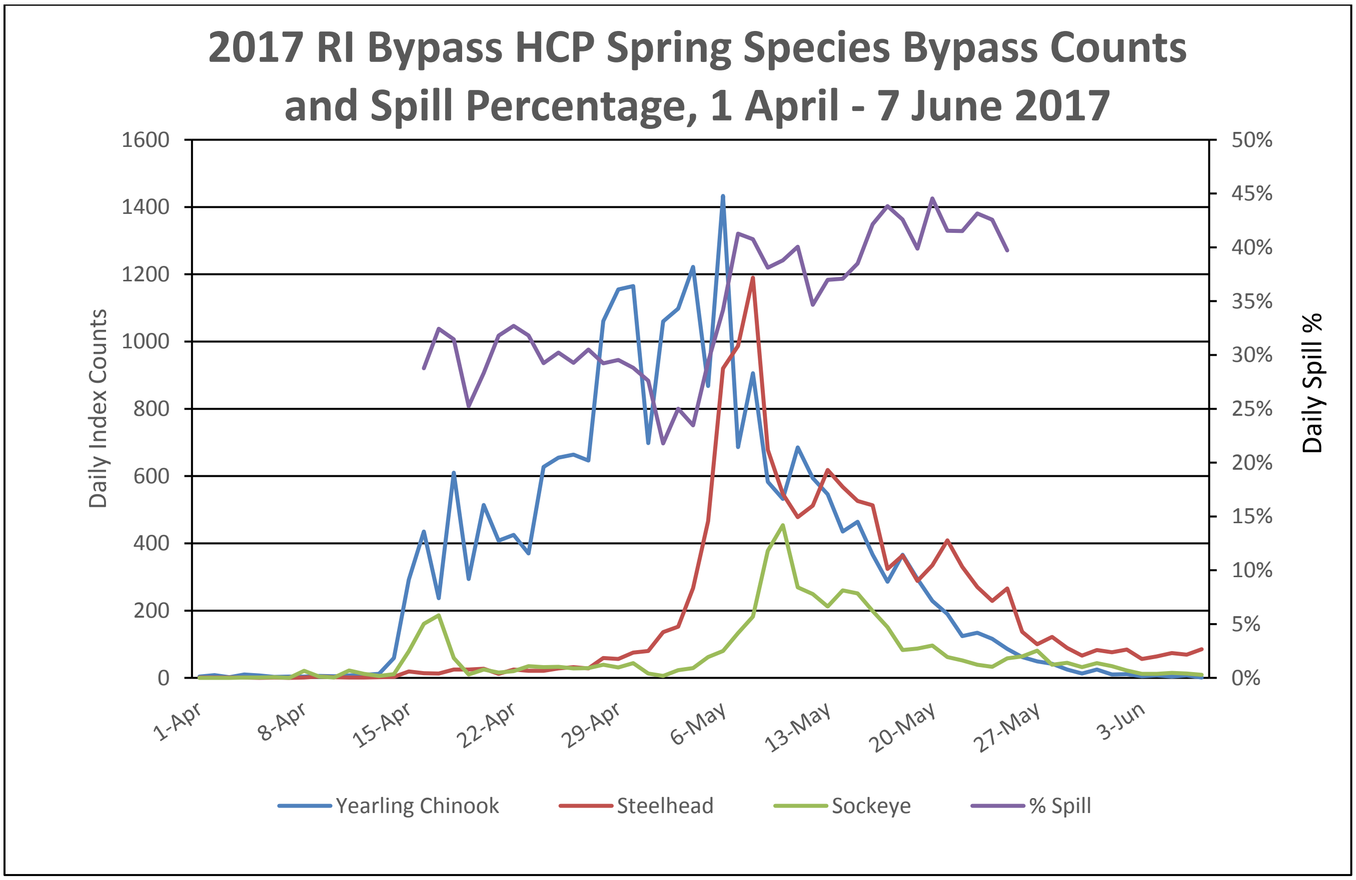
Target species:	Subyearling Chinook
Spill target percentage:	9% of day average river flow
Spill start date:	26 May, 0001 hours
Spill stop date:	25 August, 2400 hours
95% Est. passage date:	14 August
Percent of run with spill:	98.5% on 25 August (estimated as of 31 August)
Cumulative index count:	27,404 subyearling Chinook (as of 31 August)
Summer spill percentage:	21.74% (9.06% fish spill, plus 12.68% forced spill)
Avg river flow at RR:	149,598 cfs (26 May - 25 August)
Avg spill rate at RR:	32,518 cfs (26 May - 25 August)
Total spill days:	92



2017 ROCK ISLAND

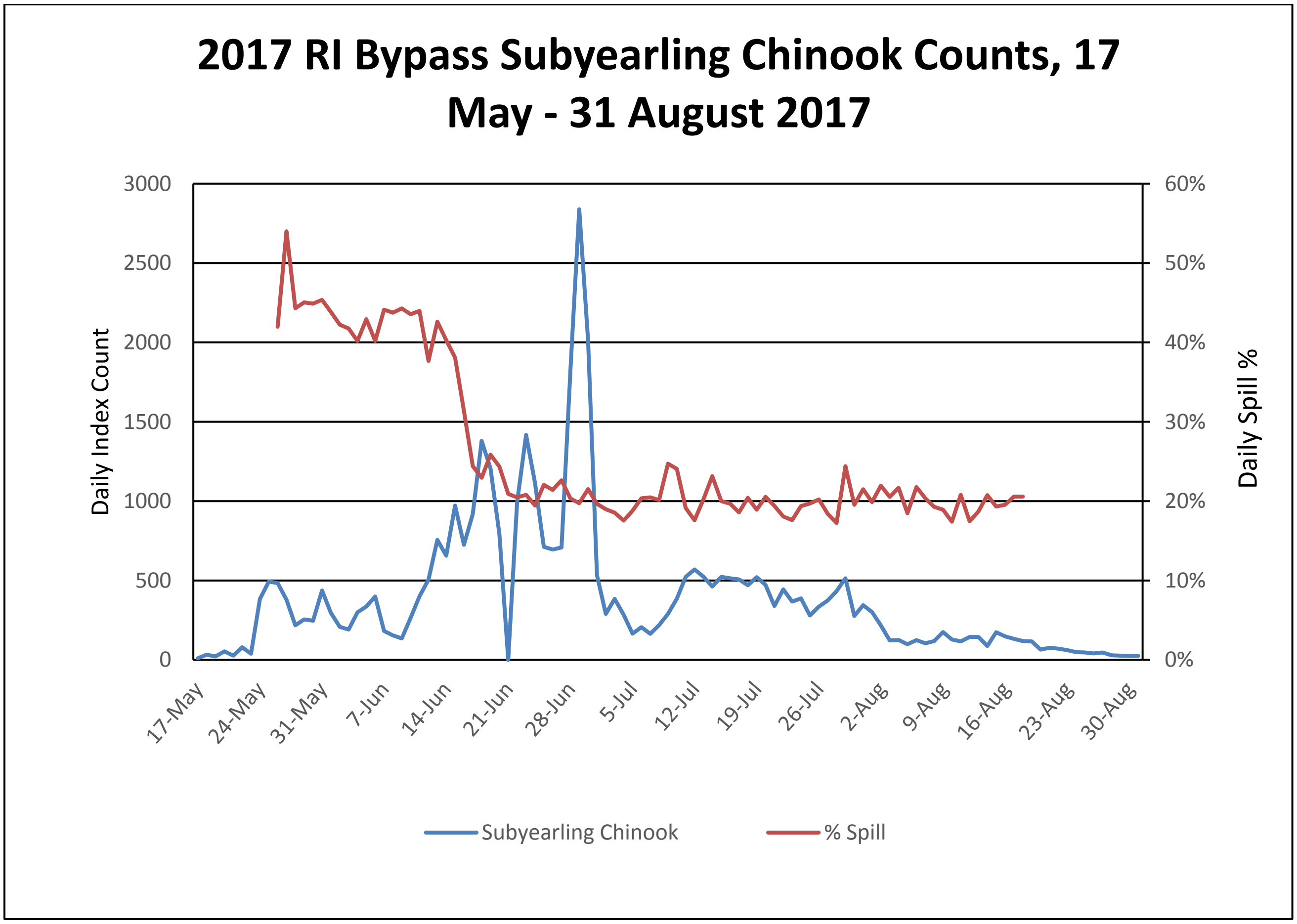
Spring Spill

Target species:	Yearling Chinook, steelhead, sockeye
Spill target percentage:	10% of day average river flow
Spill start date:	16 April, 0001 hours
Spill stop date:	25 May, 2400 hours (immediate increase to 20% summer spill)
Percent of run with spill:	Yearling Chinook – 98.4%; steelhead – 99.8%; sockeye – 97.0% (spring and summer fish spill combined)
Cumulative index count:	50,604 yearling Chinook; 32,135 steelhead; 11,117 sockeye (as of 31 August)
Spring spill percentage:	35.22% (9.69% fish spill, plus 25.53% forced spill)
Avg river flow at RI:	227,790 cfs (16 April – 25 May)
Avg spill flow at RI:	80,222 cfs (16 April – 25 May)
Total spill days:	40



Summer Spill

Target species:	Subyearling Chinook
Spill target percentage:	20% of day average river flow
Spill start date:	26 May, 0001 hours
Spill stop date:	18 August, 2400 hours
95% Est. passage date:	5 August
Percent of run with spill:	97.5% on 18 August (estimated as of 31 August)
Cumulative index count:	63,579 subyearling Chinook (as of 31 August)
Summer spill percentage:	29.47% (19.89% fish spill, plus 9.58% forced spill)
Avg river flow at RI:	162,085 cfs (26 May - 18 August)
Avg spill flow at RI:	47,774 cfs (26 May - 18 August)
Total spill days:	85



Juvenile Index Counts 2007-2017 from the Rocky Reach Juvenile Fish Bypass Sampling Facility and Rock Island Bypass Trap Smolt Monitoring Program (SMP) 1 April – 31 August (Tables 1 and 2).

Table 1. Rocky Reach Juvenile Bypass index sample counts, 2007-2017

Species	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014***	**2015**	**2016**	**2017**
Sockeye	169,937	136,206	40,758	724,394	67,879	384,224	199,497	553,645	53,575	1,374,418	**60,432**
Steelhead	4,532	8,721	6,309	4,931	5,683	4,902	2,528	5,270	4,157	1,478	**2,928**
Yearling Chinook	18,080	38,394	18,946	33,840	24,400	95,207	29,018	15,871	32,220	41,676	**37,302**
Subyearling Chinook	13,496	11,820	11,944	59,751	17,246	5,774	22,073	22,327	37,104	8,905	**27,404**

Table 2. Rock Island Smolt Monitoring Program index sample counts, 2007-2017

Species	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014***	**2015**	**2016**	**2017**
Sockeye	16,410	38,965	4,926	37,404	18,697	46,788	25,111	38,596	4,128	56,638	**11,117**
Steelhead	18,482	22,780	17,636	17,194	28,408	16,957	15,099	28,299	12,549	17,663	**32,135**
Yearling Chinook	23,714	22,562	9,225	11,802	26,407	25,759	28,324	26,429	16,762	44,784	**50,604**
Subyearling Chinook	15,686	15,940	8,189	23,205	27,397	27,298	17,170	34,527	15,349	13,270	**63,579**

* In 2014, as directed by the HCP, Chelan PUD conducted bypass operations outside of the normal operating period of 1 April to 31 August to assess achievement of bypass operations for 95% of the subyearling Chinook outmigration. The Rocky Reach juvenile fish bypass operated from 1 April through 15 September, and the Rock Island bypass facility at powerhouse 2 operated from 1 April through 15 September.

Appendix P
Monitoring and Evaluation Plan for PUD Hatchery Programs – 2017 Update

MONITORING AND EVALUATION PLAN FOR PUD HATCHERY PROGRAMS

2017 UPDATE

November 16, 2017

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Citation: Hillman, T., T. Kahler, G. Mackey, Andrew Murdoch, K. Murdoch, T. Pearsons, M. Tonseth, and C. Willard. 2017. Monitoring and evaluation plan for PUD hatchery programs: 2017 update. Report to the HCP and PRCC Hatchery Committees, Wenatchee and Ephrata, WA.

TABLE OF CONTENTS

SECTION 1: INTRODUCTION 1

SECTION 2: ADULT PRODUCTIVITY 9
2.1 Natural Replacement Rates of Supplemented Populations 9
2.2 Natural-Origin Recruits of Supplemented Populations 11

SECTION 3: JUVENILE PRODUCTIVITY 13
3.1 Freshwater Juvenile Productivity 13

SECTION 4: NATURAL ENVIRONMENT MONITORING INDICATORS 17
4.1 Hatchery Replacement Rates (HRRs) 17
4.2 Proportion of Hatchery-Origin Spawners (pHOS or PNI) 18
4.3 Run Timing, Spawn Timing, and Spawning Distribution 19
4.4 Stray Rates 22
4.5 Population Genetics 26
4.6 Phenotypic Traits 28

SECTION 5: HATCHERY ENVIRONMENT MONITORING INDICATORS 33
5.1 Release Targets 33

SECTION 6: HARVEST MONITORING INDICATORS 37
6.1 Harvest Rates 37

SECTION 7: REGIONAL OBJECTIVES 39
7.1 Incidence of Disease 39
7.2 Non-Target Taxa of Concern (NTTOC) 40

SECTION 8: ADAPTIVE MANAGEMENT 43

SECTION 9: REFERENCES 45

SECTION 10: GLOSSARY 47

APPENDIX 1: ESTIMATION OF CARRYING CAPACITY 51

APPENDIX 2: HATCHERY REPLACEMENT RATES 79

APPENDIX 3: PNI AND PHOS TARGETS AND SLIDING SCALES 81

APPENDIX 4: SPATIAL DISTRIBUTION OF SPAWNERS OR REDDS 85

APPENDIX 5: WITHIN HATCHERY REARING TARGETS 87

APPENDIX 6: IDENTIFYING AND ANALYZING REFERENCE POPULATIONS 89

LIST OF APPENDICES

Appendix 1: **Estimation of Carrying Capacity**

Appendix 2: **Hatchery Replacement Rates**

Appendix 3: **PNI and pHOS Management Targets and Sliding Scales**

Appendix 4: **Spatial Distribution of Spawners or Redds**

Appendix 5: **Within Hatchery Rearing Targets**

Appendix 6: **Identifying and Analyzing Reference Populations**

SECTION 1: INTRODUCTION

This document is an update of the monitoring and evaluation (M&E) plan of the salmon and steelhead hatchery programs funded by Douglas, Chelan, and Grant County Public Utility Districts (PUDs). Programmatic changes, evaluation of data collection methods, and M&E results from the past several years, along with shifting management paradigms affect M&E needs, all of which have occurred under advancing fish culture and monitoring techniques. As required by the programs, this document is a result of a five-year review intended to expand on and coalesce previous M&E documents (BAMP 1998; Cates et al. 2005; Murdoch and Peven 2005; Hays et al. 2006; Pearsons and Langshaw 2009a, 2009b; Hillman et al. 2013) with inclusion of new information.

Fishery management agencies developed the following general goal statements for hatchery programs, which were adopted by the HCPs Hatchery Committees and PRCC Hatchery Sub-Committee (hereafter, Hatchery Committees):

1. Support the recovery of ESA-listed species by increasing the abundance of the natural adult population, while ensuring appropriate spatial distribution, genetic stock integrity, and adult spawner productivity.
2. Increase the abundance of the natural adult population of unlisted plan species, while ensuring appropriate spatial distribution, genetic stock integrity, and adult spawner productivity. In addition, provide harvest opportunities in years when spawning escapement is sufficient to support harvest.
3. Provide salmon for harvest and increase harvest opportunities, while segregating returning adults from natural tributary spawning populations.

Following the development of Hatchery and Genetic Management Plans (HGMPs), artificial supplementation programs are now characterized into three categories. The first type, integrated conservation programs, are intended to support or restore natural populations. These programs focus on increasing the natural production of targeted fish populations. A fundamental assumption of this strategy is that hatchery fish returning to the spawning grounds are reproductively similar to naturally produced fish. The second type, safety-net programs, are extensions of conservation programs, but are intended to function as reserve capacity for conservation programs in years of low returns. The safety-net provides a demographic and genetic reserve for the natural population. That is, in years of abundant returns they function like segregated programs, and in low return years they can be managed as conservation programs. Lastly harvest augmentation programs are intended to increase harvest opportunities while limiting interactions with wild-origin counterparts.

Monitoring is needed to determine if the hatchery programs are meeting the intended management objectives of conservation, safety-net, or harvest augmentation programs. Objectives for hatchery programs are generally grouped into three categories of performance indicators:

1. In-Hatchery: Is the program meeting the hatchery production objectives?
2. In-Nature: How do fish from the program perform after release?
    a. Conservation Program:

- How does the program affect target population abundance and productivity?
- How does the program affect target population long-term fitness?

b. Safety-Net Program:

- How does the program affect target population long-term fitness?

c. Harvest Augmentation Program:

- Does the program provide harvest opportunities?

3. Risk Assessment: Does the program pose risks to other populations?

Objectives in this plan have been organized in a hierarchy where productivity indicators are the primary metrics used to assess if conservation and safety-net program goals have been met; harvest rates and effects on non-targeted populations are used for harvest programs. In cases where productivity indicators are not available or results are equivocal, monitoring indicators may be used to help evaluate the performance of the program. Evaluations of monitoring indicators may not provide sufficiently powerful conclusions on which to base management actions, although they may provide insight as to why a productivity indicator did or did not meet the program goal. Therefore, the relationship between hatchery programs and indicators can be viewed in a chain-of-causation: management actions within the hatchery programs affect the status of monitoring indicators, which in turn influence productivity indicators (Figure 1).

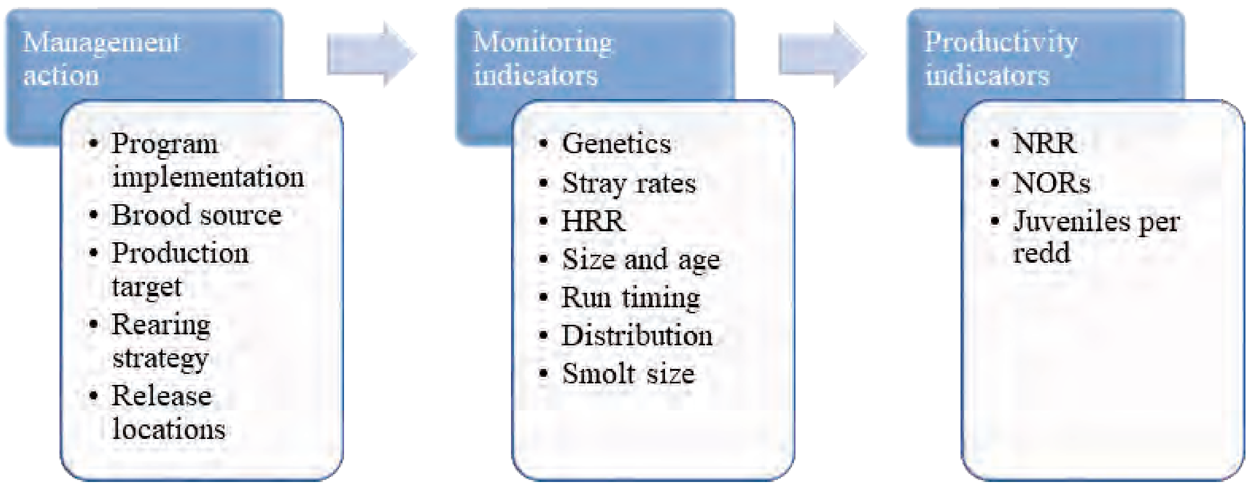

Figure 1. Relationship of indicators to the assessment of supplementation programs. Management actions affect monitoring indicators, which influence productivity indicators. Monitoring indicators may be used to hypothesize the magnitude of influence on productivity.

The primary goal of a conservation program is to contribute to the rebuilding and recovery of naturally reproducing populations within their native habitat. In this plan, natural replacement rates (NRR), recruitment of naturally-produced fish (NOR), and juvenile productivity (juveniles per redd) are important indicators for assessing the success of supplementation. These indicators are difficult to measure precisely and are quite variable in space and time. Therefore, monitoring indicators can be evaluated to help assess if productivity was related to the hatchery programs or other factors (Table 1).

Table 1. Program objectives, indicators, and goals for conservation hatchery programs including productivity and monitoring indicators (also applies to safety-net programs when used to support a conservation program).

	Objective	Indicator	Target	Program goals: Rebuild natural populations	Program goals: Maintain genetic diversity	Program goals: Opportunity for harvest
Productivity indicators	Determine if the program has increased the number of naturally spawning adults	Abundance of natural spawners	Increase	✓		✓
		Adult productivity (NRR)	No decrease	✓		
	Determine if the proportion of hatchery fish affects freshwater productivity	Residuals vs. pHOS	No relationship	✓		
		Juveniles per redd vs. pHOS	No relationship	✓		
Monitoring indicators	Determine if run timing and distribution meets objectives	Migration timing	No difference	✓	✓	
		Spawn timing[1]	No difference	✓	✓	
		Redd distribution[2]	No difference	✓	✓	
	Determine if program has affected genetic diversity and population structure	Allele frequency (hatchery vs. wild)	No difference		✓	
		Genetic distance between populations	No difference		✓	
		Effective population size	Increase		✓	
		Age and size at maturity	No difference		✓	
	Determine if hatchery survival meets expectations	HRR	HRR > NRR	✓		
		HRR	HRR ≥ Goal[3]	✓		
	Determine if recipient stray rate of hatchery fish is acceptable	Out of basin	≤ 5%	✓	✓	
		Within basin	≤ 10%	✓	✓	
	Determine if hatchery fish were released at program targets	Size and number	= Target[4]	✓		
	Provide harvest opportunities when appropriate	Harvest	Escapement goals			✓

[1] Hatchery and natural-origin fish should spawn at the same time across the range of elevations within the spawning distribution of each stock.

[2] Hatchery and natural-origin fish should spawn in the same locations. Exceptions are the Carlton and Dryden Summer Chinook programs (see Appendix 4).

[3] HRR targets are identified in Appendix 2.

[4] Number and size targets are identified in Table 3 and Appendix 5.

A flow of information following sequential, logical steps will be employed to evaluate supplementation programs, consistent with the indicators described in Table 1. For example, a hatchery program, at a minimum, must be able to produce more adults per spawner than would occur in the natural environment. Should the program fail this test, hatchery operations should be evaluated to determine if improvements can correct the problem. If a program successfully replaces the required number of adults, it is then evaluated against a reference population or condition, if available, to determine if it has increased the overall number of naturally spawning fish (including both hatchery- and natural-origin adults), increased the number of natural-origin spawners, and to test if productivity of the natural population has changed. When these goals are met, the program is considered successful. When these goals are not met, monitoring indicators may infer why the program is not achieving its goals

If suitable reference populations are not available, other comparisons can be used to help evaluate treatment responses. Evaluation of programs may pursue the following approaches:

- Comparison to reference population(s) that do not contain pre-treatment data.
- Before treatment and after treatment comparisons.
- Comparison to standard(s).
- Comparison to other suitable reference conditions.

Methodologies for selecting reference streams, analyzing data from treatment and reference stream comparisons, and other comparisons are presented in Hillman et al. (2012) (see Appendix 6).

The primary goals of a safety-net program are to provide demographic and genetic reserves for a population that is supplemented by a conservation program (Table 2). Harvest and adult management may be used to control escapement of spawners when appropriate. Monitoring focuses on estimating the number of fish that escape to spawn naturally and stray rates and in-hatchery performance evaluation.

Table 2. Program objectives, indicators, and goals for segregated harvest augmentation hatchery programs including monitoring indicators.

	Objective	Indicator	Target	Program goals: Rebuild natural populations	Program goals: Maintain genetic diversity	Program goals: Opportunity for harvest
Monitoring indicators	Determine if hatchery survival meets expectations	HRR	HRR > NRR			✓
		HRR	HRR ≥ Goal[1]			✓
	Determine if stray rate of hatchery fish is acceptable	Out of basin	≤ 5%		✓	
		Within basin	≤ 10%		✓	
	Determine if hatchery fish were released at program targets	Size and number	= Target[2]			✓
	Provide harvest opportunities when appropriate	Harvest	When greater than escapement goals			✓

[1] HRR targets are identified in Appendix 2.

[2] Number and size targets are identified in Table 3 and Appendix 5.

The primary goal of a harvest augmentation program is to increase harvest opportunities, while segregating adults from natural spawning populations. In this plan, harvest opportunity, survival rates, and stray rates are important indicators for assessing the success of harvest augmentation. These indicators are more readily quantified compared to productivity indicators (Table 2). A flow of information will be employed to evaluate harvest augmentation programs. Since harvest augmentation programs are typically segregated, monitoring indicators will be used to determine the success of a program.

Both monitoring and productivity indicators will be used to evaluate the success of hatchery programs. In the event that the statistical power of tests that involve productivity indicators is insufficient to inform sound management decisions, some of the monitoring indicators may be used to guide management. Figure 2 show the categories of indicators associated with each component of monitoring.

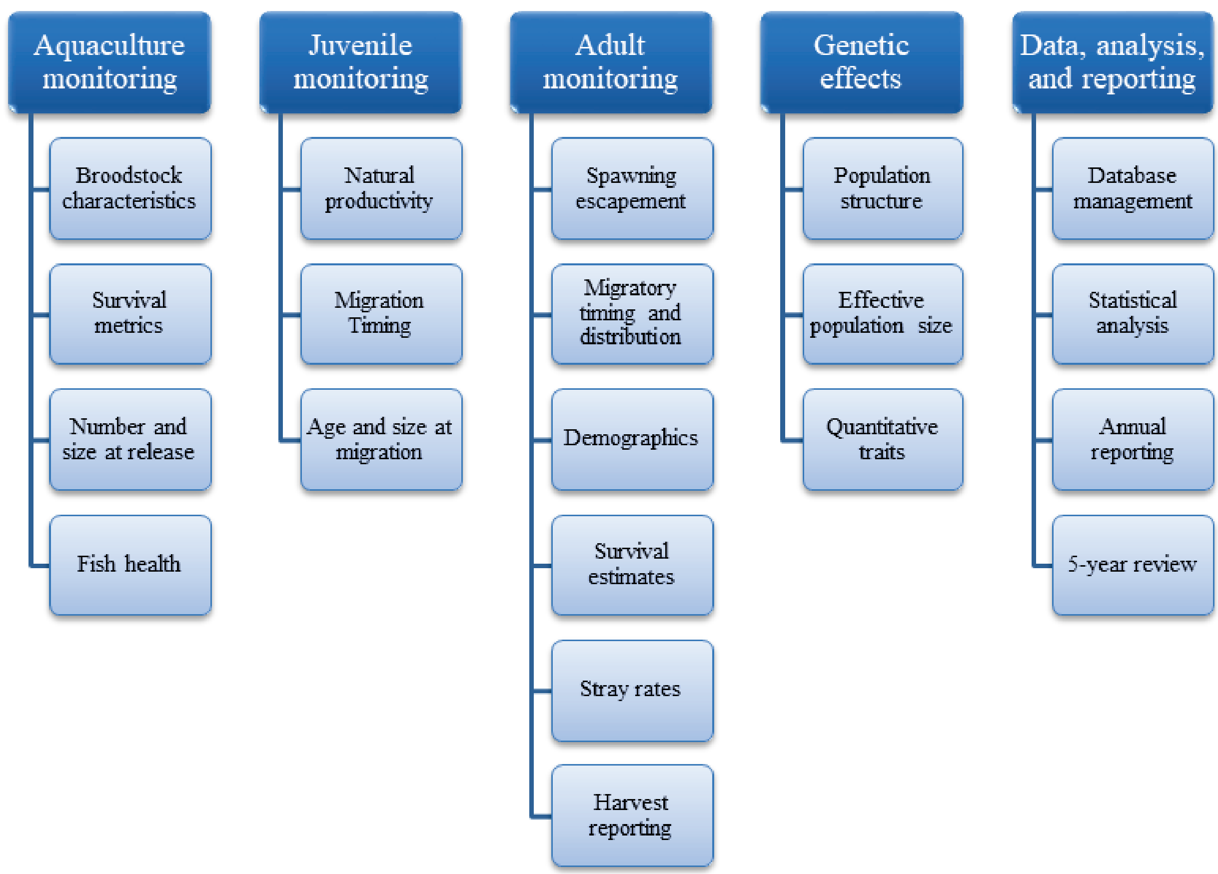

Figure 2. Overview of Monitoring and Evaluation Plan Categories and Components (not including regional objectives).

The overarching goals of conservation, safety-net, and harvest augmentation programs, as described above, are shown in detail in Figure 3. The flow chart (Figure 3) shows the relationship of overarching program goals, the strategies used to meet the goals, the monitoring and evaluation objectives used to evaluate the strategies and determine if goals are being met, and the adaptive

management cycle associated with the programs (see Tables 1 and 2 for the indicators under each objective). The logic depicted in this flow chart shall be used to assess M&E results and apply those results to management decisions. Table 3 presents the current hatchery programs releasing fish in the Upper Columbia Basin.

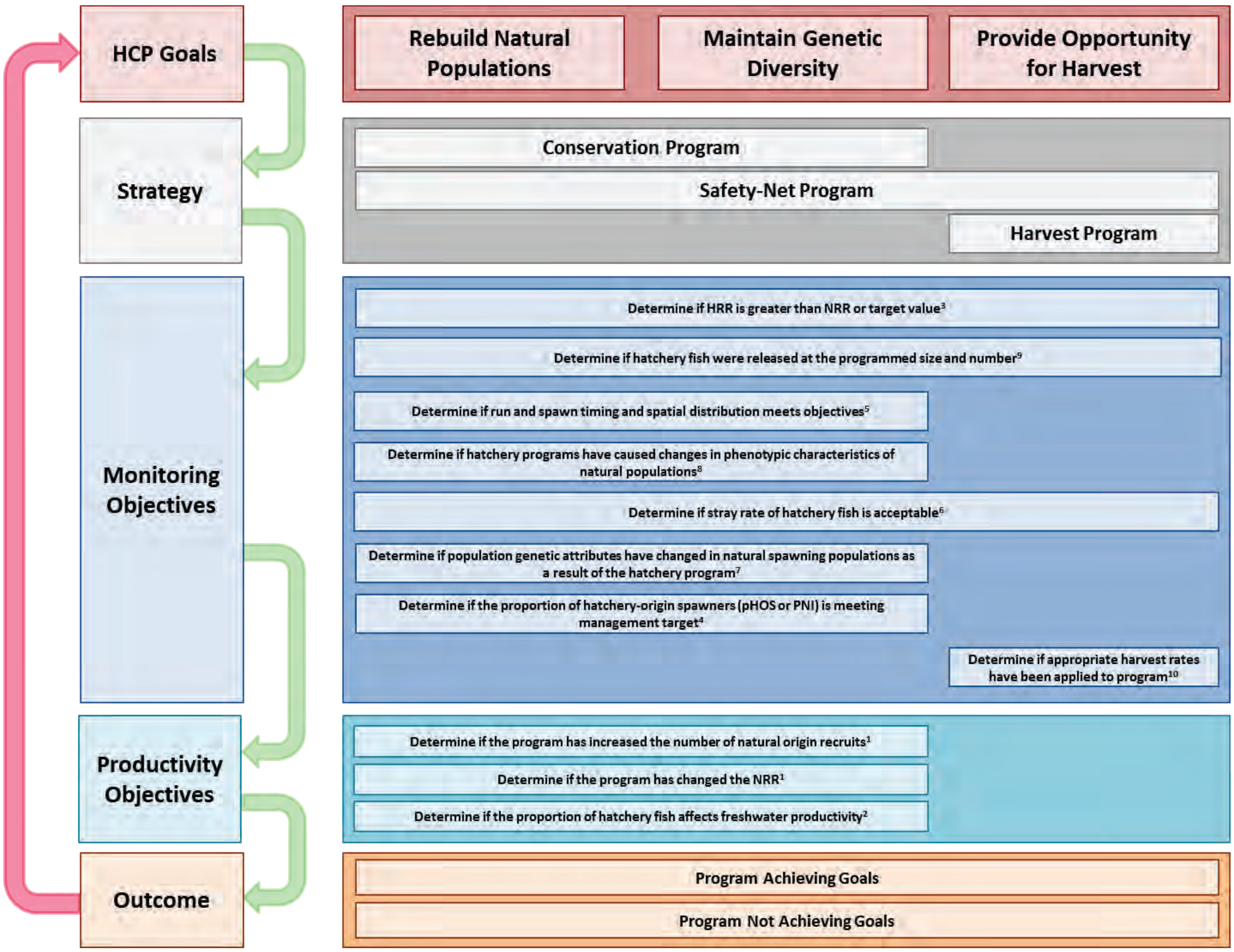

Figure 3. Adaptive management flow chart depicting HCP goals, associated strategies to meet the goals, the monitoring and evaluation objectives (indicated in superscript), and the adaptive management feedback cycle. The strategies, objectives, and outcomes are aligned vertically under the corresponding goals.

Table 3. Hatchery programs in the mid-Columbia River Basin, 2012. Funding entities included Douglas PUD (D), Chelan PUD (C), Grant PUD (G), Bonneville Power Administration (B), Bureau of Reclamation (O), and Army Corps of Engineers (A) and are listed in order of contribution. Total artificial production targets in the mid-Columbia River exceeds 20 million juveniles annually.

Program	Species	Basin	Purpose	Funding Entity	Production
Methow[5]	Spring Chinook [1]	Methow	NNI/Conservation	G, C, D	223,765
Chief Joseph[7]	Spring Chinook	Okanogan	Reintroduction/Harvest	B, G, C, D	900,000
Chiwawa[5]	Spring Chinook [1]	Wenatchee	NNI/Conservation	C	144,026
Nason[5]	Spring Chinook [1]	Wenatchee	NNI/Conservation	G	223,670
Winthrop[7]	Spring Chinook [2]	Methow	Safety-Net	O	400,000
Leavenworth	Spring Chinook [2]	Wenatchee	Harvest	O	1,200,000
Wells[5]	Steelhead [1]	Columbia	Inundation/Safety-Net	D	160,000
Winthrop[7]	Steelhead [1]	Methow	Conservation	O	100,000-200,000
Wells[5]	Steelhead [1]	Methow	Inundation/Safety-Net	D	100,000
Wells/Omak[5, 6]	Steelhead [1]	Okanogan	NNI/Conservation	G	100,000
Wells[5]	Steelhead [1]	Twisp	Inundation/Conservation	D	40,000
Wells[5]	Steelhead [1]	Twisp	NNI/Conservation	D	8,000
Chiwawa[5]	Steelhead [1]	Wenatchee	NNI/Conservation	C	22,000
Chiwawa[5]	Steelhead [1]	Wenatchee	Inundation/Harvest	C	165,000
Chiwawa[5]	Steelhead [1]	Wenatchee	Species trade	C	60,300
Ringold	Steelhead [9]	Columbia	Harvest	Mitchell Act	180,000
Wells[5]	Summer Chinook [2, 3]	Columbia	Inundation/Harvest	D	484,000
Chief Joseph[7]	Summer Chinook [3]	Okanogan	NNI/Cons./Harvest	B, C, D	700,000
Chelan Falls[5]	Summer Chinook [2]	Chelan	Inundation/Harvest	C	400,000
Chelan Falls[5]	Summer Chinook [2]	Chelan	NNI/Conservation	C	176,000
Wells[5]	Summer Chinook [2]	Columbia	Inundation/Harvest	D	320,000
Entiat	Summer Chinook	Entiat	Harvest	O	400,000
Carlton[5]	Summer Chinook	Methow	NNI/Conservation	G	200,000
Chief Joseph[7]	Summer Chinook	Okanogan	NNI/Cons./Harvest	B, G, C, D	1,300,000
Dryden[5]	Summer Chinook	Wenatchee	NNI/Conservation	C, G	500,000
Priest[5]	Fall Chinook[3]	Columbia	Inundation/Harvest	G	5,000,000
Priest[5]	Fall Chinook[3]	Columbia	NNI/Harvest	G	325,543
Priest[5]	Fall Chinook[4]	Columbia	Fry loss/Harvest	G	273,961
Priest[5, 7]	Fall Chinook[3]	Columbia	Harvest	A	1,700,000
Ringold[7]	Fall Chinook[3]	Columbia	Harvest	A	3,500,000
Yakama Nation	Coho	Wenatchee	Reintroduction/Harvest	B, G, C, D	1,000,000
Yakama Nation[8]	Coho	Methow	Reintroduction/Harvest	B, G, C, D	500,000
Skaha	Sockeye	Okanogan	Reintroduction/Harvest	C, G	≤ 5 M eggs

[1] Species listed under the Endangered Species Act.
[2] Segregated program.
[3] Sub-yearling production.
[4] Fry production.
[5] Program covered by this M&E Plan.
[6] Program also partially covered by CCT M&E Plan.
[7] Program affects PUD-funded programs covered by this plan.
[8] Planned to increase to 1,000,000.
[9] Part of the Mitchell Act suite of mitigation programs under the FCRPS BiOp.

SECTION 2: ADULT PRODUCTIVITY

2.1 Natural Replacement Rates of Supplemented Populations[1]

Objective 1: **Determine if conservation programs have increased the number of naturally spawning and naturally produced adults of the target population and if the program has reduced the natural replacement rate (NRR) of the supplemented population.**

At the core of a conservation program is the objective of increasing the number of spawning adults (i.e., the combined number of naturally produced and hatchery fish) in order to affect a subsequent increase in the number of returning naturally produced fish or natural-origin recruits (NOR). In order for the natural population to remain stable or to increase, the Natural Replacement Rate (NRR), or the ratio of NORs to the parent spawning population, must be at a level where parents are being replaced by their offspring as spawners in the next generation. It is possible to affect an increase in natural-origin spawners through supplementation with a stable or decreasing NRR. However, if the NRR is below replacement (NRR<1.0), termination of the supplementation program will result in a declining natural population should that state of NRR persist. The proportion of the hatchery-origin spawners (pHOS) that will increase natural production without creating adverse effects to the genetic diversity or reproductive success rate of the natural population is unknown, and may be dependent on how individual hatchery programs are operated, as well as available spawning and rearing habitat. Some programs restrict pHOS to reduce the risk to the natural population with the intent of optimizing productivity, concomitantly reducing the overall number of spawners. All other objectives of the M&E Plan either directly support this objective or seek to minimize negative effects of the conservation programs on non-target stocks of concern.

Differences in carrying capacities of supplemented and non-supplemented streams can confound the analysis of the effects of supplementation on total number of spawners returning to the streams. For example, if the supplemented population is at carrying capacity and the non-supplemented population is not, the total number of spawners returning to the non-supplemented population may show an increasing trend over time, while the supplemented population would show no increasing trend. To avoid concluding that the supplementation program has no effect or perhaps a negative effect on total spawners, density corrections should be included in the analyses. Hypotheses that may require density corrections are noted under each monitoring question. Appendix 1 describes methods for estimating carrying capacities.

Monitoring Questions:

Q1.1.1 Has the supplementation program changed the adult productivity (NRRs) of the supplemented populations?[2]

Target Species/Populations:

[1] Supplementation programs may include a safety-net component.

[2] Because adult productivity is affected by the abundance of the population (i.e., productivity decreases with increasing abundance), the goal of supplementation is to increase or maintain productivity, but not decrease it.

- Q1.1.1 applies to all conservation and safety-net stocks.

Statistical Hypotheses 1.1.1[3]:

- $Ho_{1.1.1.1}$: Slope in NRRs before supplementation ≤ slope in NRRs after supplementation.
- $Ho_{1.1.1.2}$: Differences in slopes in NRRs between supplemented and reference populations before supplementation ≤ differences in slopes in NRRs between supplemented and reference populations after supplementation.
- $Ho_{1.1.1.3}$: Mean NRRs before supplementation ≤ mean NRRs after supplementation.
- $Ho_{1.1.1.4}$: Mean ratio scores in NRRs before supplementation ≤ Mean ratio scores in NRRs during supplementation.
- $Ho_{1.1.1.5}$: Mean ratio scores in NRRs (adjusted for density dependence) before supplementation ≤ Mean ratio scores in NRRs (adjusted for density dependence) during supplementation. [This hypothesis adjusts NRRs for density-dependent effects (see Hillman et al. 2012 for details; Appendix 6).]
- $Ho_{1.1.1.6}$: There is no association between the proportion of hatchery-origin spawners (pHOS) and the residuals from the smooth hockey stick stock-recruitment curve; rho = 0. [If there is a significant negative association between pHOS and the residuals, then hatchery fish may be reducing the productivity of the wild population.]

Measured Variables:

- Number of hatchery and naturally produced fish on spawning grounds
- Number of naturally produced fish harvested

Derived Variables:

- Number of naturally produced recruits by brood year for both naturally produced parents and hatchery parents (≥age-3).
- NRRs (calculated as NORs/spawner).
- Stock-recruit models, parameters, and residuals.
- Includes ratio scores of NRRs (requires reference population[s]).
- Includes calculation of ratios NORs (requires reference population).
- Appendix 1: Spawning escapement and carrying capacity information (as applicable)

Spatial/Temporal Scale:

- Calculated annually based on brood year.
- Time series.

Possible Statistical Analysis:

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[3] Quality and quantity of data will determine which hypotheses are evaluated. See Hillman et al. 2012 (Appendix 6) for details.

- These analyses shall be performed every 5-years. Use graphic analyses, trend analyses, t-tests, Aspin-Welch tests, and randomization tests to evaluate the statistical hypotheses (see Hillman et al. 2012; Appendix 6). The specific analysis used will depend on the availability of reference conditions.
- Correlation analysis will examine associations between hatchery adult composition and NRRs.
- On a five-year period, correlate productivity with extraneous factors such as ocean productivity indices.

Analytical Rules:

- This is a productivity indicator that will be used to assess the success of the supplementation program.
- Type I Error of 0.05.

2.2 Natural-Origin Recruits of Supplemented Populations

Monitoring Questions:

Q1.2.1: Has the supplementation program changed the abundance of NORs within the supplemented population?

Target Species/Populations:

- Q1.2.1 applies to all supplemented or safety net stocks.

Statistical Hypotheses 1.2.1[4]:

- $Ho_{1.2.1.1}$: Slope in NORs[5] before supplementation ≥ slope in NORs after supplementation.
- $Ho_{1.2.1.2}$: Differences in slopes in NORs between supplemented and reference populations before supplementation ≥ differences in slopes in NORs between supplemented and reference populations after supplementation.
- $Ho_{1.2.1.3}$: Mean NORs before supplementation ≥ mean NORs after supplementation.
- $Ho_{1.2.1.4}$: Mean ratio scores in NORs before supplementation ≥ Mean ratio scores in NORs during supplementation.
- $Ho_{1.2.1.5}$: Mean ratio scores in NORs/Maximum Recruitment before supplementation ≥ Mean ratio scores in NORs/Maximum Recruitment during supplementation. [This hypothesis adjusts NORs for the capacity of the habitat; it tests the fraction of the habitat saturated with NORs (see Hillman et al. 2012 for details).]
- $Ho_{1.2.1.6}$: There is no association between the proportion of hatchery-origin spawners (pHOS) and NORs; rho = 0. [If there is a significant negative association between

4 Quality and quantity of data will determine which hypotheses are evaluated. See Hillman et al. 2012 (Appendix 7) for details.

5 "Slope in NORS" refers to abundance of NORs across time (years).

pHOS and NORs, then hatchery fish may be reducing the reproductive success of the wild population.]

Measured Variables:

- Number of hatchery and naturally produced fish on spawning grounds.
- Number of hatchery and naturally produced fish taken for broodstock.
- Number of hatchery and naturally produced fish taken in harvest (if recruitment is to the Columbia).

Derived Variables:

- NORs (number of naturally produced recruits (total recruits) by brood year for both naturally produced parents and hatchery parents [≥age-3]).
- Stock-recruit models, parameters, and residuals.
- Includes ratio scores of NORs (requires reference population[s]).
- Estimates of carrying capacity (see Appendix 1).

Spatial/Temporal Scale:

- Calculate annually based on brood year.
- Time series.

Possible Statistical Analysis:

- These analyses shall be performed every 5-years. Use graphic analyses, trend analyses, t-tests, Aspin-Welch tests, and randomization tests to evaluate the statistical hypotheses (see Hillman et al. 2012). The specific analysis used will depend on the availability of reference conditions.
- Correlation analysis will examine associations between hatchery adult composition and NORs.
- On a five-year period, correlate NORs with extraneous factors such as ocean productivity indices.

Analytical Rules:

- This is a productivity indicator that will be used to assess the success of the supplementation program.
- Type I Error of 0.05.

SECTION 3: JUVENILE PRODUCTIVITY

3.1 Freshwater Juvenile Productivity

Objective 2: Determine if the proportion of hatchery fish on the spawning grounds affects the freshwater productivity of supplemented stocks.

Out-of-basin effects (e.g., smolt passage through the hydro system, harvest, and ocean productivity, etc.) influence the survival of smolts after they migrate from the tributaries. These effects introduce substantial variability into the adult-to-adult survival rates (NRRs and HRRs) and may mask in-basin effects (e.g., habitat quality, density-dependent mortality, and differential reproductive success of hatchery and naturally produced fish). Therefore, an estimate of freshwater productivity may help inform the performance of hatchery and natural-origin spawners.

The objective of estimating freshwater productivity in the Upper Columbia ESU/DPS is to estimate the survival from egg to a critical juvenile life stage(s) of target stocks. Smolt or juvenile production models generated from the information obtained through these programs will provide a level of predictability with greater sensitivity to in-basin effects than spawner-recruitment models that consider all effects.

Differences in the current carrying capacities of supplemented and non-supplemented streams can confound the effects of supplementation on numbers of juveniles per redd. For example, if the supplemented population is at or above carrying capacity and the non-supplemented population is not, numbers of juveniles per redd in the non-supplemented population may be significantly greater than the number of juveniles per redd in the supplemented population. In addition, pHOS may be correlated with overall spawner abundance. In these cases, it is difficult or impossible to separate density-dependent effects from the influence of pHOS on freshwater productivity. To avoid concluding that the supplementation program has no effect or perhaps a negative effect on juveniles per redd, the capacity of the habitats must be included in the analyses. The Supplementary Hypotheses presented below are designed to address the confounding effects of different densities on the analyses.

Monitoring Questions:

Q2.1.1: Has the supplementation program changed the number of juveniles (smolts, parr, and/or emigrants) per redd within the supplemented population?

Q2.2.1: Does the number of juveniles per redd decrease as the proportion of hatchery spawners increases?[6]

Target Species/Populations:

- Both Q2.1.1 and Q2.2.1 apply to all conservation stocks.

Statistical Hypotheses for 2.1.1[7]:

[6] Information is needed to estimate the effects of density dependence on these questions. Consider spatial distribution of redds.

[7] Quality and quantity of data will determine which hypotheses are evaluated. See Hillman et al. (2012) for details.

- $Ho_{2.1.1.1}$: Slope in juveniles/redd before supplementation ≤ slope in juveniles/redd after supplementation.
- $Ho_{2.1.1.2}$: Differences in slopes in juveniles/redd between supplemented and reference populations before supplementation ≤ differences in slopes in juveniles/redd between supplemented and reference populations after supplementation.
- $Ho_{2.1.1.3}$: Mean juveniles/redd before supplementation ≤ mean juveniles/redd after supplementation.
- $Ho_{2.1.1.4}$: Mean ratio scores in juveniles/redd before supplementation ≤ Mean ratio scores in juveniles/redd during supplementation.
- $Ho_{2.1.1.5}$: Mean ratio scores in juveniles/redd (adjusted for density dependence) before supplementation ≤ Mean ratio scores in juveniles/redd (adjusted for density dependence) during supplementation. [This hypothesis adjusts juveniles/redd for density-dependent effects (see Hillman et al. 2012 for details; Appendix 6).]
- $Ho_{2.1.1.6}$: There is no association between the proportion of hatchery-origin spawners (pHOS) and the residuals from the smooth hockey stick stock-recruitment curve; rho = 0. [If there is a significant negative association between pHOS and the residuals, then hatchery fish may be reducing the productivity of the wild population.]

Statistical Hypotheses for 2.2.1:

- $Ho_{2.2.1.1}$: There is no association between the proportion of hatchery-origin spawners (pHOS) and the residuals from the smooth hockey stick stock-recruitment curve; rho = 0. [If there is a significant negative association between pHOS and the residuals, then hatchery fish may be reducing the productivity of the wild population.]
- $Ho_{2.2.1.2}$: The slope between proportion of hatchery spawners and juveniles/redd is ≥ 0.

Measured Variables:

- Number of hatchery and naturally produced fish on spawning grounds.
- Numbers of redds.
- Number of juveniles (smolts, parr [where appropriate], and emigrants).

Derived Variables:

- Number of juveniles per spawner.
- Number of juveniles per redd.
- Carrying capacity (see Appendix 1).

Spatial/Temporal Scale:

- Calculate annually based on brood year.
- Time series.

Possible Statistical Analysis:

- These analyses shall be performed every five-years. Use graphic analyses, trend analyses, t-tests, Aspin-Welch tests, and randomization tests to evaluate the statistical hypotheses (see Hillman et al. 2012; Appendix 6). The specific analysis used will depend on the availability of reference conditions.
- Correlation analysis will examine associations between hatchery adult composition and juveniles/redd.

Analytical Rules:

- This is a productivity indicator that will be used to assess the success of the supplementation program.
- Type I Error of 0.05.

SECTION 4: NATURAL ENVIRONMENT MONITORING INDICATORS

4.1 Hatchery Replacement Rates (HRRs)

Objective 3: **Determine if the hatchery adult-to-adult survival (i.e., hatchery replacement rate, HRR) is greater than the natural adult-to-adult survival (i.e., natural replacement rate, NRR) and the target hatchery survival rate.**

The survival advantage from the hatchery (i.e., egg-to-smolt) must be sufficient to produce a greater number of returning adults than if broodstock were left to spawn naturally. If a hatchery program cannot produce a greater number of adults than naturally spawning fish, then the program should be modified or discontinued. Production levels were initially developed using historical run sizes and smolt-to-adult survival rates (BAMP 1998). Using the stock specific NRR and agreed upon target values (see Appendix 2), comparisons to actual survival rates will be made to ensure the expected level of survival has been achieved.

Monitoring Questions:

Q3.2.1: Is the adult-to-adult survival rate of hatchery fish (HRR) greater than or equal to the adult-to-adult survival rate (NRR) of naturally produced fish?

Q3.2.2: Is the adult-to-adult survival rate of hatchery fish (HRR) greater than or equal to the Target Value identified in Appendix 2[8]?

Target Species/Populations:

- Q3.2.1 applies to all conservation stocks.
- Q3.2.2 applies to all stocks.

Statistical Hypothesis 3.2.1:

- $Ho_{3.2.1.1}$: $HRR_{\text{Year }x} \geq NRR_{\text{Year }x}$

Statistical Hypothesis 3.2.2:

- $Ho_{3.2.2.1}$: HRR ≥ Target Value identified in Appendix 2

Measured Variables:

- Number of hatchery and naturally produced fish on spawning grounds.
- Number of hatchery and naturally produced fish harvested.
- Number of hatchery and naturally produced fish collected for broodstock.
- Number of broodstock used by brood year (hatchery and naturally produced fish).

Derived Variables:

- Number of hatchery and naturally produced adults by brood year (≥age-3).

8 Target values may be adjusted by the hatchery committees.

- HRR (number of returning adults per brood year/broodstock)
- NRR (from Objective 1)
- Appendix 2: HRR targets identified in Appendix 2

Spatial/Temporal Scale:

- Calculate annually based on brood year.
- Time series.

Possible Statistical Analysis:

- For Q3.2.1 use graphic analysis and paired-sample quantile tests to compare HRR to NRR
- For Q3.2.2 use graphic analysis and one-sample quantile tests to compare HRR to the target value.
- On a five-year period, correlate HRRs with extraneous factors such as ocean productivity indices.

Analytical Rules:

- This is a monitoring indicator that will be used to support management decisions.
- Type I Error of 0.05.

4.2 Proportion of Hatchery-Origin Spawners (pHOS or PNI)

Objective 4: **Determine if the proportion of hatchery-origin spawners (pHOS or PNI) is meeting management target.**

Certain hatchery programs have pHOS or PNI targets, while other do not. HGMPs and permits inform the selection of targets, which are identified in Appendix 3.

Monitoring Questions:

Q4.1.1: Is the estimated proportion of hatchery-origin spawners (pHOS) less than or equal to the management target, and/or, is the estimated Percent Natural Influence (PNI) greater than or equal to the management target identified in Appendix 3?

Target Species/Populations:

- Q4.1.1 applies to all conservation and safety-net stocks that have a defined pHOS or PNI target or sliding scale (see Appendix 3).

Statistical Hypothesis 4.1.1:

- $Ho_{4.1.1.1}$: pHOS > target value or $PNI_{\text{Supplemented population}}$ < target value identified in Appendix 3

Measured Variables:

- Number of hatchery and naturally produced fish on spawning grounds

Derived Variables:

- pHOS or PNI
- Appendix 3: PNI and pHOS targets and sliding scales identified in Appendix 3

Spatial/Temporal Scale:

- Calculate annually.
- Analyzed as time series.

Possible Statistical Analysis:

- Use graphic analysis and summary statistics to compare pHOS or PNI to the target value in Appendix 3.

Analytical Rules:

- This is a monitoring indicator that will be used to support management decisions.

4.3 Run Timing, Spawn Timing, and Spawning Distribution

Objective 5: Determine if the run timing, spawn timing, and spawning distribution of the hatchery component is similar to the natural component of the target population or is meeting program-specific objectives.

Strategies for conservation programs typically intend that hatchery and natural-origin fish spawn together and in similar locations. However, in some cases, strategies may differ from this paradigm (e.g., summer Chinook salmon in the Wenatchee and Methow rivers; see Appendix 4). Phenotypic plasticity or selection resulting from the hatchery environment (i.e., domestication) may affect run (migration) timing, spawn timing, and spawning distribution. If conservation programs do not adequately represent the genetic diversity of the natural population, and if phenotypic traits in supplementation fish related to fitness deviate from the naturally produced spawning population, the goals of supplementation may not be achieved. Hatchery adults that migrate and/or spawn at different times or are spatially segregated from natural-origin fish may be subject to reduced fitness. Hatchery adults that spawn at different times or locations than natural-origin fish would be reproductively isolated from the natural population. The extent of such isolation, ranging from no isolation to substantial isolation, may be exploited for management purposes in some cases.

Migration Timing

Monitoring Questions:

Q5.1.1: Is the migration timing of hatchery and natural-origin fish from the same age class similar?

Target Species/Populations:

- Q5.1.1 applies to all conservation stocks.

Statistical Hypotheses 5.1.1:

- $Ho_{5.1.1.1}$: Migration timing $_{\text{Hatchery Age X}}$ = Migration timing $_{\text{Naturally produced Age X}}$

- $Ho_{5.1.1.2}$: The cumulative frequency of migration timing of hatchery-origin fish = the cumulative frequency of migration timing of natural-origin fish.
- $Ho_{5.1.1.3}$: The 10^{th} percentile, 50^{th} percentile (mode), 90^{th} percentile, and mean migration timing of hatchery-origin fish = the 10^{th} percentile, 50^{th} percentile (median), 90^{th} percentile, and mean migration timing of natural-origin fish.

Measured Variables:

- Ages of hatchery and natural-origin fish sampled via PIT tags or stock assessment monitoring.
- Time (Julian date) of arrival at mainstem projects and within tributaries (e.g., traps, PIT arrays) with the intent to identify biologically significant differences.

Derived Variables:

- Mean Julian date for a given age class.

Spatial/Temporal Scale:

- Calculate annually based on return year and age class.
- Time series.

Possible Statistical Analysis:

- Use graphic analyses (cumulative frequency polygons), paired t-tests, Aspin-Welch tests, and randomization tests.

Analytical Rules:

- This is a monitoring indicator that will be used to support management decisions.
- Type I Error of 0.05.

Spawn Timing

Monitoring Questions:

Q5.2.1: Is the timing of spawning similar for conservation hatchery and natural-origin fish?

Target Species/Populations:

- Q5.2.1: Applies to all semelparous species and populations supplemented by conservation programs. Steelhead can only be assessed for natural spawning in situations where hatchery and natural-origin fish can be appropriately marked and detected.

Statistical Hypotheses 5.2.1:

- $Ho_{5.2.1.1}$: The cumulative frequency of spawn timing of hatchery-origin fish = the cumulative frequency of spawn timing of natural-origin fish.
- $Ho_{5.2.1.2}$: The 10^{th} percentile, 50^{th} percentile (mode), 90^{th} percentile, and mean spawn timing of hatchery-origin fish = the 10^{th} percentile, 50^{th} percentile (mode), 90^{th} percentile, and mean spawn timing of natural-origin fish.

- $Ho_{5.2.1.3}$: The relationship between elevation and spawn timing of hatchery-origin fish = the relationship between elevation and spawn timing of natural-origin fish.

Measured Variables:

- Time (Julian date) and elevation (m) of hatchery and natural-origin salmon carcasses or marked steelhead detected on spawning grounds within defined reaches.
- Time (Julian date) of ripeness of hatchery and natural-origin steelhead captured for broodstock.

Derived Variables:

- Mean Julian date.

Spatial/Temporal Scale:

- Calculate annually based on return year.
- Time series.

Possible Statistical Analysis:

- Use graphic analyses (cumulative frequency polygons), paired t-tests, Aspin-Welch tests, and randomization tests.
- Use graphic analyses, ANCOVA, and/or regression analysis to assess relationships between elevation and spawn timing.

Analytical Rules:

- This is a monitoring indicator that will be used to support management decisions.
- Type I Error of 0.05.

Spatial Distribution of Redds

Monitoring Questions:

Q5.3.1: Is the distribution of redds similar for conservation hatchery and natural-origin fish?

Q5.3.2: Is the distribution of redds similar to defined management targets (see Appendix 4)?

Target Species/Populations:

- Q5.3.1 applies to all conservation program stocks.
- Q5.3.2 applies only to conservation program stocks with specific spawning distribution targets (Carlton and Dryden summer Chinook programs; Appendix 4).

Statistical Hypothesis 5.3.1:

- $Ho_{5.3.1.1}$: The distribution of hatchery-origin redds (hatchery females) = the distribution of natural-origin redds (natural-origin females).

Statistical Hypothesis 5.3.2:

- $Ho_{5.3.2.1}$: The distribution of hatchery-origin redds (hatchery females) = the target distribution identified in Appendix 4.

Measured Variables:

- Location (GPS coordinate) of female salmon carcasses observed on spawning grounds. The distribution of hatchery and naturally produced steelhead redds may be evaluated if marking or tagging efforts provide reasonable results.

Derived Variables:

- Location of female salmon carcass at the historic reach scale and at the 0.1 km scale.
- Calculate percent overlap in distribution across available spawning habitat or historical reaches.
- Appendix 4: Management targets for spatial distribution of spawners or redds (as applicable).

Spatial/Temporal Scale:

- Calculate annually based on return year.
- Time series.

Possible Statistical Analysis:

- Use graphic analysis and Yates' Chi-square analysis for both Q5.3.1 and Q5.3.2.

Analytical Rules:

- This is a monitoring indicator that will be used to support management decisions.
- Type I Error of 0.05.

4.4 Stray Rates

<u>Objective 6</u>: Determine if the recipient stray rate of hatchery fish is below the acceptable levels to maintain genetic variation among stocks.

Maintaining locally adapted traits among independent fish populations requires that returning hatchery fish have a high rate of site fidelity to the target population or stream. Hatchery practices (e.g., imprinting on water sources at key life history stages, release methodology, release location, age at return, broodstock used, spawner density, spawning habitat quality and access, and environmental conditions) are the main variables thought to affect stray rates. Regardless of the magnitude of homing of adult returns, if adult hatchery fish do not contribute to the natural population, the program will not meet the basic condition of a supplementation program.

Independent populations are populations that are genetically differentiated from other populations. In some cases, genetic differentiation may be assumed based on phenotypic traits or geographic isolation when molecular genetics analyses are not available. When populations are not independent, straying among them does not pose a risk of genetic homogenization. In addition, stray rates of hatchery-origin fish cannot be expected to be lower than for natural-origin fish. When estimates of stray rates for natural-origin fish are available and if they exceed the 5% among population stray rate or 10% within population stray rate thresholds identified in this plan, analysis

and interpretation of stray rates must take into account the concept that hatchery programs may be held to unattainable standards based on the natural stray rate. Current criteria established by the ICBTRT (2005) and the Upper Columbia Spring Chinook Salmon and Steelhead Recovery Plan (2007) indicate that fish that do stray to other non-target populations should not comprise greater than 5% of the non-target spawning population. Likewise, fish that stray into non-target spawning areas within an independent population should not comprise greater than 10% of the non-target spawning aggregate (see Tables 6.1 and 6.2).

This plan identifies three stray rate metrics; brood-year stray rate, among population return-year stray rate, and within population return-year stray rate. The return-year stray rates have specific targets that are from the ICBTRT (2005) and Upper Columbia Spring Chinook Salmon and Steelhead Recovery Plan (2007), and are linked to extinction risk. That is, hatchery strays from other populations cannot make up more than 5% of the spawning escapement within a non-target, recipient population. In addition, hatchery strays from other spawning aggregations within a population (e.g., Chiwawa spring Chinook) cannot make up more than 10% of the spawning escapement within a non-target, recipient spawning aggregate (e.g., White River). Brood-year stray rate, on the other hand, is not discussed in the Upper Columbia Spring Chinook Salmon and Steelhead Recovery Plan (2007) or ICBTRT (2005) and therefore has no specific target. Nevertheless, it is important to track brood-year stray rates to determine if hatchery operations affect the homing and straying of specific brood years. These data support the return-year stray metrics and are used to inform possible changes in genetic variation among stocks.

Brood-Year Stray Rates

Monitoring Questions:

Q6.1.1: What is the brood-year stray rate of hatchery fish?

Target Species/Populations:

- Q6.1.1 applies to all hatchery stocks.

Statistical Hypothesis 6.1.1:

- $Ho_{6.1.1.1}$: None.

Measured Variables:

- Number of hatchery carcasses found in non-target and target spawning areas or number of returning spawners counted via PIT-tag detection or at weirs in close temporal proximity to spawning areas.
- Number of hatchery fish collected for broodstock.
- Number of hatchery fish taken in fishery.
- Locations of live and dead strays (used to tease out overshoot).

Derived Variables:

- Total number of hatchery carcasses and take in fishery estimated from expansion analysis.
- Percent of the total brood return that strays.

Spatial/Temporal Scale:

- Calculate annually based on brood year.
- Time series.

Possible Statistical Analysis:

- Use graphical analysis to track brood-year stray rates over time.

Analytical Rules:

- This is a monitoring indicator that will be used to support management decisions.

Among-Population Return-Year Stray Rates

Monitoring Questions:

Q6.2.1: Do hatchery strays make up less than 5% of the spawning escapement within their non-target independent populations?

Target Species/Populations:

- Q6.2.1 applies to all hatchery stocks.

Statistical Hypothesis 6.2.1:

- $Ho_{6.2.1.1}$: Stray hatchery fish make up ≥ 5% of the spawning escapement (based on run year) within other independent populations [9]

Measured Variables:

- Number of hatchery carcasses (PIT-tagged steelhead) found in non-target and target spawning areas or number of returning spawners counted via PIT-tag detection or at weirs in close temporal proximity to spawning areas.

Derived Variables:

- Total number of hatchery salmon carcasses (PIT-tagged steelhead, spawners counted at weirs) estimated from expansion analysis.
- Percent of the non-target population that is made up of hatchery strays.

Spatial/Temporal Scale:

- Calculate annually based on return year.
- Time series.

Possible Statistical Analysis:

[9] This stray rate is suggested based on a literature review and recommendations by the ICBTRT (2005) and is identified in the Upper Columbia Spring Chinook Salmon and Steelhead Recovery Plan (2007). It can be re-evaluated as more information on naturally-produced Upper Columbia salmonids becomes available. This will be evaluated on a species and program specific basis and decisions made by the HCP HC and PRCC HSC. It is important to understand the actual spawner composition of the population to determine the potential effect of straying.

- Use graphical analysis and one-sample quantile tests to compare the estimated stray rate with the target (5%) stray rate.

Analytical Rules:

- This is a monitoring indicator that will be used to support management decisions.
- Type I Error of 0.05.

Within-Population Return-Year Stray Rates

Monitoring Questions:

Q6.3.1: Do hatchery strays make up less than 10% of the spawning aggregate within non-target spawning areas within the target population?

Target Species/Populations:

- Q6.3.1 applies to all hatchery stocks.

Statistical Hypothesis 6.3.1:

- $Ho_{6.3.1}$: Stray hatchery fish make up ≥ 10% of spawning escapement (based on run year) within non-target spawning areas within the target population

Measured Variables:

- Number of hatchery carcasses (possibly PIT-tagged steelhead) found in non-target and target spawning aggregates or number of returning spawners counted via PIT-tag detection or at weirs in close temporal proximity to spawning areas.

Derived Variables:

- Total number of hatchery salmon carcasses (possibly PIT-tagged steelhead or spawners counted at weirs) estimated from expansion analysis.
- Percent of the non-target spawning aggregate that is made up of hatchery strays.

Spatial/Temporal Scale:

- Calculate annually based on return year.
- Time series.

Possible Statistical Analysis:

- Use graphical analysis and one-sample quantile tests to compare the estimated stray rate with the target (10%) stray rate.

Analytical Rules:

- This is a monitoring indicator that will be used to support management decisions.
- Type I Error of 0.05.

4.5 Population Genetics

<u>Objective 7</u>: Determine if genetic diversity, population structure, and effective population size have changed in natural spawning populations as a result of the hatchery program.

The genetic component of the M&E Plan specifically addresses the potential for changes in genetic diversity in natural populations as a result of a hatchery program(s). The long-term fitness of populations is assumed to be related to maintaining the genetic diversity of natural populations. However, hatchery programs select a subset of individuals from the population to pass on genetic material to the next generation. This is often a relatively small number of individuals that produce a large number of offspring, and can result in changes in allele frequencies and reductions of effective population size. Therefore, it is important to monitor the genetic status of the natural populations to determine if there are signs of changes in genetic distance among populations, changes in allele frequencies, and to estimate effective population size. Assessing the genetic effects of the hatchery program does not require annual sampling, but does require regular sampling at generational scales. Meeting stray-rate targets (hypotheses tested under Objective 5) should reduce significant changes in population genetics. Stray rates may inform population genetic analyses. Testing statistical hypotheses associated with genetic components (Hypotheses 3.1, 3.2, and 3.3) should be conducted every ten years or two generations.

Allele Frequency

Monitoring Questions:

Q7.1.1: Is the allele frequency of hatchery fish similar to the allele frequency of naturally produced and donor (broodstock) fish?

Target Species/Populations:

- Q7.1.1 applies to all conservation stocks.

Statiscial Hypotheses 7.1.1:

- $Ho_{7.1.1.1}$: Allele frequency $_{\text{Hatchery}}$ = Allele frequency $_{\text{Naturally produced}}$ = Allele frequency $_{\text{Donor pop.}}$
- $Ha_{7.1.1.1}$: Allele frequency $_{\text{Hatchery}}$ ≠ Allele frequency $_{\text{Naturally produced}}$ = Allele frequency $_{\text{Donor pop.}}$ or
- $Ha_{7.1.1.1}$: Allele frequency $_{\text{Hatchery}}$ = Allele frequency $_{\text{Naturally produced}}$ ≠ Allele frequency $_{\text{Donor pop.}}$ or
- $Ha_{7.1.1.1}$: Allele frequency $_{\text{Hatchery}}$ ≠ Allele frequency $_{\text{Naturally produced}}$ ≠ Allele frequency $_{\text{Donor pop.}}$

Measured Variables:

- SNP genotypes

Derived Variables:

- Allele frequency

Spatial/Temporal Scale:

- Analyze as a time series, initially comparing pre- and post-hatchery samples and thereafter every 10 years.
- Compare samples within drainages.

Possible Statistical Analysis:

- Population differentiation tests, analysis of molecular variance (AMOVA), and relative genetic distances.

Analytical Rules:

- This is a monitoring indicator that will be used to support management decisions.
- Type I Error of 0.05.

Genetic Distance Between Populations

Monitoring Questions:

Q7.2.1: Does the genetic distance among subpopulations within a supplemented population remain the same over time?

Target Species/Populations:

- Q7.2.1 applies to all conservation and safety-net stocks.

Statistical Hypothesis 7.2.1:

- $Ho_{7.2.1.1}$: Genetic distance between subpopulations $_{\text{Year x}}$ = Genetic distance between subpopulations $_{\text{Year y}}$

Measured Variables:

- SNP genotypes

Derived Variables:

- Allele frequencies

Spatial/Temporal Scale:

- Analyze as a time series, initially comparing pre- and post-hatchery samples and thereafter every 10 years.
- Compare samples among spawning aggregates.

Possible Statistical Analysis:

- Population differentiation tests, AMOVA, and relative genetic distances.

Analytical Rules:

- This is a monitoring indicator that will be used to support management decisions.
- Type I Error of 0.05.

Effective Spawning Population

Monitoring Questions:

Q7.3.1: Is the ratio of effective population size (N_e) to spawning population size (N) constant over time?

Target Species/Populations:

- Q7.3.1 applies to all supplemented stocks.

Statistical Hypothesis 3.3:

- $Ho_{7.3.1.1}$: $(N_e/N)_{t0} = (N_e/N)_{t1}$ for each population

Measured Variables:

- SNP genotypes

Derived Variables:

- Allele frequencies

Spatial/Temporal Scale:

- Analyze as a time series, initially comparing pre- and post-hatchery samples and thereafter every 10 years.

Possible Statistical Analysis:

- Population differentiation tests, relative genetic distances, statistics to calculate effective population size (e.g., harmonic means).

Analytical Rules:

- This is a monitoring indicator that will be used to support management decisions.
- Type I Error of 0.05.

4.6 Phenotypic Traits

Objective 8: Determine if hatchery programs have caused changes in phenotypic characteristics of natural populations.

Fitness, or the ability of individuals to survive and pass on their genes to the next generation in a given environment, includes genetic, physiological, and behavioral components.[10] Maintaining the long-term fitness of supplemented populations requires a comprehensive evaluation of genetic and phenotypic characteristics. Evaluation of some phenotypic traits (i.e., run timing, spawn timing, spawning location, and stray rates) is addressed under Objective 5. Objective 8 assess the potential effects of domestication, including size at maturity, age at maturity, sex ratio, and fecundity. Age and size at maturity shall be assessed for both fish arriving in the Columbia system, and those recovered on the spawning grounds. Size (or age) selective mortality during migration through the Columbia system, such as through fisheries, could alter the age and size of fish on the spawning grounds.

[10] These metrics are difficult to measure, and phenotypic expression of these traits may be all we can measure and evaluate.

Age at Maturity

Monitoring Questions:

Q8.1.1: Is the age at maturity of hatchery and natural-origin fish similar at the time they enter the Columbia River and when they spawn?

Target Species/Populations:

- Q8.1.1 applies to all conservation program stocks.

Statistical Hypotheses 8.1.1:

- $Ho_{8.1.1.1}$: Age at Maturity $_{\text{Hatchery produced spawners Gender X}}$ = Age at Maturity $_{\text{Naturally produced spawners Gender X}}$
- $Ho_{8.1.1.2}$: Age at Maturity $_{\text{All hatchery produced adults Gender X}}$ = Age at Maturity $_{\text{All naturally produced adults Gender X}}$

Measured Variables:

- Total and salt (ocean) age of hatchery and natural-origin salmon carcasses collected on spawning grounds.
- Total and salt age of broodstock.
- Total and salt age of fish at stock assessment locations (e.g., Dryden, Tumwater, Wells, Priest Rapids).
- Whenever possible, age at maturity will be measured at weirs or dams near the spawning stream to avoid the size-related carcass recovery bias on spawning grounds (carcass sampling).
- Assess age of fish, including harvested fish.

Derived Variables:

- Total age and saltwater age
- Age of fish entering the Columbia River.

Spatial/Temporal Scale:

- Calculate annually based on brood year.
- Time series.

Possible Statistical Analysis:

- Use graphic analysis and Yates' Chi-square.

Analytical Rules:

- This is a monitoring indicator that will be used to support management decisions.
- Type I Error of 0.05.

Size at Maturity

Monitoring Questions:

Q8.2.1: Is the size (length) at maturity of a given age and sex of hatchery fish similar to the size at maturity of a given age and sex of natural-origin fish?

Target Species/Populations:

- Q8.2.1 applies to all conservation and safety-net stocks.

Statistical Hypothesis 8.2.1:

- $Ho_{8.2.1.1}$: Size (length) at Maturity $_{\text{Hatchery Age X and Gender Y}}$ = Size (length) at Maturity $_{\text{Naturally produced Age X and Gender Y}}$
- $Ho_{8.2.1.2}$: Size (length) at Maturity $_{\text{All hatchery adults Gender X}}$ = Size (length) at Maturity $_{\text{All naturally produced adults Gender X}}$

Measured Variables:

- Size (length), age, and gender of hatchery and natural-origin salmon carcasses collected on spawning grounds.
- Size (length), age, and gender of broodstock.
- Size (length), age, and gender of fish at stock assessment locations (e.g., Priest Rapids, Dryden, Tumwater, Wells, Twisp Weir).
- Whenever possible, size at maturity will be measured at weirs or dams near the spawning stream to avoid the size-related carcass recovery bias on spawning grounds (carcass sampling).

Derived Variables:

- Total age and saltwater age

Spatial/Temporal Scale:

- Calculate annually based on brood year.
- Time series.

Possible Statistical Analysis:

- Use graphic analysis and three-way ANOVA by origin, gender, and age

Analytical Rules:

- This is a monitoring indicator that will be used to support management decisions.
- Type I Error of 0.05.

Fecundity at Size[11]

Monitoring Questions:

Q8.3.1: Is the fecundity vs. size relationship of hatchery and natural-origin fish similar?

[11] May not apply to all programs.

Q8.3.2: Is the gonadal mass vs. size relationship of hatchery and natural-origin fish similar?

Target Species/Populations:

- Both Q8.3.1 and Q8.3.2 apply to all conservation stocks using both natural- and hatchery-origin broodstock.

Statistical Hypothesis 8.3.1:

- $Ho_{8.3.1.1}$: Slope of Fecundity vs. Size $_{\text{Hatchery}}$ = Slope of Fecundity vs. Size $_{\text{Naturally produced}}$

Statistical Hypothesis 8.3.2:

- $Ho_{8.3.2.1}$: Gonadal Mass vs. Size $_{\text{Hatchery}}$ = Gonadal Mass vs. Size $_{\text{Naturally produced}}$

Measured Variables:

- Length, weight, and age (covariate) of hatchery and natural-origin broodstock after eggs have been removed.
- Number and weight of eggs

Derived Variables:

- Total age and saltwater age.
- Mean weight per egg.

Spatial/Temporal Scale:

- Calculate annually based on brood year.
- Time series.

Possible Statistical Analysis:

- Use graphic analysis, regression, t-test, and ANCOVA.

Analytical Rules:

- This is a monitoring indicator that will be used to support management decisions.
- Type I Error of 0.05.

Sex Ratio

Monitoring Questions:

Q8.4.1: Is the sex ratio of hatchery and natural-origin fish similar?

Target Species/Populations:

- Q8.4.1 applies to all conservation stocks.

Statistical Hypothesis 8.4.1:

- $Ho_{8.4.1.1}$: Sex Ratio $_{\text{Hatchery}}$ = Sex Ratio $_{\text{Naturally produced}}$

Measured Variables:

- Age and sex of hatchery and natural-origin salmon carcasses collected on spawning grounds or sampled at dams or weirs.
- Whenever possible sex ratio will be measured at weirs or dams near the spawning stream to avoid the size-related carcass recovery bias on spawning grounds (carcass sampling or ultrasound on live fish).

Derived Variables:

- Ratio of sexes based on brood year returns

Spatial/Temporal Scale:

- Calculate annually based on brood year.
- Time series.

Possible Statistical Analysis:

- Use graphic analysis and Yates'Chi-square.

Analytical Rules:

- This is a monitoring indicator that will be used to support management decisions.
- Type I Error of 0.05.

SECTION 5: HATCHERY ENVIRONMENT MONITORING INDICATORS

5.1 Release Targets

Objective 9: Determine if hatchery fish were released at the programmed size and number.

The HCP outlines the number and size of fish that are to be released to meet NNI and inundation compensation levels. The size of the fish at release may be altered according to an adaptive management process in the Hatchery Committee(s), and the number of fish can be altered by survival study results and adjustment of hatchery production for population dynamics. Size of fish at release can affect survival, sex ratios, age at return, stray rate, and fecundity. In addition, the variation in size at release may affect performance of the fish.

The coefficient of variation (CV) will be evaluated to ascertain if program performance is related to variation in size at release. Note also that variation in a population is a natural condition and striving to control this variation could result in directional or stabilizing artificial selection that could have unforeseen long-term consequences. Attaining uniform or multi-modal growth in a hatchery environment may not be adaptive for fitness in the wild. Therefore, pursuit of a CV target should be seen as an informative exercise, but is not in itself indicative of success or failure of a hatchery program. Furthermore, growth regimes may prove to be important in affecting adult returns and age structure. Although many factors can influence both the size and number of fish released, past hatchery cultural experience with these stocks should assist in meeting program production levels. Appendix 5 presents the target size at release and CVs for the programs. These targets shall be assessed annually to ensure they are optimized to inform management decisions.

Size at Release of Hatchery Fish

Monitoring Questions:

Q9.1.1: Is the size (fish per pound; fpp) of hatchery fish released equal to the program goal identified in Appendix 5?

Target Species/Populations:

- Q9.1.1 applies to all hatchery stocks.

Statistical Hypothesis 9.1.1:

- $Ho_{9.1.1.1}$: Hatchery fish $_{\text{fpp at release}}$ = Programmed $_{\text{fpp at release}}$ (see Appendix 5)

Measured Variables:

- Fork length and weights of random samples of hatchery juveniles at release.

Derived Variables:

- Mean length (FL), mean weight, and fish per pound
- Appendix 5: Rearing targets

Spatial/Temporal Scale:

- Calculate annually.
- Time series.

Possible Statistical Analysis:

- Use graphic analysis and descriptive statistics to compare the estimated fpp of hatchery fish at time of release with the program goal.

Analytical Rules:

- This is a monitoring indicator that will be used to support management decisions.

Coefficient of Variation (CV) of Hatchery Fish Released

Monitoring Questions:

Q9.2.1: Is the CV of hatchery fish released equal to the program target identified in Appendix 5?

Target Species/Populations:

- Q9.2.1 applies to all hatchery stocks.

Statistical Hypothesis 9.2.1:

- $Ho_{9.2.1.1}$: Hatchery fish $CV_{\text{at release}}$ = Programmed CV in Appendix 5

Measured Variables:

- Length and weights of random samples of hatchery smolts.

Derived Variables:

- Coefficient of Variation: $cv = (1 + 1/4n) \times (s/x)$ (where s = standard deviation, x = estimated mean, n = sample size)
- Appendix 5: Rearing targets

Spatial/Temporal Scale:

- Calculate annually.
- Time series.

Possible Statistical Analysis:

- Use graphic analysis and descriptive statistics to compare the estimated CV of size of hatchery fish released with the program goal.

Analytical Rules:

- This is a monitoring indicator that will be used to support management decisions.

Condition Factor (K) of Hatchery Fish Released

Monitoring Questions:

Q9.3.1: Is the K of hatchery fish released equal to the program target identified in Appendix 5?

Target Species/Populations:

- Q9.3.1 applies to all hatchery stocks.

Statistical Hypothesis 9.3.1:

- $Ho_{9.3.1.1}$: Hatchery fish $K_{\text{at release}}$ = Programmed K identified in Appendix 5

Measured Variables:

- Monthly individual lengths and weights of random samples of hatchery juveniles.

Derived Variables:

- Condition Factor: $K = W/L^3 \times 10^5$

Spatial/Temporal Scale:

- Calculate annually.
- Time series.

Possible Statistical Analysis:

- Use graphic analysis and descriptive statistics to compare the estimated K of released hatchery fish with the program goal.

Analytical Rules:

- This is a monitoring indicator that will be used to support management decisions.
- Type I Error of 0.05.

Number of Hatchery Fish Released

Monitoring Questions:

Q9.4.1: Is the number of hatchery fish released equal to the program goal identified in Appendix 5?

Target Species/Populations:

- Q9.4.1 applies to all hatchery stocks.

Statistical Hypothesis 9.4.1:

- $Ho_{9.4.1.1}$: Hatchery Fish Number = Programmed Number identified in Appendix 5

Measured Variables:

- Numbers of smolts released from the hatchery.

Derived Variables:

- Appendix 5: Rearing targets

Spatial/Temporal Scale:

- Calculate annually.

- Time series.

Possible Statistical Analysis:

- Use graphic analysis and one-sample quantile tests to compare the estimated number of hatchery fish released with the program goal.

Analytical Rules:

- This is a monitoring indicator that will be used to support management decisions.
- Type I Error of 0.05.

SECTION 6: HARVEST MONITORING INDICATORS

6.1 Harvest Rates

<u>Objective 10</u>: **Determine if appropriate harvest rates have been applied to conservation, safety-net, and segregated harvest programs to meet the HCP/SSSA goal of providing harvest opportunities while also contributing to population management and minimizing risk to natural populations.**

Harvest will be applied to different types of programs in an effort to achieve the management objectives of those programs. Programs designed to augment harvest should routinely contribute to harvest at a rate that greatly reduces the incidence of straying to natural spawning grounds, but also allows the program to be sustained. Safety-net programs may be harvested as part of an adult management strategy to minimize excessive escapement of hatchery-origin fish to spawning grounds. Similarly, conservation programs may undergo harvest to manage returning adults, but the emphasis for these programs should be to achieve escapement goals. In all cases, harvest effort should not have the unintended consequence of removing excessive numbers of conservation or natural-origin fish. In years when the expected returns of hatchery adults are above the level required to meet program goals (i.e., supplementation of spawning populations and/or brood stock requirements), surplus fish may be available for harvest. The M&E Plan specifically addresses harvest and harvest opportunities upstream of Priest Rapids Dam. Harvest or removal of surplus hatchery fish from the spawning grounds may assist in reducing potential adverse ecological and genetic impacts to natural populations (e.g., loss of genetic variation within and between populations, loss of fitness, reduced effective population size, and density-dependent effects).

Monitoring Questions:

Q10.1.1: Conservation Programs: Is the harvest on conservation hatchery fish at an appropriate level to manage natural spawning of conservation hatchery fish but low enough to sustain the hatchery program?

Q10.1.2: Safety-Net Programs: Is the harvest on conservation hatchery fish at an appropriate level to manage natural spawning of safety-net hatchery fish but low enough to sustain the hatchery program?

Q10.1.3: Is the harvest on hatchery fish produced from harvest-augmentation programs high enough to manage natural spawning but low enough to sustain the hatchery program?

Q10.1.4: Is the escapement of fish from conservation and safety-net programs in excess of broodstock and natural production[12] needs to provide opportunities for terminal harvest?

Target Species/Populations:

- Q10.1.1 applies to conservation programs.
- Q10.1.2 applies to safety-net programs.

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[12] The current best estimates of carrying capacity (maximum recruits) will be used, as available.

- Q10.1.3 applies harvest augmentation programs.
- Q10.1.4 applies to conservation and safety-net programs.

Statistical Hypothesis 10.1.1:

- $Ho_{10.1.1.1}$: Harvest rate ≤ Maximum level to meet program goals

Statistical Hypothesis 10.1.2:

- $Ho_{10.1.2.1}$: Harvest rate ≤ Maximum level to meet program goals

Statistical Hypothesis 10.1.3:

- $Ho_{10.1.3.1}$: Escapement ≤ Maximum level to meet supplementation goals

Statistical Hypothesis 10.1.4:

- $Ho_{10.1.4.1}$: Harvest rate ≤ Maximum level to meet program goals

Measured Variables:

- Numbers of hatchery fish taken in harvest.
- Numbers of natural-origin fish taken in harvest.

Derived Variables:

- Total harvest by fishery estimated from expansion analysis.

Spatial/Temporal Scale:

- Calculated annually.
- Time series.

Possible Statistical Analysis:

- Use graphic analysis and one-sample quantile tests to compare the estimated harvest of hatchery fish with the program goal.

Analytical Rules:

- This is a monitoring indicator that will be used to support management decisions.
- Type I Error of 0.05.

SECTION 7: REGIONAL OBJECTIVES

Hatchery programs have the potential to increase diseases that typically occur at low levels in the natural environment (Objective 9). In addition, hatchery fish can reduce the abundance, size, or distribution of non-target taxa through ecological interactions (Objective 10). In this section, we address incidence of disease and non-target taxa of concern.

7.1 Incidence of Disease

Objective 11: Determine if the incidence of disease has increased in the natural and hatchery populations.

The hatchery environment has the potential to amplify diseases that are typically found at low levels in the natural environment. Amplification could occur within the hatchery population (i.e., vertical and horizontal transmission) or indirectly from the hatchery effluent or commingling between infected and non-infected fish (i.e., horizontal transmission). Potential impacts to natural populations have not been extensively studied, but should be considered for programs in which the hatchery fish are expected to commingle with natural fish. This is particularly important for supplementation type programs. Specifically, the causative agent of bacterial kidney disease (BKD), *Renibacterium salmoninarum* (Rs), could be monitored at selected acclimation ponds, both in the water and fish, in which the risk and potential for transmission from the hatchery is highest. Although it is technologically possible to measure the amount of Rs in water or Rs DNA in smolts and adults non-lethally sampled, the biological meaning of these data are uncertain. Currently, the only metric available for M & E purposes is measuring the antigen level from kidney/spleen samples (i.e., ELISA, PCR). When available, non-lethal sampling may replace or be used in concert with lethal sampling.

Implementation of this objective will be conducted in a coordinated approach within the hatchery and natural environment. BKD management within the hatchery population (e.g., broodstock or juveniles) has the potential to reduce the prevalence of disease through various actions (e.g., culling or reduced rearing densities). BKD management must also take into account and support other relevant objectives of the M & E program (e.g., Hatchery Return Rate [HRR], number of smolts released). Hence, the goal of BKD management is to decrease the prevalence of disease and maintain hatchery production objectives (i.e., number and HRR).

As previously discussed, disease transmission from hatchery to naturally produced fish may occur at various life stages and locations. Of these, horizontal transmission from hatchery effluent, vertical transmission on the spawning grounds, and horizontal transmission in the migration corridor have been identified as disease interactions that could be examined under this objective, although others may also be relevant. Experimental designs addressing this objective may require technology not yet available, although in some instances samples may be collected, but not analyzed until a link can be established between bacteria levels in samples and disease prevalence.

Developing a complete set of questions and hypotheses statements for this objective may not be practical at this time, because there is currently no BKD Management Plan. However, while developing experimental designs for this objective, it may be feasible to incorporate both hatchery and natural environment monitoring under a single study design. Integration of the different

aspects of the objective would likely result in a more robust approach into understanding the effectiveness of disease management strategies.

Proposed Tasks:

T1: Assemble fish health data for fish used as brood (e.g., ELISA results).

T2: Conduct data exploration exercise to identify potential relationships between pathogen profiles and likely causative variables (e.g., rearing conditions and management actions).

T3: Develop hypotheses for potential testing to meet objective.

7.2 Non-Target Taxa of Concern (NTTOC)

Objective 12: Determine if the release of hatchery fish affects non-target taxa of concern (NTTOC) within acceptable limits.

Hatchery programs have the potential to affect non-target taxa through various types of interactions (e.g., competition and predation). These interactions can reduce the distribution, size, and abundance of non-target species. The non-target taxa of concern (NTTOC) ecological risk assessment was developed as a regional objective that would addressed ecological interactions on non-target taxa.

In 2008, the Wells HCP, Rocky Reach HCP, Rock Island HCP Hatchery Committees, and the Priest Rapids Hatchery Sub-Committee agreed to an approach to evaluate the potential effects of hatchery programs on NTTOC. The committees originally planned to convene a panel of experts to conduct a preliminary evaluation of the potential effects of Plan supplemented species on NTTOC. At the 15 October 2008 Hatchery Committees meeting, the members agreed to convene an expert panel to conduct a preliminary evaluation of potential effects of supplemented Plan Species on non-target taxa using an approach similar to that used in the Yakima Basin (Pearsons and Hopley 1999; Ham and Pearsons, 2001). The Committees agreed to convene the panel in spring or early summer 2009, and focus this initial effort on HCP Plan Species and the two non-Plan Species, westslope cutthroat trout and lamprey. The Committees identified species interactions, containment objectives for non-target species, and fisheries professionals who possessed the expertise to contribute as panel members. The Committees directed the Hatchery Evaluation Technical Team (HETT) to pursue assessment of the hatchery programs potential effects on NTTOC.

The HETT evaluated methods to conduct a risk assessment on NTTOC, and proposed using a combined modeling and a Delphi panel approach, whereby the modeling results would be compared and correlated with the Delphi panel results. The HETT identified the PCD Risk 1 model (Busack et al., 2005; Pearsons and Busack, 2012) to conduct the modeling evaluation. The PCD Risk 1 model is a data intensive, individual-based stochastic model. The HETT determined that the assembled data to be used as inputs for the PCD Risk 1 model would also serve to provide expert panelists the necessary data for them to conduct risk assessments. Hence, the HETT embarked on an extensive effort to gather, organize, and extract the required data from existing datasets, literature, and biologists familiar with the programs and/or particular NTTOC. Ultimately, the input data were assembled in a relational database that allowed the data to be output in user-friendly formats for modeling or Delphi panel use. The database also served to hold the modeling results, which could be extracted and summarized as needed. Following the modeling work, the Committees decided not to assemble the expert panel, because the panel would not be able to evaluate adequately the very large number of possible interactions.

A report titled *Ecological Risk Assessment of Upper-Columbia Hatchery Programs on Non-Target Taxa of Concern* was drafted in 2013 and finalized in 2014, which included the modeling results to date. The results in the report represent a very extensive effort to model the risk of all the upper Columbia hatchery programs for the identified NTTOC for which data and model runs were available. Should new information become available, the Committees agreed to assess the suitability of the data as it relates to conducting future NTTOC evaluations as a regional objective.

SECTION 8: ADAPTIVE MANAGEMENT

One of the challenges of evaluating PUD hatchery programs is that hatchery programs are modified resulting in hatchery treatments that are uneven throughout the duration of the hatchery program. Modifications occur as a result of recalculating hatchery release numbers every 10 years and also through adaptive management. To solve this evaluation challenge, we propose to conduct two scales of analysis. First, the entire duration of the program will be analyzed using the entire data set. This evaluation will analyze whether the overall adaptively managed program achieved objectives. Second, where appropriate, analyses will be compared across periods or programs to determine if major program changes have resulted in hypothesized changes to key response variables. We acknowledged that partitioning data into shorter periods will likely result in reduced statistical power so only the biggest changes will be evaluated. In the future, the hatchery committees will develop a table or figure that identifies major program changes in fish culture or M&E.

In the past, hatchery programs have been evaluated at the hatchery program scale (e.g., Nason Creek, Carlton summer Chinook). In some cases, it may be worthwhile to evaluate supplementation programs at different spatial scales. For example, the Nason Creek spring Chinook salmon program can be evaluated at the scale of Nason Creek, the combined effects of spring Chinook hatchery programs in the Wenatchee basin at the Wenatchee basin scale, and then all of the spring Chinook programs in the upper Columbia at the upper Columbia basin scale.

Comparisons of supplemented populations (treatments) to in-basin reference populations are the best way to evaluate whether treatments have caused changes to variables such as natural-origin recruits or productivity. Many suitable out-of-basin references are available (see Appendix 6), but these references do not control for unique factors that may be happening in the upper Columbia or areas outside the upper Columbia. For example, large fires that occur in the Upper Columbia may not occur at similar times in areas outside of this area. Candidate in-basin reference populations are not ideal for spring Chinook salmon because they are small and are above a lake (e.g., Little Wenatchee River) or they have had a long history of hatchery stocking (e.g., Entiat River). Every population of upper Columbia summer and fall Chinook is supplemented so in-basin references are not currently available. Without a suitable number of in-basin reference populations that are similar in size and distribution to treated populations, it will be difficult to unambiguously assess hatchery effects on certain variables. Although not ideal, the only way to increase in-basin reference comparisons is to strategically reduce the number of places where hatchery fish are released such as was done for the Entiat River.

Previous stocking history will lessen the value of reference populations; however, they can still be of value. For instance, the Committees can still test whether NORs are increased under supplementation compared to periods when other populations are not supplemented (i.e., a reverse BACI analysis).

SECTION 9: REFERENCES

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SECTION 10: GLOSSARY

Adult-to-Adult survival (Ratio)	The number of parent broodstock relative to the number of returning adults.
Age at maturity	The age of fish at the time of spawning (hatchery or naturally).
Augmentation	A hatchery strategy where fish are released for the sole purpose of providing harvest opportunities.
Broodstock	Adult salmon and steelhead collected for hatchery fish egg harvest and fertilization.
Donor population	The source population for supplementation programs before hatchery fish spawned naturally.
Effective population size (Ne)	The number of reproducing individuals in an ideal population (i.e., Ne = N) that would lose genetic variation due to genetic drift or inbreeding at the same rate as the number of reproducing adults in the real population under consideration (Hallerman 2003).
ESA	Endangered Species Act passed in 1973. The ESA-listed species refers to fish species added to the ESA list of endangered or threatened species and are covered by the ESA.
Expected value	The number of smolts or adults derived from survival rates agreed to in the Biological Assessment and Management Plan (BAMP 1998).
Extraction rate	The proportion of the spawning population collected for broodstock.
Genetic diversity	All the genetic variation within a species of interest, including both within and between population components.
Genetic stock structure	A type of assortative mating, in which the gene pool of a species is composed of a group of subpopulations, or stocks, that mate panmictically within themselves.
Genetic variation	All the variation due to different alleles and genes in an individual, population, or species.
HCP	Habitat Conservation Plan is a plan that enables an individual or organization to obtain a Section 10 Permit which outlines what will be done to “minimize and mitigate” the impact of the permitted take on a listed species.

HCP-HC	Habitat Conservation Plan Hatchery Committee is the committee that directs actions under the hatchery program section of the HCP's for Chelan and Douglas PUDs.
HRR	Hatchery Replacement Rate is the ratio of the number of returning hatchery adults relative to the number of adults taken as broodstock, both hatchery and naturally produced fish (i.e., adult-to-adult replacement rate).
Long-term fitness	Long-term fitness is the ability of a population to self-perpetuate over successive generation.
Naturally produced	Progeny of fish that spawned in the natural environment, regardless of the origin of the parents.
Mean Ratio	The ratio between a treatment and control population, with the mean taken across a time period, such as years. Used in analysis in Before-After-Control-Impact studies.
Ne	Effective population size.
Non-target taxa of concern (NTTOC)	Species, stocks, or components of a stock with high value (e.g., stewardship or utilization) that may suffer negative effects because of a hatchery program.
NRR	Natural replacement rate is the ratio of the number of returning naturally produced adults relative to the number of adults that naturally spawned, both hatchery and naturally produced.
NTTOC	Non-target taxa of concern.
pHOS	Proportion of Hatchery Origin Spawners.
PNI	Proportionate Natural Influence.
pNOB	Proportion of Natural Origin Broodstock.
PRCC HSC	Priest Rapids Coordinating Committee Hatchery Subcommittee.
Productivity	The capacity in which juvenile fish or adults can be produced.
Reference population	A population in which no directed artificial propagation is currently directed, although may have occurred in the past. Reference populations are used to monitor the natural variability in survival rates and out of basin impacts on survival.
Smolt-to-adult survival rate (SAR)	Smolt-to-adult survival rate is a measure of the number of adults that return from a given smolt population.
Segregated	A type of hatchery program in which returning adults are spatially or temporally isolated from other populations.

Size at maturity	The length or weight of a fish at a point in time during the year in which spawning will occur.
Smolts per redd	The total number of smolts produced from a stream divided by the total number of redds from which they were produced.
SNP or single-nucleotide polymorphism	A single-nucleotide polymorphism is a variation in a single nucleotide that occurs at a specific position in the genome, where each variation is present to some appreciable degree within a population.
Spawning Escapement	The number of adult fish that survive to spawn.
Stray rate	The rate at which fish spawn outside of natal rivers or the stream in which they were released.
Supplementation	A hatchery strategy where the main purpose is to increase the relative abundance of natural spawning fish without reducing the long-term fitness of the population.
Target population	A specific population in which management actions are directed (e.g., artificial propagation, harvest, or conservation).

APPENDIX 1: ESTIMATION OF CARRYING CAPACITY

In the ecological literature, carrying capacity is often defined as the maximum population size that can be supported indefinitely by the environment (Cain et al. 2014). Said another way, carrying capacity is the maximum number or biomass of a species that a given habitat can support. This maximal environment load is often referred to as "habitat capacity" and is identified with the letter "C." In contrast, the carrying capacity parameter "K" in population models (e.g., logistic equation, Beverton-Holt model, hockey stick model, and the Ricker model) defines a maximum equilibrium population size. Maximum equilibrium population size is generated from density dependent mechanisms that reduce population growth rates as population size increases (negative density dependence). This is referred to as compensation. Population size fluctuates about the maximum equilibrium size because of variability in vital rates that are unrelated to density (density independent factors) and measurement error. Maximum equilibrium population size is often referred to as "population capacity." The two capacities (habitat capacity and population capacity) are related but not identical and therefore should not be confused. Habitat capacity will usually be greater than population capacity.

Estimation of carrying capacity is important because hatchery managers use it to inform supplementation programs, harvest managers use it to set appropriate harvest and escapement levels, modelers use it in life-cycle models to predict the effects of different recovery scenarios, and restoration practitioners use it to guide restoration actions. The purpose of this paper is to describe methods that can be used to estimate carrying capacity for stocks within the Upper Columbia River basin. We apply these methods to Wenatchee and Chiwawa River spring Chinook salmon.[13] Data used in this exercise are shown in Tables 1 and 2 and come from Hillman et al. (2017). We begin by identifying simple methods used to detect density dependence. We then describe the use of population models to estimate population capacity. We also discuss the use of habitat models and quantile regression to estimate habitat capacity. We end by comparing results of different methods and offering recommendations for estimating carrying capacity.

Table 1. Numbers of redds, adult spawners (estimated from redd surveys), eggs (estimated as the number of redds times average brood-year fecundity), summer parr (estimated using snorkel surveys), and yearling smolts (estimates using a rotary screw trap) by brood year for spring Chinook salmon in the Chiwawa River watershed. Smolts represent the number of yearling Chinook produced entirely within the Chiwawa River watershed. Date are from Hillman et al. (2017). NS = not sampled.

Brood year	Numbers of Chiwawa spring Chinook				
	Redds	Spawners	Eggs	Parr	Smolts
1991	104	242	478,400	45,483	42525
1992	302	676	1,570,098	79,113	39723
1993	106	233	556,394	55,056	8662
1994	82	184	485,686	55,241	16472
1995	13	33	66,248	5,815	3830

[13] Technically, Wenatchee River spring Chinook are one population. Chiwawa River spring Chinook are a subgroup of the Wenatchee spring Chinook population.

Brood year	Numbers of Chiwawa spring Chinook				
	Redds	Spawners	Eggs	Parr	Smolts
1996	23	58	106,835	16,066	15475
1997	82	182	374,740	68,415	28,334
1998	41	91	218,325	41,629	23,068
1999	34	94	166,090	NS	10,661
2000	128	346	642,944	114,617	40,831
2001	1,078	1,725	4,984,672	134,874	86,482
2002	345	707	1,605,630	91,278	90,948
2003	111	270	648,684	45,177	16,755
2004	241	851	1,156,559	49,631	72,080
2005	332	599	1,436,564	79,902	69,064
2006	297	529	1,284,228	60,752	45,050
2007	283	1,296	1,256,803	82,351	25,809
2008	689	1,158	3,163,888	106,705	35,023
2009	421	1,347	1,925,233	128,220	30,959
2010	502	1,094	2,165,628	141,510	47,511
2011	492	2,032	2,157,420	103,940	37,185
2012	880	1,478	3,716,240	149,563	34,334
2013	714	1,378	3,367,224	121,240	39,396
2014	485	999	1,961,825	111,224	37,170
2015	543	967	2,631,921	140,172	

Table 2. Numbers of redds, adult spawners (estimated from redd surveys), eggs (estimated as the number of redds times average brood-year fecundity), and yearling smolts (estimates using a rotary screw trap) by brood year for spring Chinook salmon in the Wenatchee River basin. Smolts represent the number of yearling Chinook produced entirely within the Wenatchee River basin. Date are from Hillman et al. (2017). NS = not sampled.

Brood year	Numbers of Wenatchee spring Chinook			
	Redds	Spawners	Eggs	Smolts*
2000	350	830	1,758,050	76,643
2001	2,109	3,217	8,674,624	243,516
2002	1,139	1,965	5,300,906	165,116
2003	323	673	1,887,612	70,738
2004	574	1,686	2,663,445	55,619
2005	830	1,484	3,587,083	302,116
2006	588	1,000	2,542,512	85,558
2007	466	2,035	2,069,506	60,219
2008	1,411	2,278	6,479,312	82,137
2009	733	2,299	NS	NS

Brood year	Numbers of Wenatchee spring Chinook			
	Redds	Spawners	Eggs	Smolts*
2010	968	1,921	NS	NS
2011	872	3,139	3,823,720	89,917
2012	1,704	2,720	7,195,992	67,973
2013	1,159	2,133	5,512,204	58,595
2014	885	1,600	3,894,000	36,752

* From 2000-2010 the smolt trap operated near the Town of Monitor; from 2013 to present the trap operated near the Town of Cashmere.

Evidence of Density Dependence

To calculate population capacity, the size of the population or stock must be influenced to a large degree by density-dependent factors. That is, population growth is affected by mechanisms whose effectiveness increases as population size increases. As population density increases, factors such as competition, predation, and disease (and parasites) cause birth rates to decrease, death rates to increase, and dispersal to increase. When densities decrease, the opposite occurs; birth rates increase and death and emigration rates decrease. In general, when the density of the population becomes high enough, density-dependent factors decrease population size because food or space are in short supply (Chapman 1966). In the ecological literature, this is referred to as "population regulation."

A simple way to determine if density-dependent factors regulate population size is to plot population growth rate (or appropriate surrogate) against population size. If population regulation is occurring, the relationship between population size and population growth rate decreases exponentially (decreases linearly if data are log-transformed). Surrogates for population growth rate include survival rates, natality (birth rates), productivity, recruits, individual growth rates, and movement. Figure 1 shows the relationship between productivity (parr/spawner and smolts/spawner) and spawning escapement for Wenatchee River and Chiwawa River spring Chinook. One could use redd counts as a surrogate for spawning abundance. Because most female spring Chinook construct only one redd (Murdoch et al. 2009), redd counts reflect the number of female spawners in the population. In this report, we use number of spawners (spawning escapement) because most management decisions are based on spawning escapement.

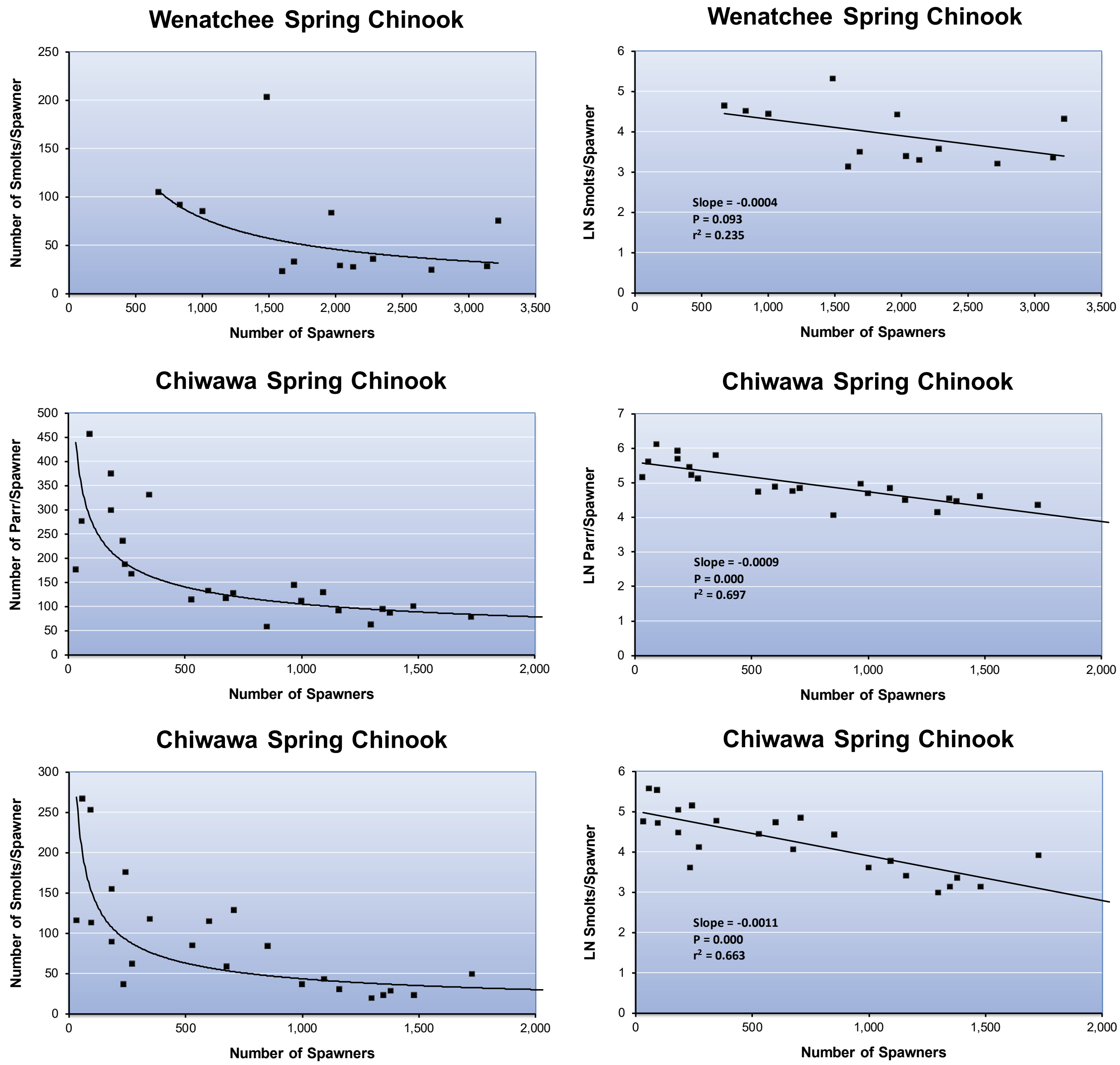


Figure 1. Relationship between spawner abundance and smolts/spawner for Wenatchee spring Chinook (top figures), spawner abundance and parr/spawner for Chiwawa spring Chinook (middle figures), and spawner abundance and smolts/spawner for Chiwawa spring Chinook (bottom figures). Figures on the right show natural log transformed productivity data.

The negative relationship between spawner abundance and juvenile productivity indicates the presence of density dependence in Chiwawa spring Chinook. Although there is a hint of density dependence in the Wenatchee River productivity data, the relationship was not significant statistically. This in part may be related to changes in sampling over the 13-year period. The negative relationship was significant for both summer parr and yearling smolts in the Chiwawa River watershed. We caution, however, that there may be a bias in the simple regression analysis presented in the figures. That is, the dependent (productivity) and independent (abundance) variables are not independent and this can produce a negative bias in regression estimates of slope. Nevertheless, the decline in juvenile productivity with increasing spawner abundance indicates the

presence of density dependence. Given the presence of density dependence, we should be able to estimate population capacity.

Estimating Carrying Capacity

Several different methods can be used to estimate population capacity. For example, time series analyses, including the logistic or Gompertz functions, or stock-recruitment models can be used to estimate population capacity. Common stock-recruitment models include Ricker, Beverton-Holt, and smooth hockey stick models. These models incorporate environmental variability and can be used to estimate the size of the spawning population needed to produce the maximum number of recruits. Habitat capacity, on the other hand, can be estimated using fish-habitat models. In general, these models estimate habitat capacity as the product of habitat area and fish/habitat relationships. These range from simple models such as percent habitat saturation models to more complex models including habitat suitability, quantile regression forest models, dynamic food-web models, and bioenergetic or net rate of energy intake models. In this report, we explore the use of stock-recruitment models to estimate population capacity. We apply quantile regression to stock-recruitment models to estimate habitat capacity and compare those results to a habitat model, the quantile regression forest model.

Population Capacity

To estimate population capacity, we evaluated the fit of three different stock-recruitment models to Chiwawa and Wenatchee River spring Chinook data: Ricker, Beverton-Holt, and smooth hockey stick models. In using these models, we assume:

- *Density-dependent mortality*—For some time period before recruitment, the brood instantaneous mortality rate is proportional to the number of parent spawners (Ricker 1954).
- *Lognormal variation*—At any particular spawning stock size, the variation in recruitment is log-normally distributed about its average, and acts multiplicatively (Quinn and Deriso 1999).
- *Measurement error*—Error in spawning stock size estimates (measurement error) is small relative to the range of spawning stock sizes observed (Hilborn and Walters 1992). Variation in realized recruitment at any particular spawning stock size (process error) dominates recruitment measurement error.
- *Stationarity*—The average stock-recruitment relationship is constant over time (Hilborn and Walters 1992). That is, environmental conditions randomly affect survival independent of stock size or time.

In general, the methods we used to fit the models to the data followed those outlined in Hilborn and Walters (1992) and Froese (2008). The Ricker model, which assumes that the number of recruits increases to a maximum and then declines as the number of spawners increases, takes the form:

$$\boldsymbol{E(R) = \alpha S e^{-\beta S}}$$

where E(R) is the expected recruitment, S is spawner abundance, α is the number of recruits per spawner at low spawning levels, and β describes how quickly the recruits per spawner drop as the number of spawners increases. We estimated population capacity (K) as:

$$K = \left(\frac{\alpha}{\beta}\right) e^{-1}$$

and the number of spawners (SP) needed to produce the maximum number of recruits as:

$$SP = \frac{1}{\beta}$$

The Beverton-Holt model assumes that the number of recruits increases constantly toward an asymptote as the number of spawners increases. After the asymptote is reached, the number of recruits neither increases nor decreases. The asymptote represents the maximum number of recruits the system can support (i.e., population capacity for the system; K). The Beverton-Holt curve takes the form:

$$E(R) = \frac{(\alpha S)}{(\beta + S)}$$

where E(R) and S are as above, α is the maximum number of recruits produced (i.e., α = K), and β is the number of spawners needed to produce (on average) recruits equal to one-half the maximum number of recruits. The number of spawners needed to produce the maximum number of recruits is ∞ in the Beverton-Holt model.

Like the Beverton-Holt model, the smooth hockey stick model assumes that the number of recruits increases toward an asymptote (population capacity; K) as the number of spawners increases. After the carrying capacity is reached, the number of recruits neither increases nor decreases. The carrying capacity represents the maximum equilibrium number of recruits the system can support. This curve takes the form (Froese 2008):

$$E(R) = R_\infty\left(1 - e^{-\left(\frac{\alpha}{R_\infty}\right)S}\right)$$

where E(R) and S are as above, α is the slope at the origin of the spawner-recruitment curve, and R_∞ is the carrying capacity of recruits (i.e., R_∞ = K). There is no direct estimate of SP in the smooth hockey stick model. Therefore, we estimated SP as the number of spawners needed to produce 0.95(K).

We used non-linear regression to fit the three models to spawner-recruitment data. Before fitting the models, we transformed recruitment data using natural logs. We estimated bias and uncertainty measures (95% CI) for the model parameters using bootstrap procedures, which assumed that the {R, S} sample represented or approximated the population. The number of bootstrap samples was 3,000. We computed and stored the non-linear regression results for each bootstrap sample. We then calculated the bootstrap 95% CI by arranging the 3,000 bootstrap parameter values in sorted order and selected the 2.5 and 97.5 percentiles from the list.

We used Akaike's Information Criterion for small sample size (AIC_c) to determine which model(s) best explained the relationship between spawners and recruitment in the supplemented and reference populations. AIC_c was estimated as:

$$AIC_c = -2log(\pounds(\theta|data)) + 2K + \left(\frac{2K(K+1)}{n-K-1}\right)$$

where $log(£(\theta|data))$ is the maximum likelihood estimate, K is the number of estimable parameters (structural parameters plus the residual variance parameter), and n is the sample size (Burnham and Anderson 2002). We used least-squares methods to estimate $log(£(\theta|data))$, which was calculated as $log(\sigma^2)$, where σ^2 = residual sum of squares divided by the sample size ($\sigma^2 = RSS/n$). AIC_c assessed model fit in relation to model complexity (number of parameters). The model with the smallest AIC_c value represented the "best approximating" model within the model set. Remaining models were ranked relative to the best model using AIC_c difference scores (ΔAIC_c), Akaike weights (w_i), and evidence ratios. Models with ΔAIC_c values less than 2 indicated that there is substantial support for these models as being the best-fitting models within the set (Burnham and Anderson 2002). Models with values greater than 2 had less support. Akaike weights are probabilities estimating the strength of the evidence supporting a particular model as being the best model within the model set. Models with small w_i values are less plausible as competing models (Burnham and Anderson 2002). If no single model could be specified as the best model, a "best subset" of competing models was identified using (1) AIC_c differences to indicate the level of empirical support each model had as being the best model, (2) evidence ratios based on Akaike weights to indicate the relative probability that any model is the best model, and (3) coefficients of determination (R^2) assessing the explanatory power of each model.

Chiwawa River Spring Chinook Parr

We successfully fit the three stock-recruitment curves to the Chiwawa spring Chinook parr data (Figure 2).

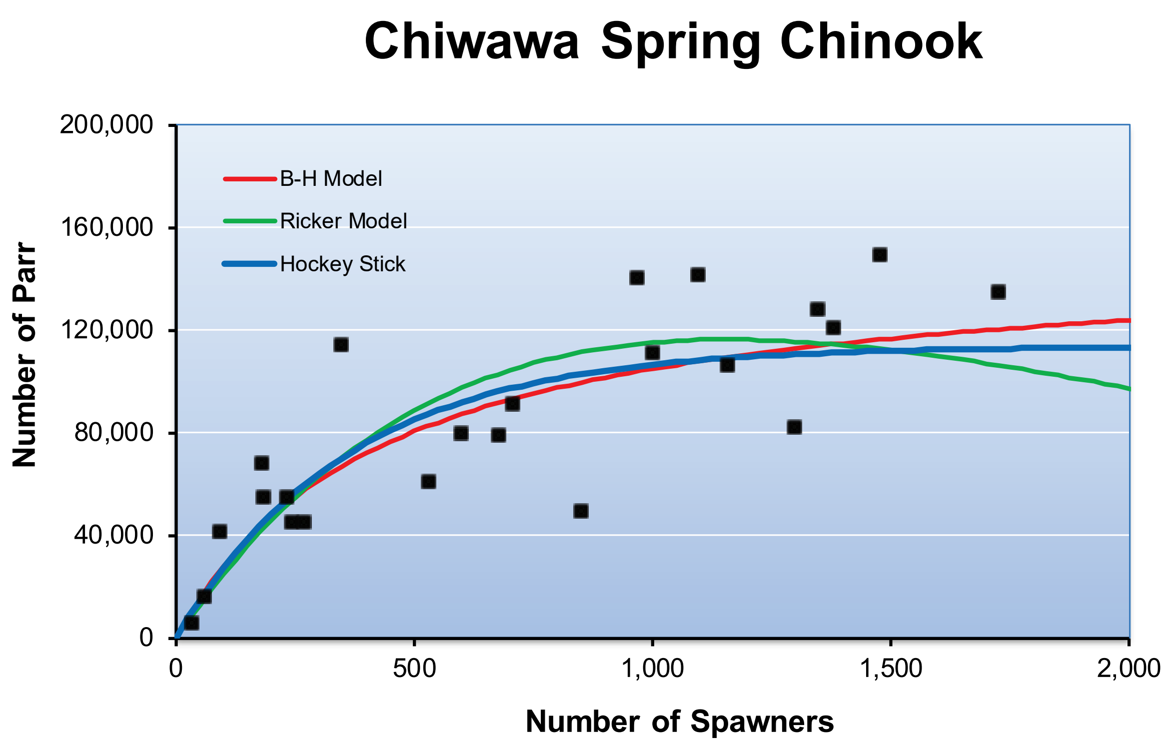


Figure 2. Relationship between numbers of spring Chinook parr and numbers of spawners in the Chiwawa River watershed, 1992-2016 (no sampling occurred in 2000). Figure shows the fit of the Beverton-Holt, Ricker, and smooth hockey stick models to the data.

For summer parr, the use of AIC_c indicated that the Beverton-Holt model best approximated the information in the productivity data. The estimated structural parameters for this model were:

$$Parr = \frac{(150{,}902 \times Spawners)}{(438 + Spawners)}$$

where the bootstrap estimated standard errors for the two parameters were 21,142 and 145, respectively. The adjusted $R^2 = 0.812$.

The second-best model was the smooth hockey stick model, which was 0.245 AIC_c units from the best model. The estimated parameters for this model were:

$$LN(Parr) = 11.6 + LN\left(1 - e^{-\left(\frac{312.9}{113{,}801}\right)Spawners}\right)$$

where the bootstrap estimated standard errors of the two parameters were 0.097 and 57.578, respectively, and the $R^2 = 0.810$.

The AIC_c difference scores, Akaike weights, and evidence ratios indicated that there was substantial support for both the Beverton-Holt and smooth hockey stick models. There was less support for the Ricker model, which was > 2 AIC_c units from the best models. This was further supported by the fact that, relative to the best models, the Ricker model had an evidence ratio greater than 3.

Depending on the stock-recruitment model used, population capacity ranged from 113,801 to 150,902 parr (Table 3). The Beverton-Holt model estimated the highest capacity, while the smooth hockey stick model estimated the lowest. The number of spawners needed to produce the population capacity of parr ranged from 1,089 to 1,163 (Table 3).

Table 3. Estimates of Beverton-Holt, smooth hockey stick, and Ricker model parameters, parr capacity (K), parr productivity (parr per spawner), and the number of spawners needed to produce the maximum number of parr for Chiwawa River spring Chinook.

Model	Parameter		Population capacity (K)	Intrinsic productivity	Spawners
	A	B			
Beverton-Holt	150,902.145	437.655	150,902	345	∞
Smooth Hockey Stick	11.642	312.913	113,801	313	1,089
Ricker	272.696	0.0009	116,650	273	1,163

It is important to note that the population capacity estimates are based on the number of parr counted in the Chiwawa River watershed during August. There are spring Chinook fry and parr that move out of the Chiwawa River watershed during spring and early summer (Hillman et al. 2017). It is unknown if these fish leave because of density-dependent pressures, they are flushed out during high flows, it is a life-history characteristic, or a combination of these. Regardless of the mechanism or reason, some of these fish may survive and rear in the Wenatchee or Columbia rivers. These emigrants are not included in the capacity estimates shown in Table 3.

The capacity estimates for spring Chinook parr apply only to the Chiwawa River watershed, a watershed within the Wenatchee River basin. Estimating parr capacity for the entire Wenatchee River basin using stock-recruitment models is difficult because there is no long-term time series of parr data for the entire basin. However, we can extrapolate parr capacity estimates from the

Chiwawa River watershed to the entire Wenatchee River basin using intrinsic potential (IP). Multiplying the parr capacity per intrinsic potential within the Chiwawa River watershed by the total intrinsic potential within the Wenatchee River basin yields an estimate of parr capacity for the Wenatchee River basin (Table 4). The Interior Columbia Basin Technical Recovery Team estimated IP based on wetted width, valley width (confinement), and gradient (see Cooney and Holzer 2006). They used sedimentation and temperature to refine IP for each 200-m long reach. We used the total stream area (km^2) weighted by intrinsic potential and temperature limited to extrapolate parr capacity to the entire Wenatchee River basin.

Table 4. Estimates of Wenatchee River basin parr capacity based on intrinsic potential (IP). The amount of IP within the Chiwawa River watershed is 0.481 km^2; the total amount of IP within the Wenatchee River basin is 1.798 km^2.

Model	Chiwawa parr capacity	Chiwawa parr/IP	Wenatchee parr capacity
Beverton-Holt	150,902	313,726	564,079
Smooth Hockey Stick	113,801	236,593	425,395
Ricker	116,650	242,516	436,043

Using this simple method, we estimate the Wenatchee River basin supports about 425,395-564,079 parr depending on which model is used. An important assumption of this simple method is that each unit of IP supports the same number of parr. This is clearly not true given that the quality of habitat within each unit of IP can vary greatly. That is, one unit of IP may contain more habitat structure (e.g., wood and cover) than another unit of IP. Importantly, the ratio of parr to IP comes from the Chiwawa River watershed, which contains some of the highest quality habitat within the Wenatchee River basin. Therefore, the estimated total parr capacity for the entire Wenatchee River basin is likely biased high. If habitat conditions throughout the Wenatchee River basin are enhanced to conditions similar to those in the Chiwawa River watershed, we may expect parr abundance to approach those estimated with this simple method.

Chiwawa River Spring Chinook Smolts

We successfully fit the three stock-recruitment curves to the Chiwawa spring Chinook smolt data (Figure 3). This information allows us to better understand the quality and quantity of overwintering habitat in the Chiwawa River basin.

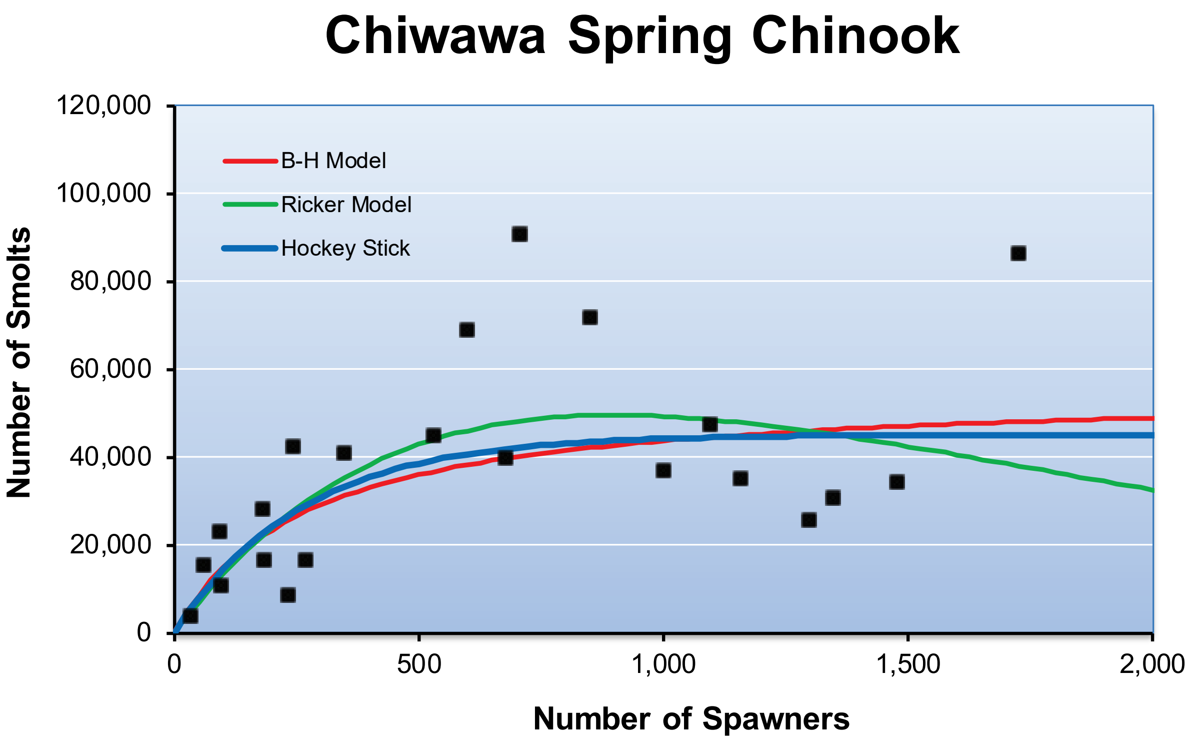


Figure 3. Relationship between numbers of spring Chinook smolts and numbers of spawners in the Chiwawa River watershed, 1992-2015. Figure shows the fit of the Beverton-Holt, Ricker, and smooth hockey stick models to the data.

For yearling smolts produced entirely within the Chiwawa River watershed, the use of AIC$_c$ indicated that the smooth hockey stick model best approximated the information in the productivity data. The estimated structural parameters for this model were:

$$LN(Smolts) = 10.7 + LN\left(1 - e^{-\left(\frac{174.1}{45,161}\right)Spawners}\right)$$

where the bootstrap estimated standard errors for the two parameters were 0.13 and 41.29, respectively. The adjusted $R^2 = 0.569$.

The second-best model was the Ricker model, which was 0.234 AIC$_c$ units from the best model. The estimated parameters for this model were:

$$Smolts = 149.45 \times Spawners(\mathrm{e}^{-0.00111 \times Spawners})$$

where the bootstrap estimated standard errors of the two parameters were 26.23 and 0.00018, respectively, and the $R^2 = 0.573$.

The third-best model was the Beverton-Holt model, which was 0.725 AIC$_c$ units from the best model. The estimated parameters for this model were:

$$Smolts = \frac{(55,702 \times Spawners)}{(273 + Spawners)}$$

where the bootstrap estimated standard errors of the two parameters were 10,421.9 and 123.0, respectively, and the $R^2 = 0.560$.

The AIC_c difference scores, Akaike weights, and evidence ratios indicated that there was substantial support for all three models. Relative to the best model, the other two models had evidence ratios less than 1.5.

Depending on the stock-recruitment model used, population capacity ranged from 45,161 to 55,702 smolts (Table 5). The Beverton-Holt model estimated the highest capacity, while the smooth hockey stick model estimated the lowest. The number of spawners needed to produce the population capacity of smolts ranged from 777 to 901 (Table 5).

Table 5. Estimates of Beverton-Holt, smooth hockey stick, and Ricker model parameters, smolt capacity (K), smolt productivity (smolts per spawner), and the number of spawners needed to produce the maximum number of smolts for Chiwawa River spring Chinook.

Model	Parameter		Population capacity (K)	Intrinsic productivity	Spawners
	A	B			
Smooth hockey stick	10.718	174.077	45,161	174	777
Ricker	149.452	0.00111	49,532	149	901
Beverton-Holt	55,702.281	273.910	55,702	203	∞

It is important to note that the population capacity estimates are based on the number of smolts produced entirely within the Chiwawa River watershed. As noted earlier, there are spring Chinook fry and parr that move out of the Chiwawa River watershed during spring, early summer, and fall (Hillman et al. 2017). Fall emigration is common and occurs even when densities of juveniles are very low, indicating that fall emigration is a life-history characteristic. Regardless of why the fish emigrate as fry and parr, some of these fish survive and rear in the Wenatchee or Columbia rivers. Some survive to smolt (unpublished WDFW data), but are not included in the smolt capacity estimates shown in Table 5.

As with parr, the capacity estimates for spring Chinook smolts apply only to the Chiwawa River watershed. As before, we can extrapolate smolt capacity estimates from the Chiwawa River watershed to the entire Wenatchee River basin using intrinsic potential (IP). In this case, we multiply the smolt capacity per intrinsic potential within the Chiwawa River watershed by the total intrinsic potential within the Wenatchee River basin. This yields an estimate of smolt capacity for the Wenatchee River basin (Table 6).

Table 6. Estimates of Wenatchee River basin smolt capacity based on intrinsic potential (IP). The amount of IP within the Chiwawa River watershed is 0.481 km^2; the total amount of IP within the Wenatchee River basin is 1.798 km^2.

Model	Chiwawa smolt capacity	Chiwawa smolts/IP	Wenatchee smolt capacity
Beverton-Holt	55,702	115,805	208,218
Smooth Hockey Stick	45,161	93,891	168,816
Ricker	49,532	102,976	185,152

Using this simple method, we estimate the population capacity for the Wenatchee River basin at 168,816-208,218 smolts depending on which model is used. Based on smolt trapping in the lower Wenatchee River over a 13-year period, total smolt abundance has ranged from 36,752 to 302,116 smolts (average = 107,300 smolts) (Table 2).[14] Thus, recent (2000-2014) smolt production appears to be below capacity estimates for most years but higher in some years.

An important assumption of this simple method is that each unit of IP supports the same number of smolts. As we noted earlier, this is not the case given that the quality of habitat within each unit of IP can vary greatly. Nevertheless, the ratio of smolts to IP comes from the Chiwawa River watershed, which contains some of the highest quality habitat within the Wenatchee River basin. Therefore, the estimated total smolt capacity for the entire Wenatchee River basin is likely biased high. If habitat conditions throughout the Wenatchee River basin are enhanced to conditions similar to those in the Chiwawa River watershed, we may expect smolt abundance to approach those estimated with this simple method.

Wenatchee River Spring Chinook Smolts

Rather than extrapolate results from the Chiwawa River watershed to the entire Wenatchee River basin, we can fit stock-recruitment models to the smolt data collected in the lower Wenatchee River and estimate population capacity directly from the population models. We successfully fit the three stock-recruitment curves to the Chiwawa spring Chinook smolt data; although, the models explained little of the variation in the stock-recruitment data ($R^2 < 0.05$) (Figure 3).

[14] It is important to point out that the trapping location has changed over time. During the period 2000-2008 and 2011-2012, the trap was located near the Town of Monitor. During the period 2013-present, the trap was located near the Town of Cashmere.

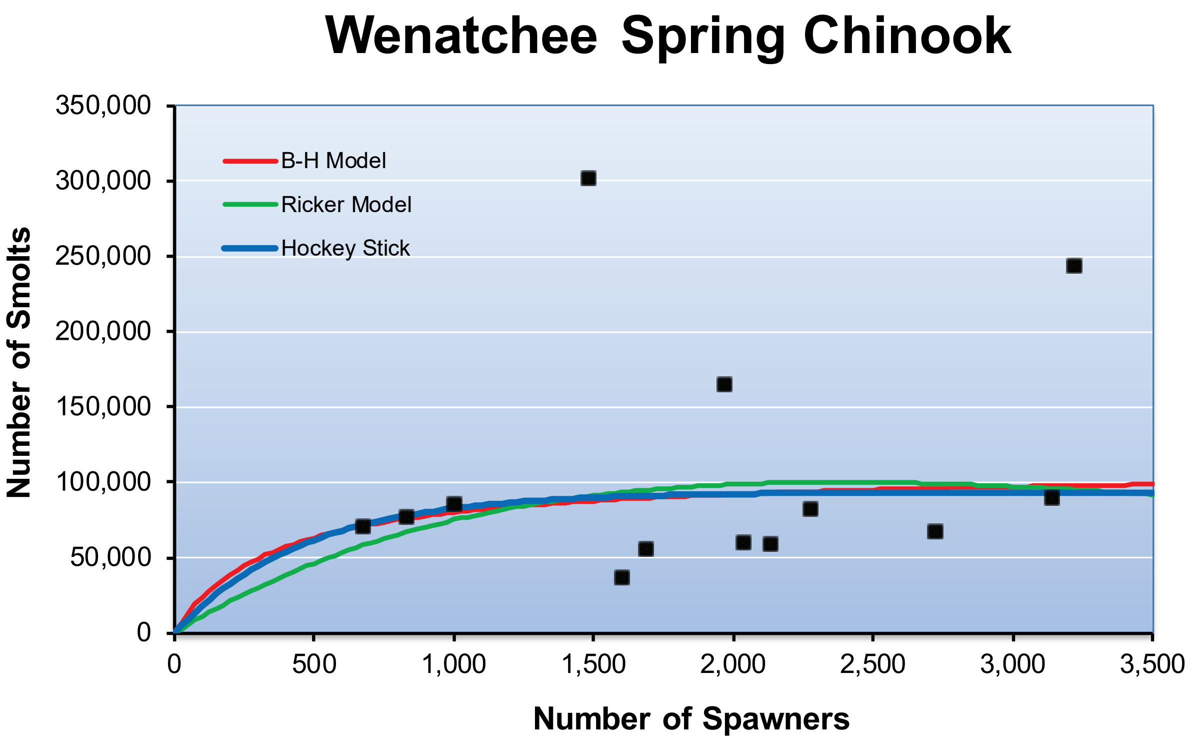


Figure 4. Relationship between numbers of spring Chinook smolts and numbers of spawners in the Wenatchee River basin, 2000-2014 (no data were collected in 2009 or 2010). Figure shows the fit of the Beverton-Holt, Ricker, and smooth hockey stick models to the data.

For yearling smolts produced within the Wenatchee River basin, the use of AIC_c indicated that the Beverton-Holt model best approximated the information in the productivity data. The estimated structural parameters for this model were:

$$Smolts = \frac{(108{,}696 \times Spawners)}{(359 + Spawners)}$$

where the bootstrap estimated standard errors for the two parameters were 49,948 and 836, respectively. The adjusted $R^2 = 0.026$.

The second-best model was the smooth hockey stick model, which was 0.112 AIC_c units from the best model. The estimated parameters for this model were:

$$LN(Smolts) = 11.4 + LN\left(1 - e^{-\left(\frac{20.72}{93{,}560}\right)Spawners}\right)$$

where the bootstrap estimated standard errors of the two parameters were 30.74 and 225.43, respectively, and the $R^2 = 0.017$.

The third-best model was the Ricker model, which was 0.0.808 AIC_c units from the best model. The estimated parameters for this model were:

$$Smolts = 114.10 \times Spawners(\mathrm{e}^{-0.00042 \times Spawners})$$

where the bootstrap estimated standard errors of the two parameters were 56.16 and 0.00021, respectively, and the $R^2 = 0.001$.

The AIC_c difference scores, Akaike weights, and evidence ratios indicated that there was substantial support for all three models. Relative to the best model, the other two models had evidence ratios less than 2.0.

Depending on the stock-recruitment model used, population capacity for the Wenatchee River basin ranged from 93,560 to 108,696 smolts (Table 7). The Beverton-Holt model estimated the highest capacity, while the smooth hockey stick model estimated the lowest. The number of spawners needed to produce the population capacity of smolts ranged from 1,389-2,381 (Table 7).

Table 7. Estimates of Beverton-Holt, smooth hockey stick, and Ricker model parameters, smolt capacity (K), smolt productivity (smolts per spawner), and the number of spawners needed to produce the maximum number of smolts for Wenatchee River spring Chinook.

Model	Parameter		Population capacity (K)	Intrinsic productivity	Spawners
	A	B			
Smooth hockey stick	11.446	201.724	93,560	202	1,389
Ricker	114.104	0.00042	99,944	114	2,381
Beverton-Holt	108,696.009	358.616	108,696	303	∞

The population capacity estimates reported here are based on the number of smolts produced within the Wenatchee River basin. It is likely that some juvenile spring Chinook rear in the Columbia River and survive to smolt. Those fish are not included in these estimates of capacity.

Habitat Capacity

Habitat capacity can be estimated using fish-habitat models and creative modeling of stock-recruitment data. As we noted earlier, there are several different fish-habitat models that can be used to estimate habitat capacity. In this paper, we explore the use of two different methods, quantile regression applied to stock-recruitment functions and the Quantile Regression Random Forest model. The former relies on simple stock and recruitment data, while the latter requires estimates of habitat quality and quantity, and functional relationships between maximum fish density and habitat conditions.

Quantile Regression Analysis of Stock-Recruitment Data

To estimate population capacity, we used non-linear regression techniques to fit stock-recruitment functions to the data. These techniques approximate the conditional mean of the recruitment data given the range of stock sizes. As such, the functions (curves) estimated from the analyses lie near the center of the distribution of data resulting in data points above and below the curve. Although this technique is useful for estimating population capacity, it is not appropriate for estimating habitat capacity. The fact that there are actual recruitment data above the estimated population capacity indicates that habitat capacity must be greater than the population capacity, or that measurement error is high. The former explanation is more likely than the latter.

One way to possibly estimate habitat capacity with stock-recruitment data is to fit stock-recruitment functions to the juvenile spring Chinook data using quantile regression techniques. Quantile regression estimates quantiles of the recruitment data given the range of stock sizes. Thus,

we can use quantile regression to fit a stock-recruitment function to, say, the upper 90% or 95% of the recruitment distribution. In other words, we fit a stock-recruitment function to the upper limits of the recruitment data given the range of stock sizes. In this case, the resulting stock-recruitment curve is above most of the recruitment data and therefore few data points lie above the curve. Calculation of capacity from these functions should more closely represent habitat capacity, provided there is an adequate range of stock sizes. Quantile regression gives results similar to those obtained from calculating reference intervals (RI).

In this exercise, we calculated the upper 90% RI for the Beverton-Holt and Ricker functions. We assume the 90% RI will closely represent the habitat capacity for juvenile spring Chinook. We calculated the 90% RI only for the Beverton-Holt and Ricker models, because these functions can be transformed into linear function (see Hilborn and Walters 1992). RIs are easier to calculate on linear functions than non-linear functions. We were unable to transform the smooth hockey stick model into a linear function and therefore we did not calculate RIs for this function.

Chiwawa River Spring Chinook Parr—We calculated 90% RIs for Chiwawa Chinook parr data for both the Ricker and Beverton-Holt models (Figure 5). The estimated parameters for the 90% RI for the Ricker model were:

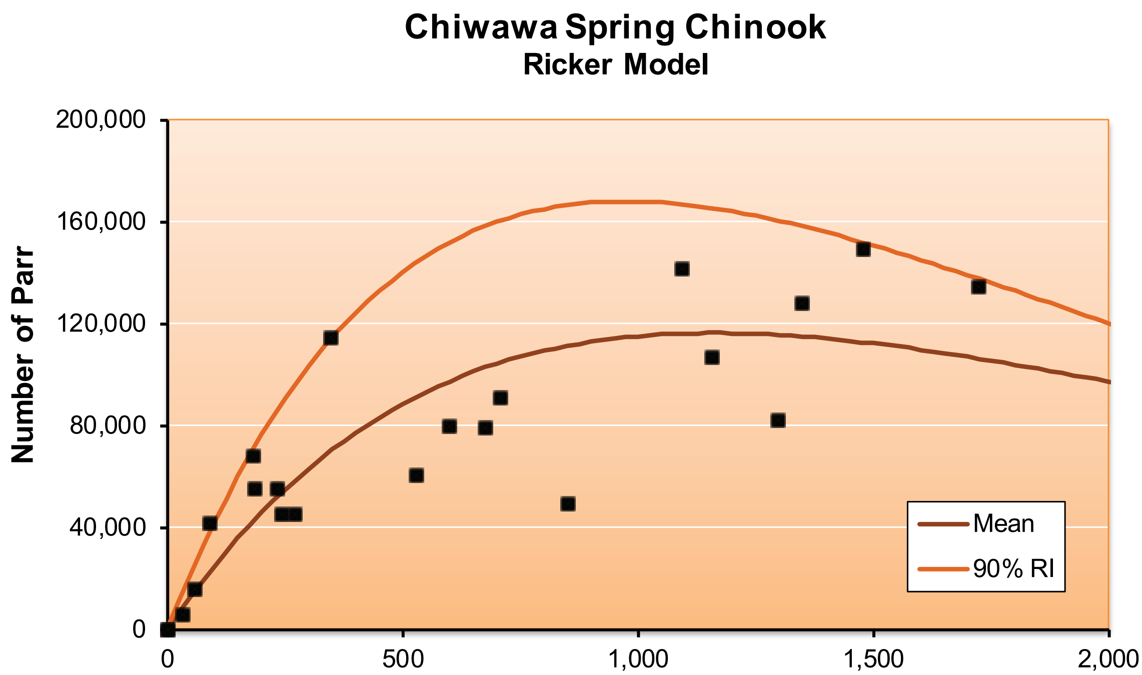
$$\log\left(\frac{Parr}{Spawners}\right) = 6.152 - \frac{6.152}{5{,}984.436}(Spawners)$$

This resulted in an estimated habitat capacity of 168,071 parr, which is about 1.4 times greater than the population capacity estimated with the Ricker model.

The estimated parameters for the 90% RI for the Beverton-Holt model were:

$$\frac{Spawners}{Parr} = \frac{196.91}{181{,}818} + \frac{1}{181{,}818}(Spawners)$$

This function resulted in an estimated habitat capacity of 181,818 parr, which was about 1.2 times greater than the population capacity estimated with the Beverton-Holt model.



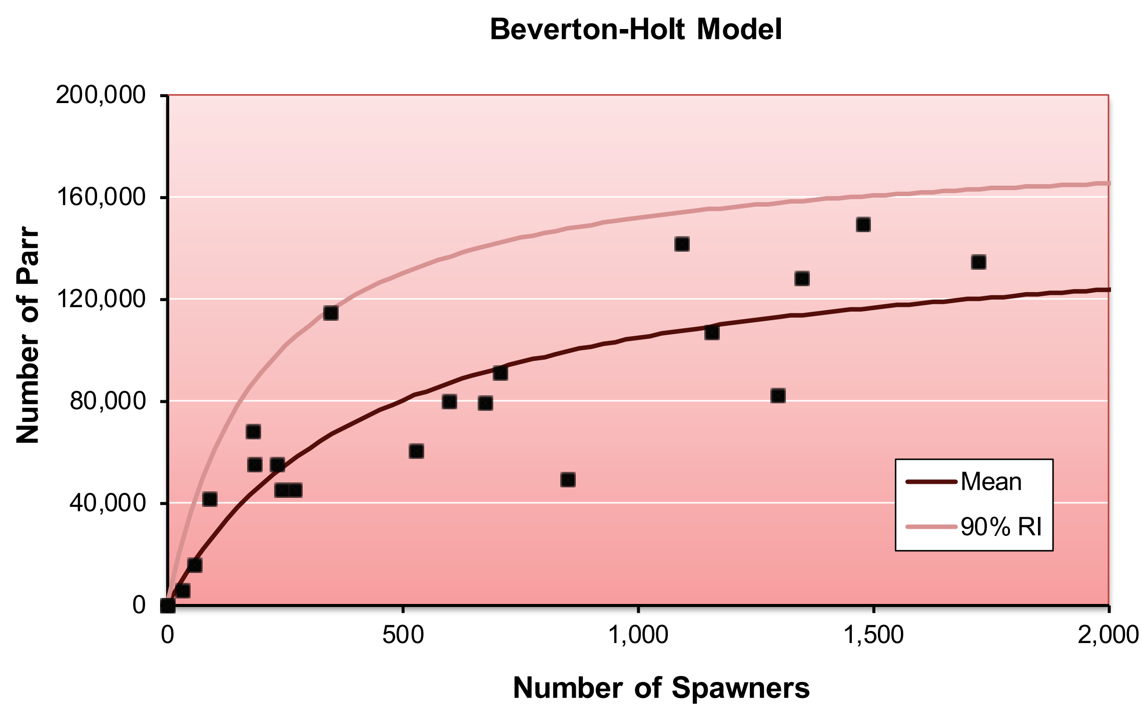


Figure 5. Relationship between numbers of spring Chinook parr and numbers of spawners in the Chiwawa River watershed, 1992-2016. Upper figure shows the fit of the Ricker model and its 90% reference interval to the data; lower figure shows the fit of the Beverton-Holt model and its 90% reference interval.

If we extrapolate the habitat capacity estimates for Chiwawa spring Chinook parr to the entire Wenatchee River basin (using the IP method described earlier), we estimate the habitat capacity for the Wenatchee River basin to be 628,256 parr from the Ricker model and 679,645 parr from the Beverton-Holt model.

Chiwawa River Spring Chinook Smolts—As with parr, we calculated 90% RIs for Chiwawa Chinook smolt data for both the Ricker and Beverton-Holt models (Figure 6). The estimated parameters for the 90% RI for the Ricker model were:

$$\log\left(\frac{Smolts}{Spawners}\right) = 5.687 - \frac{5.687}{4{,}687.964}(Spawners)$$

This resulted in an estimated habitat capacity of 89,425 smolts, which is about 1.8 times greater than the population capacity estimated with the Ricker model.

The estimated parameters for the 90% RI for the Beverton-Holt model were:

$$\frac{Spawners}{Smolts} = \frac{102.129}{64{,}516} + \frac{1}{64{,}516}(Spawners)$$

This function resulted in an estimated habitat capacity of 64,516 smolts, which was about 1.2 times greater than the population capacity estimated with the Beverton-Holt model.

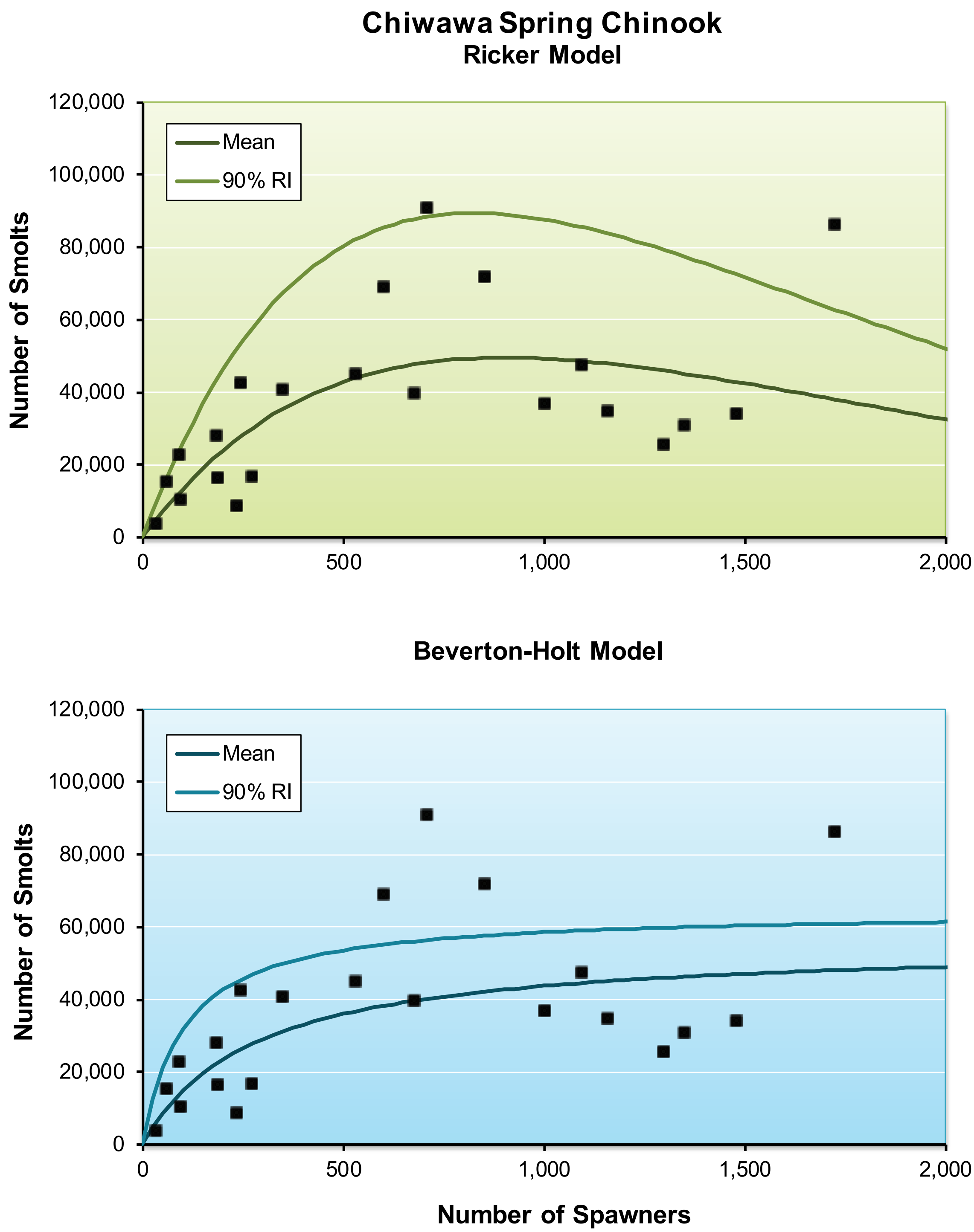


Figure 6. Relationship between numbers of spring Chinook smolts and numbers of spawners in the Chiwawa River watershed, 1992-2015. Upper figure shows the fit of the Ricker model and its 90% reference interval to the data; lower figure shows the fit of the Beverton-Holt model and its 90% reference interval.

If we extrapolate the habitat capacity estimates for Chiwawa spring Chinook smolts to the entire Wenatchee River basin (using the IP method described earlier), we estimate the habitat capacity

for the Wenatchee River basin to be 334,276 smolts based on the Ricker model and 241,164 smolts from the Beverton-Holt model.

Wenatchee River Spring Chinook Smolts—We calculated 90% RIs for Wenatchee River Chinook smolt data for both the Ricker and Beverton-Holt models (Figure 7). The estimated parameters for the 90% RI for the Ricker model were:

$$\log\left(\frac{Smolts}{Spawners}\right) = 5.320 - \frac{5.320}{16{,}642.420}(Spawners)$$

This resulted in an estimated habitat capacity of 235,131 smolts, which is about 2.4 times greater than the population capacity estimated with the Ricker model.

The estimated parameters for the 90% RI for the Beverton-Holt model were:

$$\frac{Spawners}{Smolts} = \frac{357.593}{186{,}567} + \frac{1}{186{,}567}(Spawners)$$

This function resulted in an estimated habitat capacity of 186,567 smolts, which was about 1.7 times greater than the population capacity estimated with the Beverton-Holt model.

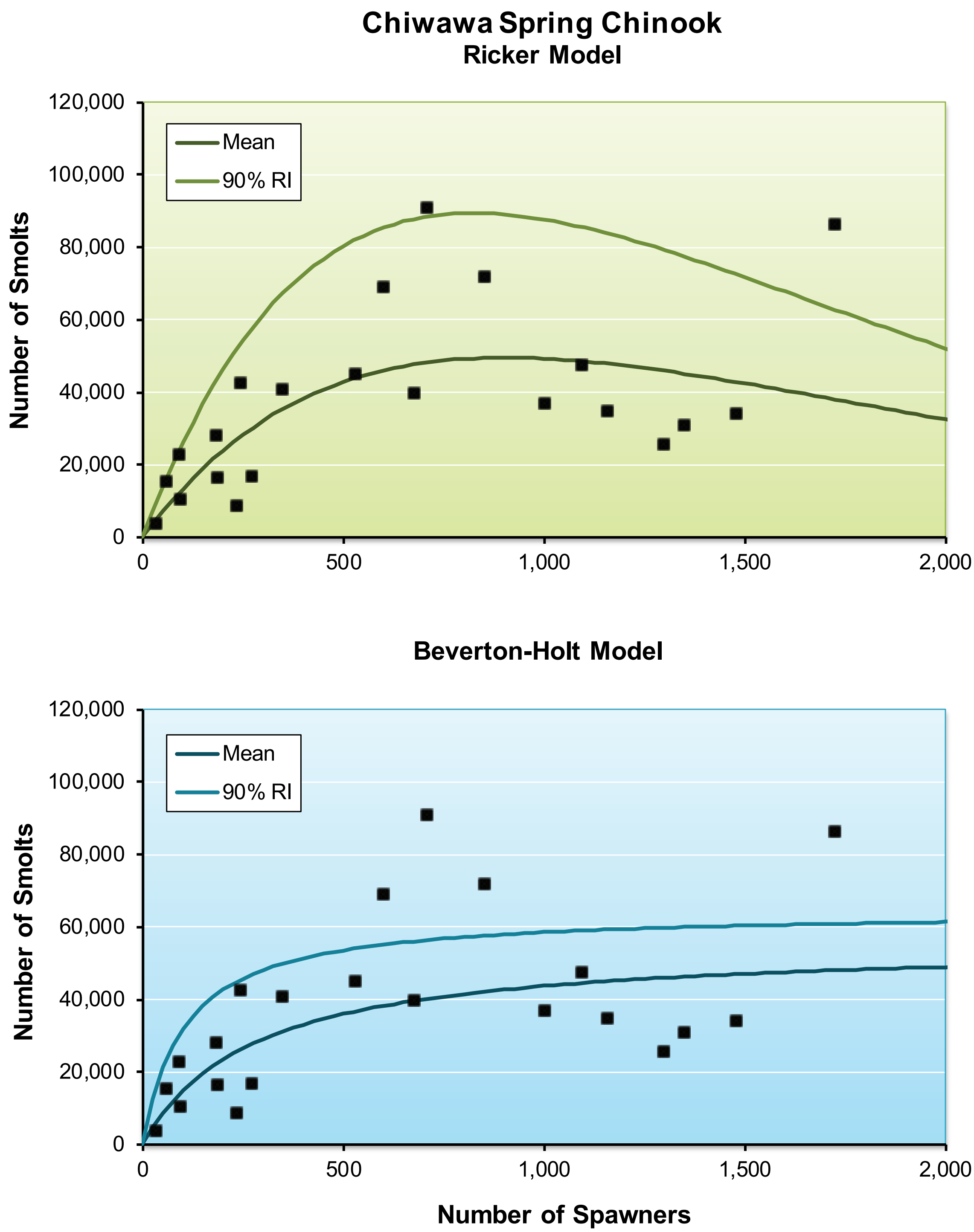


Figure 7. Relationship between numbers of spring Chinook smolts and numbers of spawners in the Wenatchee River basin, 2000-2015 (no data were collected in 2009 or 2010). Upper figure shows the fit of the Ricker model and its 90% reference interval to the data; lower figure shows the fit of the Beverton-Holt model and its 90% reference interval.

Quantile Regression Random Forest Model

Researchers with the Integrated Status and Effectiveness Monitoring Program (ISEMP) developed a model that estimates Chinook parr habitat capacity based on fish-habitat relationships (ISEMP/CHaMP 2015). Based on extensive sampling throughout the Columbia River basin, these researchers developed relationships between maximum densities of Chinook parr (summer estimates) and various habitat variables. Quantile regression forest (QRF) models use these relationships to estimate carrying capacities for juvenile Chinook. Very simply, QRF analysis develops non-linear relationships between fish density and different habitat variables. In this case, however, QRF analysis predicts the 90% quantile of fish density rather than the mean or median density. The researchers assume that the 90% quantile represents habitat capacity. This is important because the numbers of fish counted in some field sampling sites may not have been at maximum capacity. That is, it is likely that not all sites sampled were fully "seeded" with Chinook salmon. Thus, using the mean or median (50% quantile) would not represent habitat capacity, but some level below habitat capacity.

Researchers fit the QRF model to parr density data and 12 habitat variables that were collected from 227 sites within the distribution of Chinook throughout the Columbia River basin (within CHaMP/ISEMP watersheds). These variables were selected to represent a variety of types of habitat variables (e.g., substrate, riparian, complexity, temperature, etc.), contain the most "fish information," and be as uncorrelated as possible (ISEMP/CHaMP 2015). The 12 habitat variables and their relative importance are shown in Figure 8.

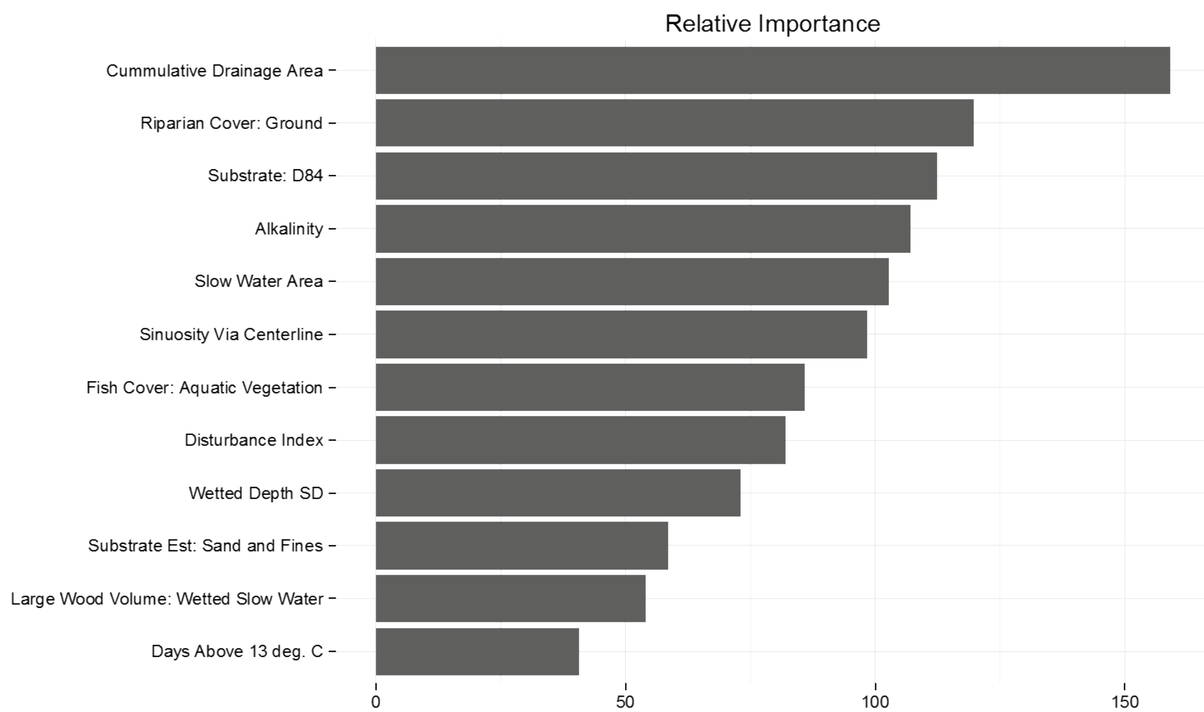


Figure 8. Relative importance of habitat variables included in juvenile Chinook salmon quantile regression forest models (Figure is from ISEMP/CHaMP 2015).

As a way of testing the model, ISEMP researchers used their QRF model to estimate Chinook parr capacities in different watersheds, including the Chiwawa River watershed, and compared their

estimates to those generated from fish population data using stock-recruitment modeling. Figure 9 shows the relationship between the QRF model results and population model results for the Chiwawa River watershed. The red curve was generated using the QRF model and the blue curve was generated using the Beverton-Holt model. At the time of this analysis, the Beverton-Holt model was fit to 21 years of parr data, not the 24 years of data used in the analyses above.

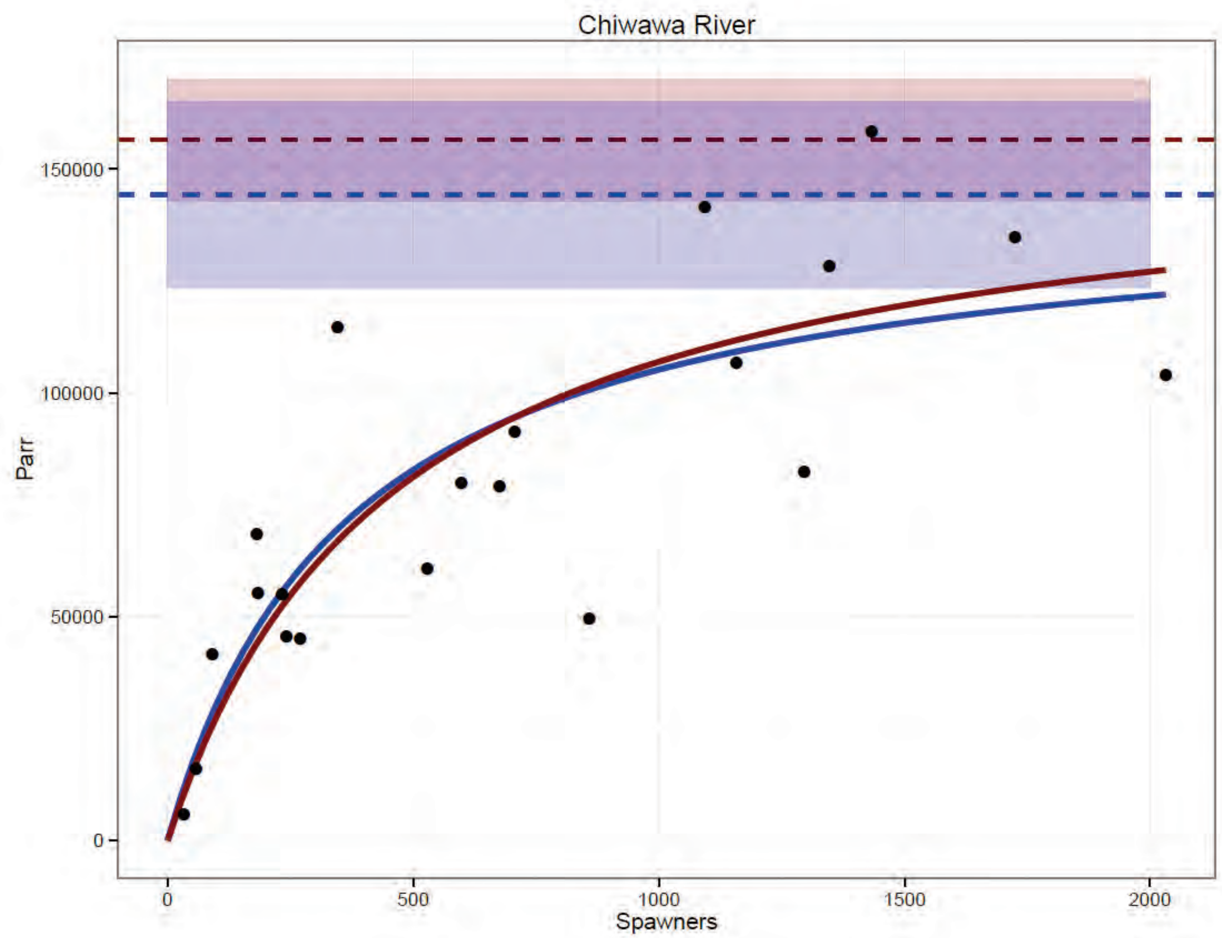


Figure 9. Comparison of productivity curves for Chiwawa spring Chinook parr generated from the QRF model (red line) and Beverton-Holt model (blue line). Dashed horizontal lines represent carrying capacity estimates. Shading about the capacity estimates represent the 95% confidence bounds. Figure is from ISEMP/CHaMP (2015).

The comparison shows that although the curves are very similar, the carrying capacity estimates (dashed horizontal lines) differed, with the habitat capacity generated from the QRF model being larger than the population capacity generated from the population data. That is, the QRF model estimated a habitat capacity of about 164,000 spring Chinook parr, while the population model estimated a population capacity of about 145,000 parr. Including more recent parr data in the Beverton-Holt model indicates that the population capacity estimate is about 151,000 parr for the Chiwawa River watershed. The 90% RI for the Beverton-Holt model estimated a habitat capacity of about 182,000, which is 1.1 times greater than the estimate from the QRF model. Note that the 90% RI for the Ricker model estimated a habitat capacity of about 168,000, which is close to the QRF model estimate.

Comparing Results

We estimated capacities for both spring Chinook parr and smolts for the Chiwawa River watershed and the entire Wenatchee River basin using different analytical tools. In this section, we compare the results from the different approaches.

Parr Capacity

Depending on the population model used, population capacity estimates for the Chiwawa River watershed ranged from 113,801 to 150,902 parr (Table 8). Not surprisingly, the Beverton-Holt model generally predicts the highest capacity estimates, while the smooth hockey stick model predicts the lowest. As expected, the population capacity estimates for Chiwawa parr were less than the habitat capacity estimates for parr. Habitat capacity estimates were about 1.2 to 1.5 times greater than the population capacity estimates (Table 8). Importantly, the fish-habitat model (QRF model) calculated a habitat capacity estimate that was close to that estimated from calculating 90% RI for the population models. Extrapolating Chiwawa capacity estimates to the entire Wenatchee River basin resulted in population capacities of 425,395 to 564,079 parr and habitat capacity estimates of 613,040 to 679,645 parr (Table 8).

Table 8. Comparison of spring Chinook parr capacity estimates for the Chiwawa River watershed and the Wenatchee River basin. Population capacities were estimated directly from the stock-recruitment functions; habitat capacities were estimated by calculating 90% reference intervals (using quantile regression; QR) for the stock-recruitment models and using a fish-habitat model (Quantile Regression Forest Model; QRF). Capacities for the Wenatchee River basin were estimated by extrapolating Chiwawa capacities using intrinsic potential.

Capacity type	Model	Chiwawa parr capacity	Wenatchee parr capacity
Population capacity	Beverton-Holt	150,902	564,079
	Smooth Hockey Stick	113,801	425,395
	Ricker	116,650	436,043
Habitat capacity	QR Beverton-Holt	181,818	679,645
	QR Ricker	168,071	628,256
	QRF Model	164,000	613,040

The number of spawners needed to achieve parr capacity also varied depending on the population model used (Table 9). For the Chiwawa River watershed, maximum spawners needed to achieve population capacity for parr ranged from 1,089 to 1,163 adults. Extrapolating Chiwawa results to the entire Wenatchee River basin resulted in maximum spawner estimates of 4,070 to 4,347 adults. We were able to estimate habitat capacity only with the Ricker model (Table 9). Using quantile regression to calculate the 90% RI for the Ricker model resulted in a maximum spawner abundance of 973 adults, which is less than the number needed to achieve population capacity. This is because the 90% RI for the Ricker function estimates a higher intrinsic productivity, which shifts the "hump" of the curve to the left resulting in a higher capacity estimate but a lower maximum spawner estimate (see Figure 5).

Table 9. Comparison of the number of spawners needed to achieve parr capacities in the Chiwawa River watershed and the Wenatchee River basin. For the Chiwawa River watershed, maximum spawners were estimated directly from the stock-recruitment functions. Maximum spawners for the entire Wenatchee River basin were estimated as the product of the extrapolated parr numbers times the ratio of maximum spawners to parr capacity for Chiwawa spring Chinook. Because of the nature of the Beverton-Holt model, no maximum spawners can be calculated from that model.

Capacity type	Model	Spawners need to achieve parr capacity	
		Chiwawa	Wenatchee
Population capacity	Smooth Hockey Stick	1,089	4,070
	Ricker	1,163	4,347
Habitat capacity	QR Ricker	973	3,636

Smolt Capacity

As with parr estimates, population capacity estimates for smolts varied depending on the population model used. For Chiwawa spring Chinook smolts, population capacities ranged from 45,161 to 55,702 smolts, with the smooth hockey stick providing the lowest estimate and the Beverton-Holt model providing the highest (Table 10). The population capacity estimates were about 55 to 86% of the habitat capacity estimates. Extrapolating Chiwawa capacity estimates to the entire Wenatchee River basin resulted in population capacities of 168,816 to 208,218 smolts and habitat capacity estimates of 241,164 to 334,276 smolts (Table 10). These were greater than those estimated using smolt and spawner data for the entire Wenatchee River basin. Fitting population models to smolt and spawner data for the entire basin resulted in population capacities of 93,560 to 108,696 smolts and habitat capacities of 186,567 to 235,131 smolts (Table 10).

Table 10. Comparison of spring Chinook smolt capacity estimates for the Chiwawa River watershed and the Wenatchee River basin. Population capacities were estimated directly from the stock-recruitment functions; habitat capacities were estimated by calculating 90% reference intervals (using quantile regression; QR) for the stock-recruitment models. Capacities for the Wenatchee River basin were estimated by extrapolating Chiwawa capacities using intrinsic potential and by fitting population models to the smolt and spawner data for the entire basin.

Capacity type	Model	Chiwawa smolt capacity	Wenatchee smolt capacity	
			Chiwawa extrapolation	Wenatchee data
Population capacity	Beverton-Holt	55,702	208,218	108,696
	Smooth Hockey Stick	45,161	168,816	93,560
	Ricker	49,532	185,152	99,944
Habitat capacity	QR Beverton-Holt	64,516	241,164	186,567
	QR Ricker	89,425	334,276	235,131

The number of spawners needed to achieve smolt capacity varied depending on the population model used (Table 11). For the Chiwawa River watershed, maximum spawners needed to achieve

population capacity for smolts ranged from 777 to 901 adults. Note that the maximum number of adults needed to achieve population capacity for smolts is less than those needed to achieve population capacity for parr. Extrapolating Chiwawa results to the entire Wenatchee River basin resulted in maximum spawner estimates of 2,904 to 3,368 adults. These estimates are considerably higher than those estimated from fitting population models to Wenatchee River basin data. The latter estimated maximum spawners ranging from 1,389 to 2,381 adults. We were able to estimate habitat capacity only with the Ricker model (Table 11). Using quantile regression to calculate the 90% RI for the Ricker model resulted in a maximum spawner abundance of 824 adults for the Chiwawa River watershed and 3,129 adults for the entire Wenatchee River basin. Extrapolating Chiwawa results to the entire Wenatchee River basin resulted in a maximum spawner estimate of 3,080, which is close to the estimate generated by fitting the model to Wenatchee River basin data.

Table 11. Comparison of the number of spawners needed to achieve smolt capacities in the Chiwawa River watershed and the Wenatchee River basin. Maximum spawners were estimated directly from the stock-recruitment functions. Maximum spawners for the entire Wenatchee River basin were also estimated as the product of the extrapolated smolt numbers times the ratio of maximum spawners to smolt capacity for Chiwawa spring Chinook. Because of the nature of the Beverton-Holt model, no maximum spawners can be calculated from that model.

Capacity type	Model	Spawners need to achieve smolt capacity		
		Chiwawa	Wenatchee	
			Chiwawa extrapolation	Wenatchee data
Population capacity	Smooth Hockey Stick	777	2,904	1,389
	Ricker	901	3,368	2,381
Habitat capacity	QR Ricker	824	3,080	3,129

As an additional exercise, we calculated smolt capacities and maximum spawners generated from fitting population models to smolt and spawner data in the Chiwawa River, Nason Creek, and White River watersheds, and compared the sum of those estimates to the Wenatchee River basin estimates. Only the Ricker model could be fit to the White River and Nason Creek data (see Hillman et al. 2017). Estimated population capacities from the Ricker model were 49,532 smolts in the Chiwawa, 4,412 smolts in Nason Creek, and 4,659 smolts in the White River, resulting in a cumulative population capacity of 58,603 smolts (1,550 spawners are needed to achieve this cumulative smolt capacity). The cumulative population capacity estimate is nearly 60% of the total population capacity calculated from fitting the Ricker model to the entire Wenatchee River basin data. If these estimates are correct, this means that about 40% of the current Wenatchee River basin smolt capacity is outside the Chiwawa River, Nason Creek, and White River watersheds. Hillman et al. (2017) report that over the period 1989 to 2016, on average, 76% of spring Chinook spawning occurs in the three watersheds. Thus, a large percentage of smolt capacity is generated outside the major spawning areas. We believe this highlights the importance of the mainstem Wenatchee River as a rearing area for juvenile spring Chinook.

Recommendations

Based on the simple analyses conducted in this report, we offer the following recommendations:

1. Where sufficient stock and recruitment data are available, and the data have sufficient contrast, then use population (stock-recruitment) modeling as the primary method to calculate population capacity and the number of spawners needed to produce the maximum number of recruits under current or average habitat conditions. Select the best fitting stock-recruitment model based upon AIC_c, unless other factors suggest otherwise, such as evidence for a biological mechanism. A biological mechanism supporting a Ricker function, for example, would be that there is a stock-dependent effect on the mortality of eggs and juveniles (i.e., mortality is proportional to the initial cohort size). When AIC_c values are not appreciably different, then select the model that is most useful (e.g., Ricker and smooth hockey stick models are easier to work with than the Beverton-Holt model).
2. Adult-to-adult data are the most relevant because they account for all life stages and delayed effects in freshwater (e.g., small size at migration), but they are also the most variable (i.e., low R^2). Therefore, adult-to-juvenile data (e.g., parr, yearling smolts, total migrants) are likely the most useful for determining freshwater population capacity. Where data are available, pre-spawn adult to spawning adult survival can also be assessed using population models to evaluate density dependence and pre-spawn adult capacity.
3. The population models used to estimate population capacity should also be used in reference streams so one can make comparisons of carrying capacities and density-corrected productivities. Unless there are good reasons for selecting a different juvenile life-stage, the default should be to use yearling smolts because they represent the capacity of the tributaries to produce yearlings and it is also a clear identification and quantification of a migrant life-stage.
4. In the absence of fish-habitat models, quantile regression can be used to estimate habitat capacity by calculating reference intervals for the population models. The percentage of the reference interval should be set using the error in the estimation of the recruits and the level of desire to exclude anomalous data. For example, if the 95% confidence interval is approximately 10% of the recruitment estimate, then the reference interval should be set at 90% (e.g., RI = 100% - C.I.%).
5. Where sufficiency conditions in (1) are not met, use habitat-based expansion of density at capacity for the most ecologically similar population. For example, use Twisp capacity estimates for habitat-based expansions in the Methow. The habitat expansion metric should be "total stream area weighted by intrinsic potential and temperature limited," unless there are good reasons for a different expansion. The primary idea is to exclude areas that are known to not produce fish because of passage, temperature, or other limitations.
6. Capacity estimates should be described within the context of the information that was used to derive estimates. For example, spawner distribution of hatchery-origin fish could influence estimates of capacity if they are within poor habitat. However, the capacity estimates do reflect the historic and current hatchery practices. It is unknown how the capacity estimates would change if a different hatchery program that produced different spawning distributions was to be implemented. However, if those data do become available, then capacity estimates can be revised. Similarly, significant enhancements (e.g.,

improved passage) or degradations (e.g., fire) in habitat can also change capacity and can be incorporated into future estimates of capacity.

7. Regardless of the method used to estimate capacity, always describe the limitations of the data and assumptions of the models. Note where assumptions are violated and how these violations could affect the results of the analysis.

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APPENDIX 2: HATCHERY REPLACEMENT RATES

Based on ideas developed by the HETT, in February 2016, the HCP Hatchery Committees and PRCC Hatchery Subcommittee agreed to the following rules and HRR targets:

1. Use the estimated 40% HRR Target during 5-year statistical evaluation periods.
2. Use varying degrees of action depending on the numbers of years that annual HRR deviates from Target.
    a. Green Light (below Target for ≤ 2 years).
    b. Red Light (below Target for > 2 years).
3. Each program will have its own HRR target with the following exceptions.
    a. Nason Creek spring Chinook will use the Chiwawa Target (there are currently no data to calculate a target for Nason Creek spring Chinook).
    b. Methow and Chewuch spring Chinook will use the greater of their two Targets (they are MetComp stock and evaluated similarly).

Table 1. Release numbers and 5-year hatchery replacement rates (HRR) targets for Upper Columbia River Hatchery Programs.

Species	Owner	Program (Hatchery)	Basin (Purpose)	Smolts released[1]	5-Year HRR[2]
Steelhead	CPUD	Eastbank (Chiwawa)	Wenatchee (Conservation)	123,650	6.9
Steelhead	CPUD	Eastbank (Chiwawa)	Wenatchee (Safety Net)	123,650	6.9
Steelhead	DPUD	Wells (Wells)	Columbia (Safety Net)	160,000	26.5
Steelhead	DPUD	Wells (Wells)	Methow (Safety Net)	100,000	26.5
Steelhead	DPUD	Wells (Wells)	Twisp (Conservation)	48,000	26.5
Steelhead	GPUD	Wells (Omak)	Okanogan (Conservation)	100,000	7.3 [3]
SUM Chinook	CPUD	Eastbank (Chelan Falls)	Chelan (Conservation)	176,000	5.7
SUM Chinook	CPUD	Eastbank (Chelan Falls)	Chelan (Harvest)	400,000	5.7
SUM Chinook	CPUD, GPUD	Eastbank (Dryden)	Wenatchee (Conservation)	500,000	5.7
SUM Chinook	DPUD	Wells (Wells)	Columbia (Harvest)	320,000	3.0
SUM Chinook	GPUD	Eastbank (Carlton)	Methow (Conservation)	200,000	3.0
SUM Chinook	CCT	Chief Joseph	Okanogan (Harvest)	1,100,000	8.6
SPR Chinook	CPUD	Eastbank (Chiwawa)	Wenatchee (Conservation)	144,026	6.7

SPR Chinook	CPUD, DPUD, GPUD	Wells (Methow)	Methow (Conservation)	193,765	3.8
SPR Chinook	DPUD, GPUD	Wells (Twisp)	Methow (Conservation)	30,000	2.7
SPR Chinook	GPUD	Eastbank (Nason)	Wenatchee (Conservation)	223,670	6.7

[1] Release goal established by HCPs and adjusted by HC.
[2] Derived from Annual Reports.
[3] Harvest not included.

APPENDIX 3: PNI and pHOS Targets and Sliding Scales

Select CPUD, DPUD, and GPUD funded hatchery mitigation programs have PNI management targets, while others do not. Table 1 summarizes management strategies by species and population. Detailed information can be found in the sections that follow. Descriptions provided in the following sections are taken directly from HGMPs and/or issued and draft permits.

Table 1. Summary of management strategies by species and population.

Species	Population	Management Strategy	Comments
Spring Chinook	Wenatchee	Sliding Scale of PNI management	Details can be found in Section 2.0
	Methow	Two—population sliding scale PNI management	Details can be found in Section 3.0
	Okanogan	None Currently	Details can be found in Section 4.0
Steelhead	Wenatchee	Two-zone management.	Details can be found in 5.0
	Methow	In-development	Details forthcoming; Section 6.0
	Okanogan	None Currently	Details can be found in Section 7.0
Summer Chinook	Wenatchee	None Currently	Details can be found in Section 9.0
	Methow	None Currently	Details can be found in Section 10.0
	Okanogan	0.67; pHOS 0.30	Details can be found in Section 11.0
	Upper Columbia River	None Currently	Details can be found in Section 12.0
Fall Chinook	Hanford Reach	0.67	Details can be found in Section 13.0

2.0 Wenatchee Spring Chinook

Wenatchee spring Chinook will be managed according to the sliding scale identified in the Wenatchee Spring Chinook Management Plan (2010) and Permit Numbers 18118 and 18121. The sliding scale is based upon the estimated number of natural origin spring Chinook over Tumwater Dam. As more information becomes available the sliding scale may be adjusted as a result of gaining a better understanding of the pre-spawn mortality rate and carrying capacity.

Table 2. Sliding scale of PNI goals based on natural origin spring Chinook run size expected to the Wenatchee River basin. Percentiles are based on adult returns observed between 1999 and 2008.

Percentile	NOR Run Size				PNI
	Chiwawa	Nason Creek	White	Wenatchee River (above TWD)	
>75th	>372	>350	>87	>910	≥ 0.80
50% - 75%	278-372	259-349	68-86	631-909	≥ 0.67
25% - 50%	209-277	176-258	41-67	525-630	≥ 0.50
10%-25%	176-208	80-175	20-40	400-524	≥ 0.40

<10th	<175	<80	<20	<400	Any PNI

3.0 Methow/ Chewuch Spring Chinook

The following sliding scale (Table 3) is presented in the April 14, 2016 draft Methow Hatchery Spring Chinook Section 10-Draft. It is anticipated that no further changes will be made to the sliding scale prior to issuance of the final permits.

Table 3. PUD PNI sliding scale calculations for a range of natural run sizes.

Natural Origin Returns	PUD pHOS	WNFH pHOS	PUD pNOB	2-Pop PNI	PUD PNI (equation)
<300	Ensure minimum of 500 total spawners				
300	0.40	0.2	0.75	0.67	0.67
500	0.40	0.2	0.80	0.68	0.76
900	0.30	0.15	1.00	0.78	0.80
1500	0.25	0.1	1.00	0.8	0.80
2000	0.25	0.1	1.00	0.8	0.80
2500	0.25	0.1	1.00	0.8	0.80

4.0 Okanogan Spring Chinook

The Okanogan spring Chinook program is a re-introduction effort implemented as a non-essential experimental population under ESA Section 10j to re-introduce spring Chinook into the Okanogan River. As a non-essential experimental population targeting re-introduction and establishment of a local population of spring Chinook, the Okanogan spring Chinook program will not conduct adult management actions to reduce the proportion of 10j hatchery fish on the spawning grounds or conduct broodstocking efforts in the Okanogan for a 10-year period (2014 – 2023), as such, no PNI or pHOS objectives have been identified for this program in this 10-year period.

CJH Program segregated production released into the mainstem Columbia River are non-listed Leavenworth stock released reared/acclimated/released at CJH. Although no PNI or pHOS targets are identified for the Okanogan 10j population, minimizing strays from the CJH segregated spring Chinook program is a program objective, as such, returning segregated program fish will be subject to directed harvest and aggressive adult surplusing at CJH to minimize straying to the Okanogan River Basin as well as other extant upper Columbia River spring Chinook populations. Stray targets for the segregated program are 5% or less stray rate (i.e. spawning contribution to other upper Columbia River spring Chinook populations).

5.0 Wenatchee Steelhead

Interim escapement goal for Wenatchee River steelhead will be 1,500 spawners with an additional goal of attaining an average PNI of 0.67 for the Wenatchee River basin population as a whole. To achieve the stated goal, the Wenatchee steelhead program will use a two-zone management approach wherein the upper basin (above TWD) will be managed for recovery using an integrated recovery program, a separate spawning escapement goal, and a PNI standard to achieve the overall basin goal of an average PNI over time of 0.67 (Table 4). Areas below TWD will be managed to minimize hatchery supplementation with a pHOS goal of < 0.10.

Steelhead returning upstream of TWD will be managed as an integrated recovery program with a pNOB goal of 1.0. The above TWD escapement goal will be 1,094 spawners. Working within this framework, pNOB will be maximized above TWD while pHOS will be minimized.

Table 4. Wenatchee steelhead two-zone management and PNI targets.

Location	Run Escapement Goal	pNOB Conservation Program	pNOB Safety Net Program	pHOS	PNI
Above TWD	1,094	1.0	0.0	Varies	Varies
Below TWD	406	N/A	N/A	< 0.10	< 0.67
Basin Total	1,500	N/A	N/A	Minimal	Average = 0.67

6.0 Methow Steelhead

Methow steelhead PNI targets are currently in development.

7.0 Okanogan Steelhead

Current program has no PNI goal. CTCR submitted an Okanogan steelhead HGMP to NOAA Fisheries on February 4, 2014. Within the HGMP provisions were included to allow a greater collection of natural-origin broodstock and multiple adult management strategies to address over-escapement of hatchery-origin steelhead to the spawning grounds. The HGMP also identified a near-term (1-4 years) and a long-term PNI objectives of 0.50 and > 0.67, respectively. Once NOAA has completed the consultation and issued a new permit, providing the opportunity to increase the proportion of natural-origin fish in the broodstock and additional adult management strategies, the program will adopt the PNI objectives and this Appendix can be amended accordingly.

8.0 Wells Columbia Mainstem Safety-net Steelhead

The Safety-Net Mainstem Columbia component released below Wells Dam will be managed primarily at the Wells Hatchery volunteer channel. The objective of the adult management of the Safety-Net Mainstem Columbia component is to prevent runs of this component from moving into natural spawning areas. This will be accomplished through in-river harvest and removal of volunteers at the Wells Hatchery outfall. There are no PNI goals for this component.

9.0 Wenatchee Summer Chinook

No PNI goals are established.

10.0 Methow Summer Chinook

No PNI goals are established.

11.0 Okanogan Summer Chinook

Okanogan summer/fall Chinook will be managed to achieve a 5-year rolling average PNI of 0.67 and pHOS of 0.30. Strategies to achieve that PNI target include up to 100% pNOB, aggressive removal of hatchery-origin Chinook in selective fisheries, at the Okanogan weir, and during surplusing at CJH ladder. Reduction in the number of juveniles released in the Okanogan River Basin (integrated program) is also a management option, should adult management actions be unable to control the proportion of hatchery fish on the spawning grounds to achieve that PNI target.

CJH segregated summer/fall Chinook program rears/acclimates/releases smolts into the mainstem Columbia River at CJH. Broodstock are 100% hatchery-origin, as such no PNI target for this production component. Stray rate (i.e. contribution to upper Columbia summer/fall Chinook populations) is 5% or less. Adult management on returning adults from the segregated program include fisheries, removal at the Okanogan weir, and removal at the CJH ladder.

12.0 Upper Columbia Summer Chinook (Chelan Falls and Wells)

No PNI goals are established. Chelan Falls and Wells FH summer Chinook programs are segregated harvest programs designed to provide opportunity for harvest. Adult returns are not intended to spawn naturally; therefore, there is no escapement goal for natural spawning areas. Adult returns will be managed to meet program objectives. Chelan Falls and Wells Hatchery summer Chinook are available for harvest in the ocean and Columbia River commercial, tribal, and recreational fisheries.

13.0 Priest Rapids Fall Chinook

The Hanford Reach fall Chinook population is intentionally supplemented by Grant PUD at the Priest Rapids Hatchery and the ACOE at the Priest Rapids and Ringold Springs hatcheries. Managers desire to achieve a population level PNI that includes all hatchery programs of $\geq$0.67. Grant PUD and the HSC do not have control over operation or expansion of the ACOE program and therefore will strive to operate the Priest Rapids Hatchery fall Chinook program in a way that does its fair share of achieving a population level PNI of 0.67.

APPENDIX 4: SPATIAL DISTRIBUTION OF SPAWNERS OR REDDS

Strategies for conservation programs typically intend that hatchery and naturally produced fish spawn together and in similar locations. However, in some cases, strategies may differ from this paradigm. In Table 1, conservation programs that have a spatial distribution management plan that deviates from similar to the natural spawning spatial distributions are presented. Otherwise, conservation programs are intended to have a spawning distribution similar to the natural origin spawning spatial distributions, as described by M&E Objective 5.3.

Table 1. Management targets for the spatial distribution of hatchery-origin redds for conservation programs that deviate from Objective 5.3.

Program	Target	Rational	Source
Carlton Summer Chinook	The observed spawning distribution of hatchery origin Methow summer Chinook from 2005-2010 represents the base-line spawner distribution for evaluating the performance of the hatchery program (i.e., M&E plan check-ins). It is acknowledged that this distribution is lower in the River than the spawning distribution of natural origin summer Chinook salmon.	Based upon an assessment of summer Chinook and ESA-listed spring Chinook abundance and spawner distribution, it was determined that an increase in summer Chinook spawning abundance in the upper most range of natural origin summer Chinook distribution or potentially above the current range may pose an unknown and potentially adverse impact to ESA listed spring Chinook. Due to the concern for spring Chinook, the HSC has endorsed an acclimation site in the Methow Basin that is lower in the basin than may be required to attain exact replication of natural and hatchery origin summer Chinook spawner distribution.	SOA 2011-02 Priest Rapids Coordinating Committee Hatchery Subcommittee Statement of Agreement on Monitoring & Evaluation (M&E) Objective for Spawning Distribution of Hatchery-Origin Summer Chinook
Dryden Summer Chinook	The observed spawning distribution of hatchery origin Wenatchee summer Chinook from 2008-2013 (previous 5 years to the current M&E check-in cycle) represents the base-line spawner distribution for evaluating the performance of the	The primary site endorsed by the HSC for Grant PUD overwinter acclimation of summer Chinook is the Dryden Pond, and is the current acclimation and release site for the existing summer Chinook supplementation program	Adapted from SOA 2011-02 Priest Rapids Coordinating Committee Hatchery Subcommittee Statement of Agreement on Monitoring & Evaluation (M&E) Objective for Spawning Distribution of Hatchery-Origin Summer Chinook

	hatchery program (i.e., M&E plan check-ins).	funded and owned by Chelan PUD. Because current data indicates that spawning distribution of hatchery summer Chinook from the existing program is lower in the Wenatchee River than natural origin spawners, expectations are that acclimation of Grant PUD's summer Chinook at Dryden Pond would continue to return hatchery origin summer Chinook that result in different spawning distributions for hatchery and natural summer Chinook.	

APPENDIX 5: WITHIN HATCHERY REARING TARGETS

Rearing Targets for Upper Columbia River Hatchery Programs. K-factor or fork length targets will be determined based on data from the pending "Five-Year Report."

Table 1. Numbers, fish per pound (fpp), coefficient of variation (CV), and condition factor (K) targets at release of Upper Columbia River Hatchery Programs.

Hatchery	Species	Life Stage	Basin	Release number	FPP	CV	K-factor
Methow	Spring Chinook	Yearling	Methow	193,765[1]	15	<10	TBD
Methow	Spring Chinook	Yearling	Twisp	30,000	15	<10	TBD
Chief Joseph	Spring Chinook	Yearling	Columbia	700,000	15	<10	TBD
Chief Joseph	Spring Chinook	Yearling	Okanogan	200,000	15	<10	TBD
Chiwawa	Spring Chinook	Yearling	Wenatchee	144,026	18	<10	TBD
Nason	Spring Chinook	Yearling	Wenatchee	223,670[3]	18-24	<10	TBD
Winthrop	Spring Chinook	Yearling	Methow	400,000	17	<10	TBD
Leavenworth	Spring Chinook	Yearling	Wenatchee	1.2 M	17	<10	TBD
Wells	Steelhead	Yearling	Columbia	160,000	6	<10	TBD
Wells	Steelhead	Yearling	Methow	100,000	6	<10	TBD
Wells	Steelhead	Yearling	Twisp	48,000	6	<10	TBD
Wells	Steelhead	Yearling	Omak	~100,000[4]	5-8	<10	TBD
Wells	Steelhead	Yearling	Okanogan	~100,000[4]	5-8	<10	TBD
Winthrop	Steelhead	Two year	Methow	200,000	4-6	<10	TBD
Chiwawa	Steelhead	Yearling	Wenatchee	247,300[5]	6	9.0	TBD
Wells	Summer Chinook	Subyearling	Columbia	480,000	50[6]	<7	TBD
Wells	Summer Chinook	Yearling	Columbia	320,000	10	<7	TBD
Chief Joseph	Summer Chinook	Subyearling	Columbia	400,000	50	<7	TBD
Chief Joseph	Summer Chinook	Subyearling	Okanogan	300,000	50	<7	TBD
Chelan Falls	Summer Chinook	Yearling	Chelan	576,000	13	9.0	TBD
Entiat	Summer Chinook	Yearling	Entiat	400,000	17	<10	TBD
Carlton	Summer Chinook	Yearling	Methow	200,000	13-17	<12	TBD
Chief Joseph	Summer Chinook	Yearling	Columbia	500,000	10	<7	TBD
Chief Joseph	Summer Chinook	Yearling	Okanogan	799,998[7]	10	<7	TBD
Dryden	Summer Chinook	Yearling	Wenatchee	500,001	18	9.0	TBD
Priest	Fall Chinook	Subyearling	Columbia	7.3 M[8]	50	<10	TBD
Ringold	Fall Chinook	Subyearling	Columbia	3.5 M	50	<10	TBD

[1] The total release includes the release of 108,249 into the Methow River at the Methow Fish Hatchery, 25,000 into the Methow River at the Goat Wall site, and 60,516 into the Chewuch River at the Chewuch Acclimation Facility.

[2] These fish come from Winthrop National Fish Hatchery (MetComp) eyed eggs.

[3] The total release includes 125,000 conservation fish and 98,670 safety net fish.

[4] The combined Okanogan and Omak steelhead release number is 100,000.

[5] The total release includes 66,771 fish into Nason Creek, 53,170 into the Chiwawa River, 102,359 into the Wenatchee River, and 25,000 into Blackbird Pond.

[6] The Wells subyearling Chinook are not reared to achieve a specific size target. The fish are released on a date to optimize survival and are grown to the largest size possible before release.

[7] The total release is divided equally among the Omak, Riverside, and Similkameen Acclimation Ponds.

[8] The total release consists of 5.6 m fall Chinook for the Grant PUD program and 1.7 M fall Chinook for the Army Corps of Engineers program.

APPENDIX 6: IDENTIFYING AND ANALYZING REFERENCE POPULATIONS

An important goal of supplementation is to increase spawning abundance and natural-origin recruitment of the supplemented population, and not reduce the productivity of the supplemented population. Indeed, a successful supplementation program must increase spawning abundance and natural-origin recruitment to levels above those that would have occurred without supplementation. There are several methods that can be used to test the effects of supplementation programs on these population metrics. One important method is to compare the performance of population metrics (e.g., spawning abundance, natural-origin recruitment, and productivity) in the supplemented population to those in un-supplemented (reference) populations. By comparing supplemented populations to reference populations, one can determine if the supplementation programs benefit, harm, or have no effect on the supplemented populations. These comparisons, however, are only valid if the performance of the reference populations is similar to the performance of the supplemented population prior to the period of supplementation. If the performance of the two populations differs significantly before any supplementation occurs, then any results from comparing the two populations after supplementation will be suspect. It is therefore important to select reference populations that are as similar as possible to the supplemented populations.

One of the goals of the Conceptual Approach to Monitoring and Evaluating the Chelan County PUD Hatchery Programs (Murdoch and Peven 2005) is to use reference populations to analyze the potential effects of hatchery supplementation programs on natural-origin salmon and steelhead spawner abundance and productivity[15]. Murdoch and Peven (2005) identified specific objectives to evaluate the performance of the program. For example, Objective 1 determines if the supplementation programs have increased the number of naturally spawning and naturally produced adults of the target population (supplemented population) relative to a reference population. Objective 7 determines if the proportion of hatchery fish on the spawning grounds affects the freshwater productivity (e.g., number of juveniles per redd) of supplemented streams when compared to reference streams. The relevant questions tested under each objective are as follows:

Objective 1:

- Is the annual change in the number of natural-origin recruits produced from the supplemented populations greater than or equal to the annual change in natural-origin recruits in an un-supplemented population?
- Is the change in natural replacement rates within the supplemented population greater than or equal to the change in natural replacement rates in an un-supplemented population?

Objective 7:

[15] Productivity is defined as adult recruits per spawner, where recruits are the number of adults produced from a given brood year (i.e., spawners plus adults harvested).

- Is the change in numbers of juveniles (smolts, parr, or emigrants) per redd in the supplemented population greater than or equal to that in an un-supplemented population?[16]

In this paper, we describe methods used to identify suitable reference streams and statistical techniques that can be used to compare reference populations with supplemented populations. Although we apply the methods described in this paper to Chiwawa spring Chinook salmon (hereafter referred to as Chinook), the methods should also apply to steelhead and other supplemented salmon stocks in the Upper Columbia Basin.

Identification of Reference Populations

Reference populations are an important component of an effectiveness monitoring design because they provide the standard by which treatment conditions are compared (ISRP and ISAB 2005; Murdoch and Peven 2005; Galbreath et al. 2008). Selecting appropriate reference areas and maintaining them over long periods of time is needed to establish the effectiveness of supplementation programs.

We developed a three-step process for identifying suitable reference populations (Figure 1). Each step serves as a filter. That is, potential reference populations are evaluated based on specific criteria under each step. Populations that pass through each step are considered suitable reference populations for a specific supplemented population.

[16] In this paper, we only address adult recruits, not juvenile recruits. This is because we were unable to find suitable reference populations for analysis of juveniles. However, the methods described in this paper would also apply to juveniles.

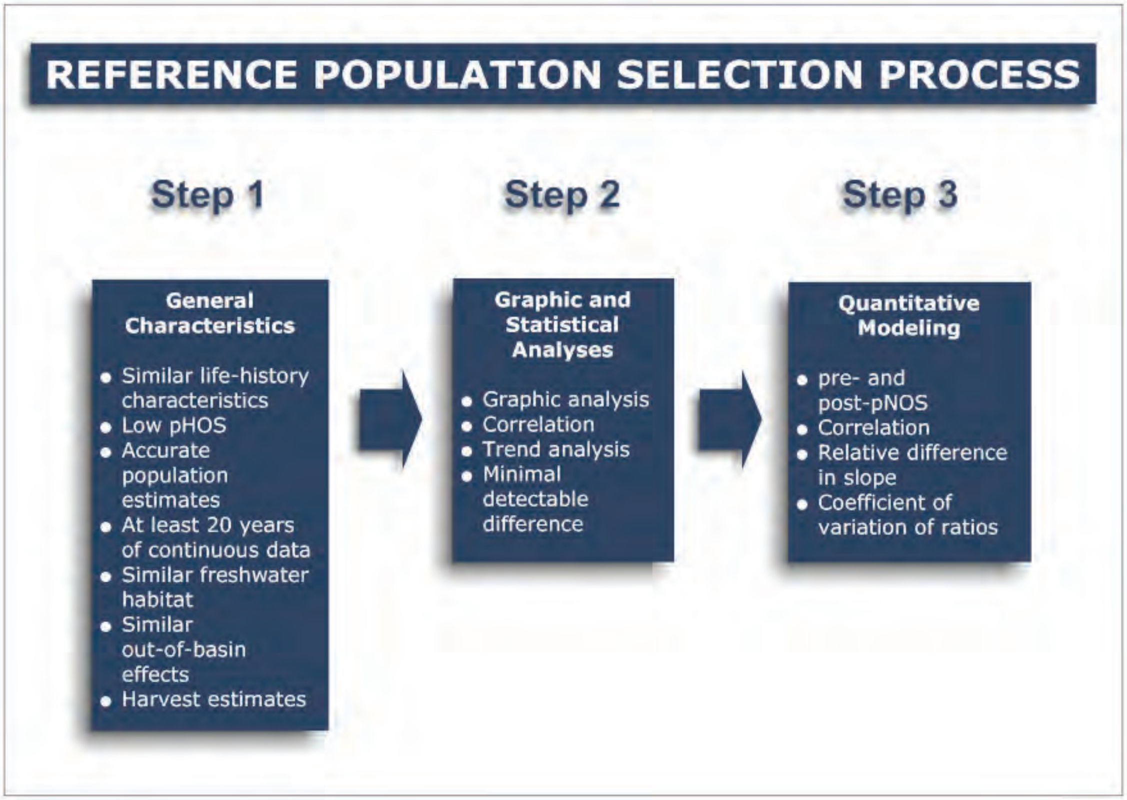

Figure 1. Criteria evaluated during each step in the process of identifying suitable reference populations.

Step 1: General Characteristics

Under step 1, potential reference populations are evaluated based on several general criteria. When compared to the supplemented population, potential reference populations should have:

- Similar life-history characteristics (e.g., run timing, migration characteristics, etc.).
- No or few hatchery fish in the reference area (pHOS < 10%).
- Accurate abundance estimates.
- Long time series of natural-origin abundance and productivity estimates (at least 20 years of continuous data).
- Similar trends in freshwater habitat.
- Similar out-of-basin effects (i.e., similar migration and ocean survivals).
- Harvest estimates for adjusting escapement estimates.

We used these criteria to begin the process of selecting suitable reference populations for the Chiwawa spring Chinook program. We began by identifying stream-type Chinook populations within the Columbia Basin. Galbreath et al. (2008; their Table 1) identified stream-type Chinook populations within the Columbia River Basin that may serve as suitable reference populations for hatchery programs. Supplementing their work with data from the NOAA Fisheries Salmon Population Summary Database, we identified 18 candidate stream-type Chinook populations that may serve as reference populations for the Chiwawa supplementation program (Table 1).

Table 1. Populations of stream-type Chinook salmon and their comparison to Chiwawa spring Chinook.

Population	Similar life-history	No or few hatchery fish	Accurate abundance estimates	Long time series (at least 20 years)	Similar freshwater habitat impairments	Similar out-of-basin effects	Comments
Deschutes River	Yes	Yes	Yes	Yes	No	No	
John Day mainstem	Yes	Yes	Yes	Yes	No	No	
Middle Fk John Day	Yes	Yes	Yes	Yes	No	No	
North Fk John Day	Yes	Yes	Yes	Yes	No	No	
Granite Creek	Yes	Yes	Yes	Yes	No	No	
Wenaha River	Yes	No	Yes	Yes	Yes	No	Hatchery strays (>10%)
Minam River	Yes	No	Yes	Yes	Yes	No	Hatchery strays (>10%)
Slate Creek	Yes	Yes	Yes	No	No	No	
Secesh River	Yes	Yes	Yes	Yes	Yes	No	
Middle Fk Salmon River	Yes	Yes	Yes	No	No	No	Fair productivity est.
Big Creek	Yes	Yes	Yes	Yes	No	No	
Camas Creek	Yes	Yes	Yes	Yes	No	No	Fair productivity est.
Loon Creek	Yes	Yes	Yes	Yes	No	No	Fair productivity est.
Sulphur Creek	Yes	Yes	Yes	Yes	No	No	
Bear Valley Creek	Yes	Yes	Yes	Yes	No	No	
Marsh Creek	Yes	Yes	Yes	Yes	Yes	No	
North Fk Salmon River	Yes	Yes	No	No	Yes	No	
Lemhi River	Yes	Yes	Yes	Yes	No	No	
East Fk Salmon River	Yes	No	Yes	Yes	No	No	Hatchery strays (>10%)
Valley Creek	Yes	No	Yes	Yes	No	No	Hatchery strays (>10%)
Chamberlain Creek	Yes	Yes	Yes	No	Yes	No	
Naches River	Yes	Yes	Yes	Yes	Yes	No	
Little Wenatchee River	Yes	No	Yes	Yes	Yes	Yes	Hatchery strays (>10%)
Entiat River	Yes	No	Yes	Yes	No	No	Hatchery release ending

We then assessed the accuracy and length of the series of abundance estimates. We assumed that abundance estimates generated from expanded redd counts or adjusted weir counts would compare well with estimates in the Chiwawa Basin, which were based on expanded redd counts. In addition, we looked for populations that had an abundance data series that extended from at least 1981 to present. Based on this analysis, we identified 18 populations with abundance estimates that could be compared to those from the Chiwawa Basin (Table 1).

Next, we determined if the potential reference populations came from watersheds with habitat conditions similar to those in the Chiwawa Basin. For this exercise, we searched recovery plans and draft recovery plans to identify tributary factors that limit Chinook abundance, productivity, and survival within the reference populations. We compared these factors with those limiting

Chinook salmon in the Chiwawa Basin. Based on this analysis, we identified eight populations with habitat impairments similar to those in the Chiwawa Basin (Table 1).

Finally, we examined the potential reference populations to see if they experienced out-of-basin effects similar to spring Chinook from the Chiwawa Basin. In this case, we compared the number of mainstem dams that each potential reference population passes during migration. Six of the potential reference populations pass less than six mainstem dams; the other populations pass eight mainstem dams (Table 1). Only the Little Wenatchee population passes seven dams, similar to the Chiwawa population.

In sum, there were no reference populations that matched the Chiwawa spring Chinook population on all the criteria identified above. Differential out-of-basin effects and freshwater habitat conditions prevented most reference populations from matching with Chiwawa spring Chinook. However, some of the potential reference populations were similar to the Chiwawa population on several criteria and warranted further investigation. We selected the following populations for further investigation: Sesech River, Marsh Creek, Naches River, Little Wenatchee, and Entiat River.

We included the Little Wenatchee because it is within the Wenatchee River basin and experiences similar out-of-basin effects and has the same climatic and environmental conditions as the Chiwawa. A confounding effect with the Little Wenatchee is that Chiwawa hatchery fish have strayed into the Little Wenatchee. However, straying of Chiwawa hatchery fish should decrease with the change in source water to the Chiwawa acclimation ponds in 2006. We also included the Entiat River because it is an adjacent basin to the Chiwawa and experiences similar climatic and environmental conditions. The spring Chinook hatchery program that has operated in the Entiat since 1975 has been discontinued. Therefore, this population offers a unique opportunity to compare the Chiwawa population to a population in which the hatchery program has been discontinued.

Step 2: Graphic and Statistical Analysis

Graphic Analysis

Although we were unable to find potential reference populations that matched with the Chiwawa population on all criteria considered under Step 1, spawner abundance, natural-origin recruits (NORs), and productivity of some of the potential reference populations may nevertheless track closely with the Chiwawa population. If the time series of abundance, NORs, and productivity of a potential reference population tracks closely with the abundance, NORs, and productivity of the Chiwawa population, the reference population may provide a reasonable reference condition for testing the effects of supplementation on the Chiwawa population.

Under Step 2, we used graphing techniques to examine the relationship of abundance, NORs, and productivity between the Chiwawa population and the five reference populations (Sesech River, Marsh Creek, Naches River, Little Wenatchee, and Entiat River). We compiled spawner abundance, NORs, and productivity data from local biologists and the NOAA Fisheries Salmon Population Summary Database. We then compared time series plots of spawner abundance, NORs, and productivity data of potential reference populations with the Chiwawa population (Figures 2, 3, and 4; plots on the left side of figures). The time series only included the period 1981 to 1992, which represented the period before supplementation of the Chiwawa population (pre-treatment period). We also plotted the relationship between the abundance, NORs, and productivity of each

potential reference population to the Chiwawa population (Figures 2, 3, and 4; plots on right side of figures). These plots show whether the reference populations closely tracked the Chiwawa population. As a point of reference, data points that fall along the dashed line would represent a perfect relationship between the two populations (i.e., both populations have identical abundance, NORs, and productivity estimates). While a perfect relationship between two independent populations is unrealistic, a strong linear relationship between the two populations indicates populations with similar trends.

Based on analysis of spawner abundance, the Naches River time series tracked more closely with the abundance of Chiwawa spring Chinook than did the other potential reference populations. The poor relationship with the other potential reference streams was largely because of the relatively high abundance of Chiwawa spring Chinook during the mid-1980s. As with spawner abundance, analyses of NORs indicated a close relationship between the Naches and Chiwawa populations. The other potential reference populations tracked poorly with the Chiwawa. The analyses of productivity indicated close relationships between potential reference populations and the Chiwawa population. The Naches, Sesech, and Little Wenatchee populations tracked the closest with the Chiwawa population.

When analyzing the potential effects of a supplementation program on fish performance, it is common to transform the data to meet various assumptions of statistical analysis. The most common transformation used to adjust abundance, NORs, and productivity data is the natural logarithm (LN or $\log_e$). We therefore transformed the spawner abundance, NORs, and productivity data using LN and re-plotted the relationships between the potential reference populations and the Chiwawa population (Figures 5, 6, and 7). We added 1 to each observation before taking its logarithm to avoid taking the logarithm of 0, which is undefined (note that the LN of 1 is 0).

By transforming spawner abundance, NORs, and productivity data, most of the potential reference populations tracked more closely with the Chiwawa population. The Naches, Entiat, and Little Wenatchee abundance data tracked the closest with the Chiwawa abundance data (Figure 5). For NORs, Marsh Creek and the Little Wenatchee populations tracked the closest with the Chiwawa (Figure 6). For productivity, the Naches, Sesech, and Little Wenatchee tracked the closest with the Chiwawa (Figure 7).

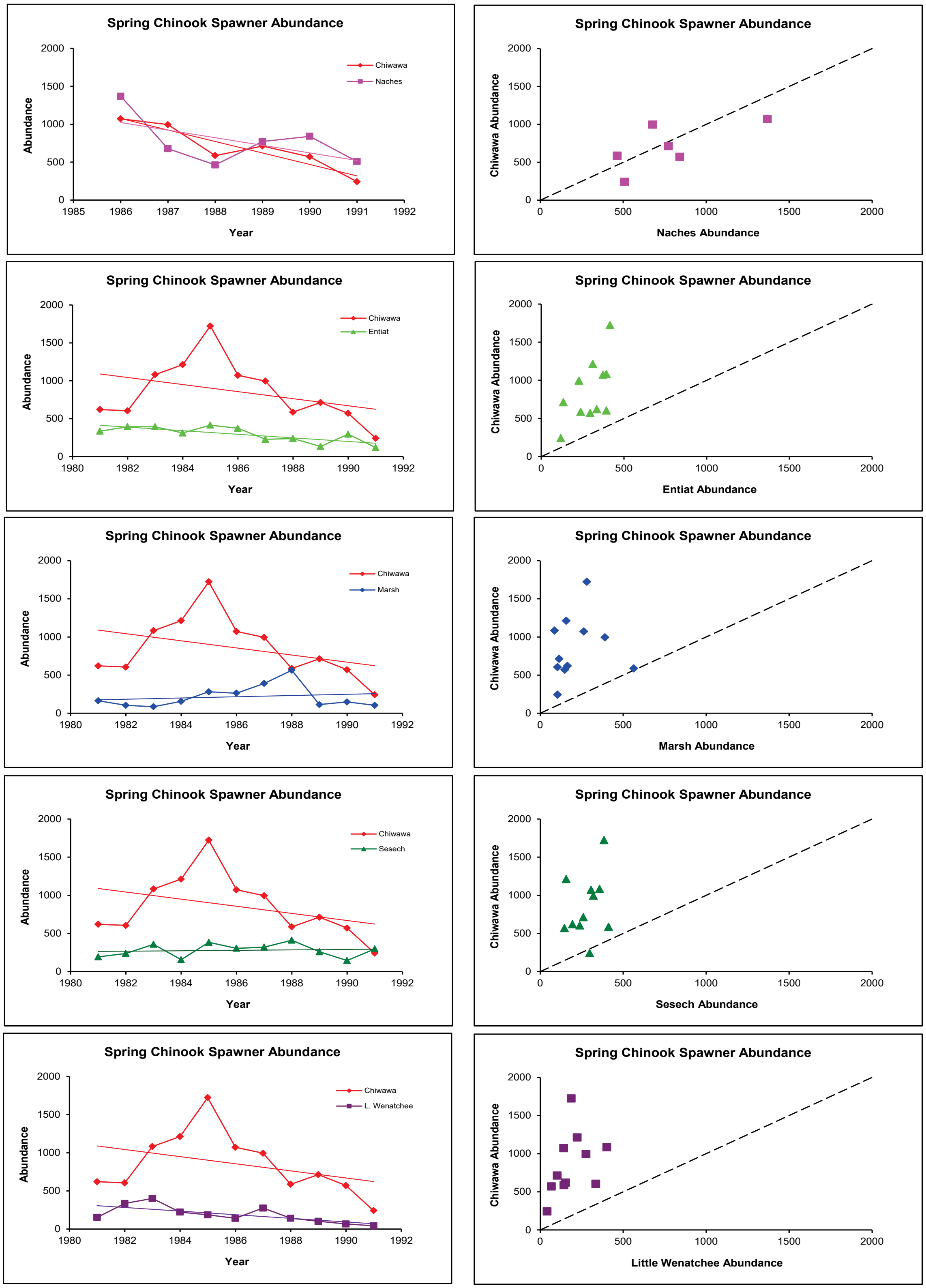

Figure 2. Time series of spawner abundance of potential reference populations and the Chiwawa spring Chinook population before the Chiwawa population was supplemented with hatchery fish.

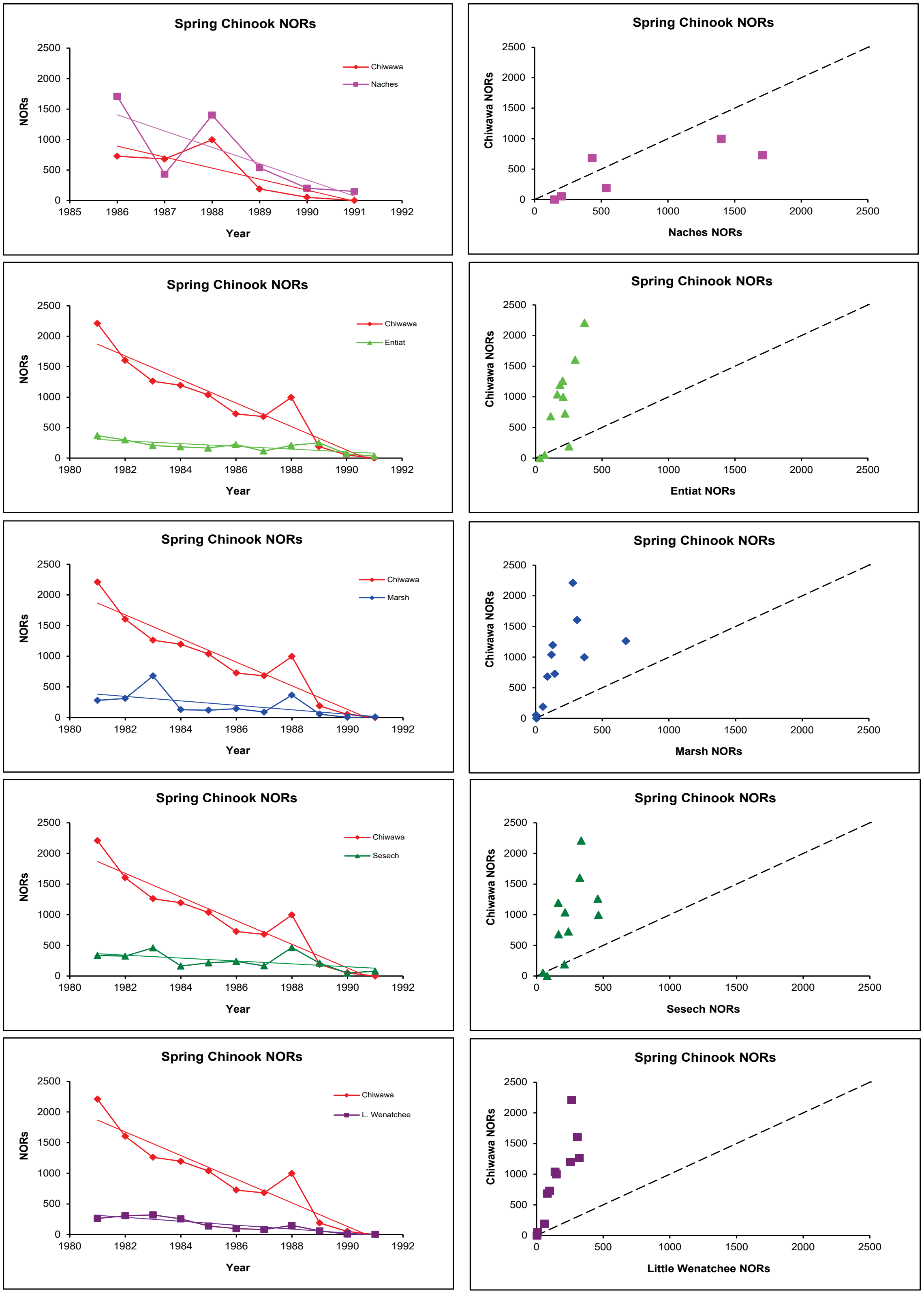

Figure 3. Time series of natural-origin recruits (NORs) of potential reference populations and the Chiwawa spring Chinook population before the Chiwawa population was supplemented with hatchery fish.

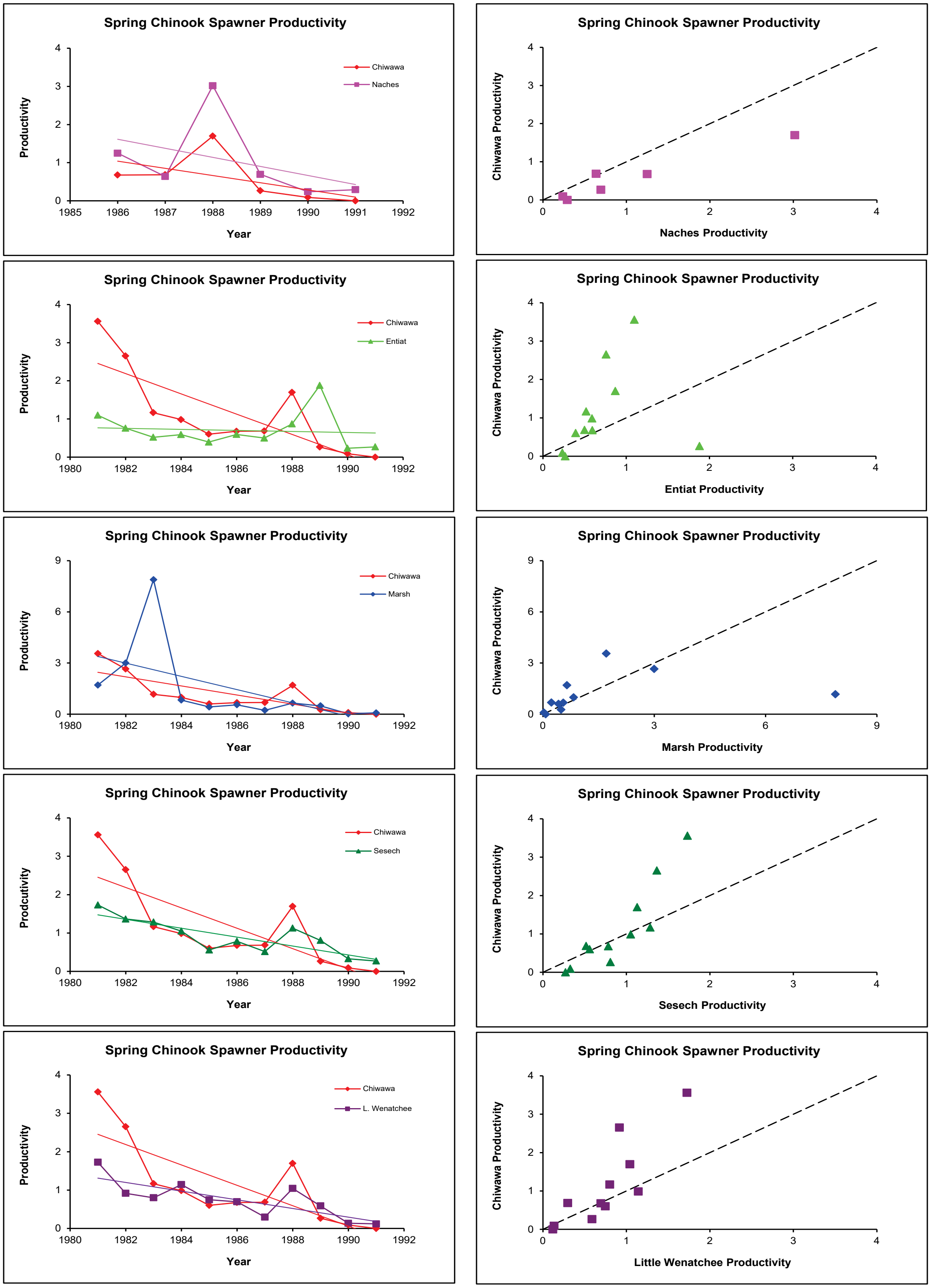

Figure 4. Time series of adult productivity of potential reference populations and the Chiwawa spring Chinook population before the Chiwawa population was supplemented with hatchery fish.

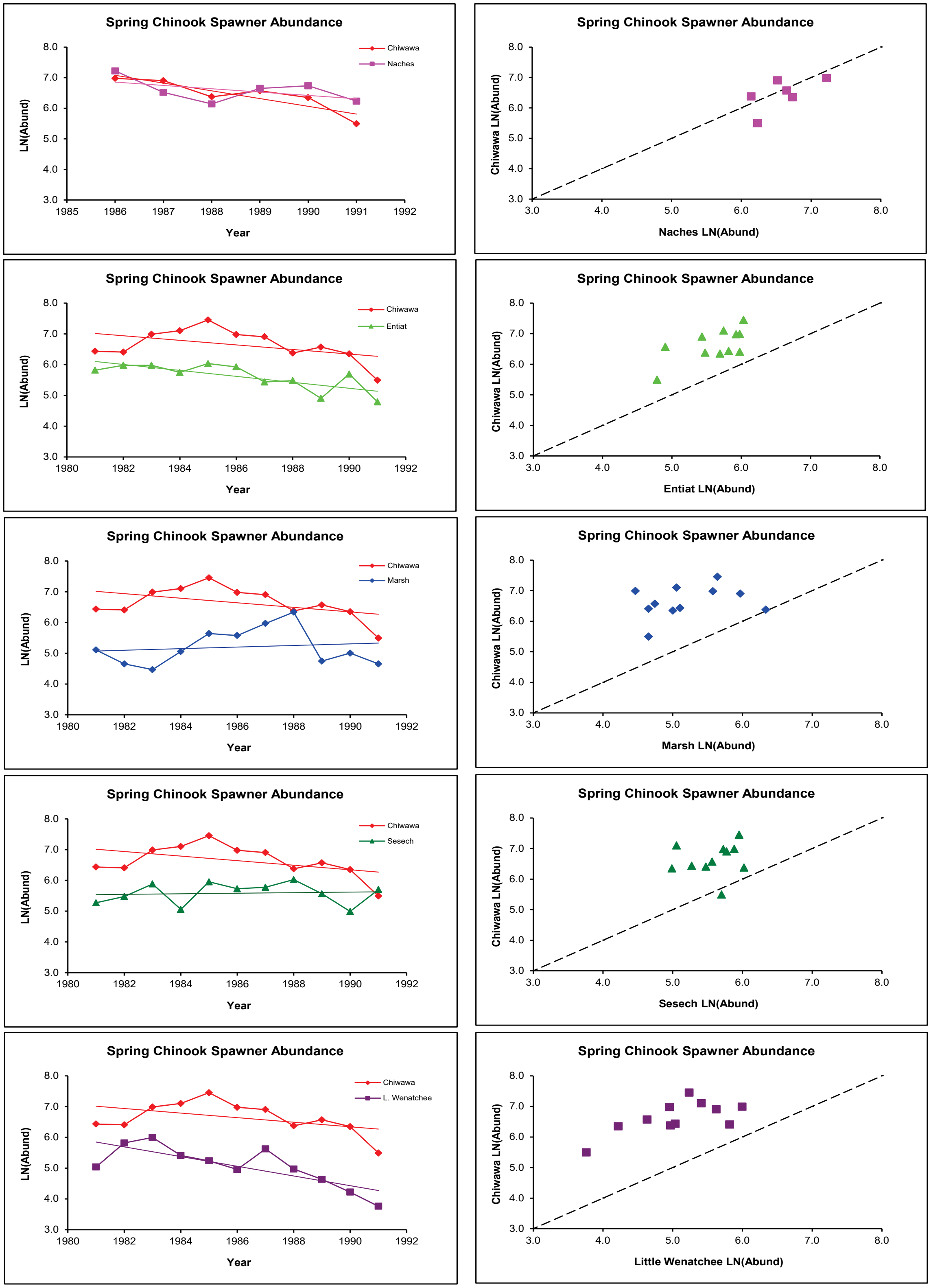

Figure 5. Time series of natural log spawner abundance of potential reference populations and the Chiwawa spring Chinook population before the Chiwawa population was supplemented with hatchery fish.

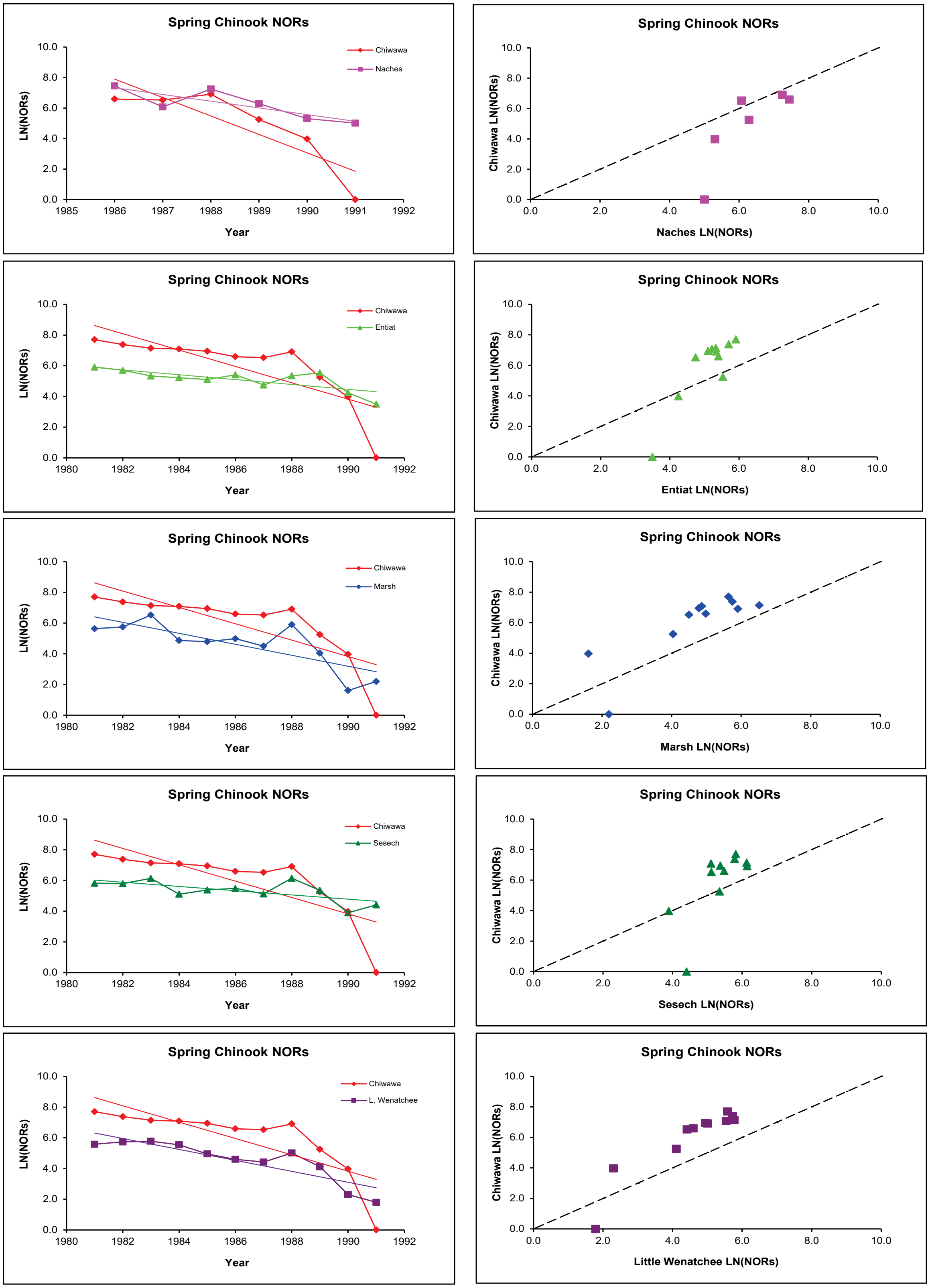

Figure 6. Time series of natural log natural-origin recruits (NORs) of potential reference populations and the Chiwawa spring Chinook population before the Chiwawa population was supplemented with hatchery fish.

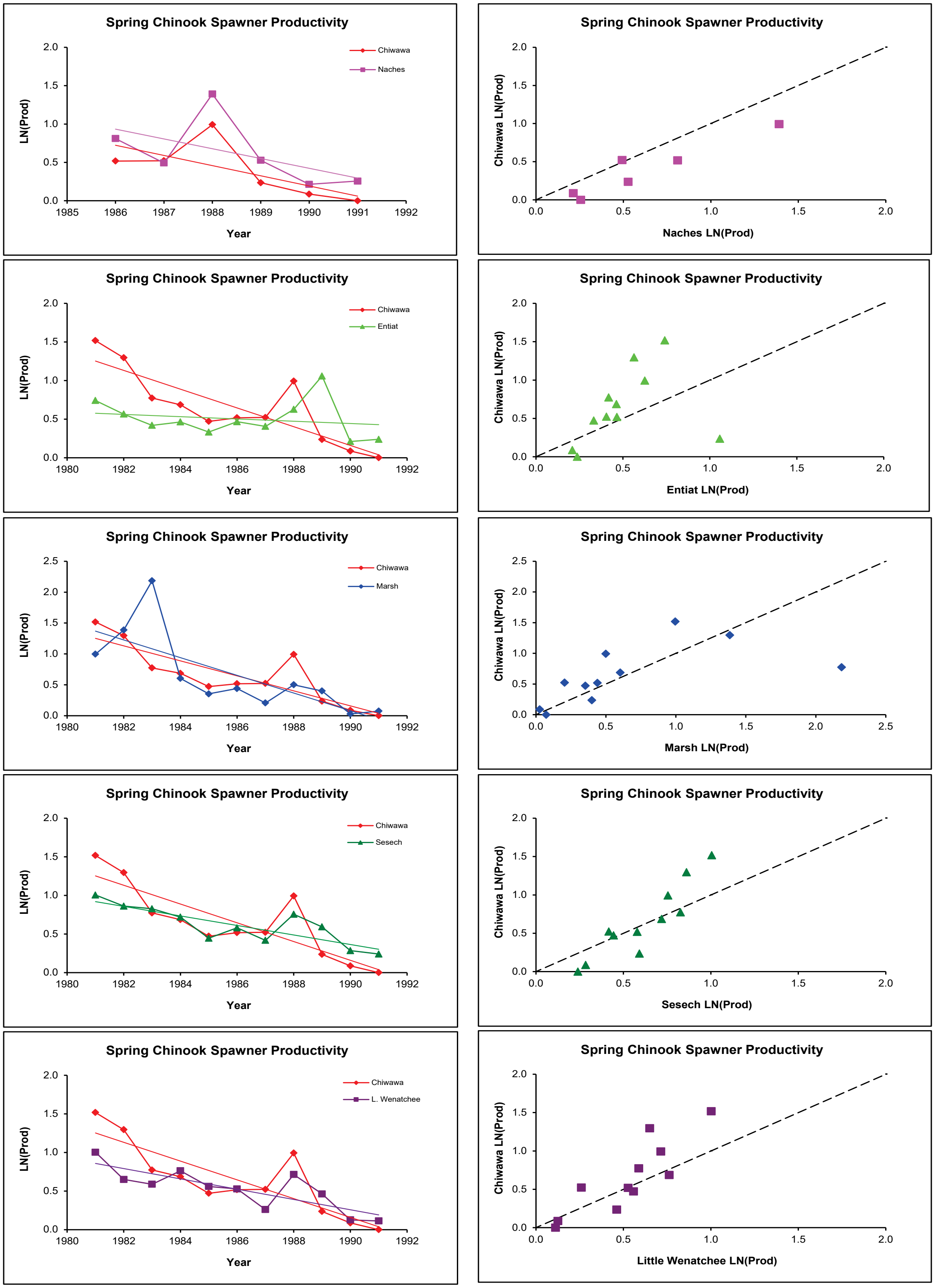

Figure 7. Time series of natural log adult productivity of potential reference populations and the Chiwawa spring Chinook population before the Chiwawa population was supplemented with hatchery fish.

Correlations and Trends

Other methods for evaluating the suitability of potential reference populations under Step 2 include correlation and trend analyses. For correlation analysis, we simply calculated the Pearson correlation coefficient, which is an index of the strength of the association between the potential reference populations and the Chiwawa population. The coefficient ranges from -1 to 1, where a value near 1 or -1 represents that strongest association between the populations. A value of 0 means no association. We used only spawner abundance, NORs, and productivity data during the pre-treatment period (1981-1992). We assumed that populations with coefficients greater than 0.6 represented reasonable reference conditions.

For trend analyses, we used least squares techniques to compute a straight-line trend through the spawner abundance and productivity data for the potential reference populations and the Chiwawa population. Trends were fit to the pre-treatment time series data (1981-1992). We then used t-tests to determine if the slopes of the trends between potential reference populations and the Chiwawa population differed significantly.

It is important to note that time-series trend analyses are susceptible to temporal correlations in the data. Autoregressive integrated moving average (ARIMA) models can be used to describe the correlation structure in temporal data (Gotelli and Ellison 2004). However, these models require a long time series (N > 40) and therefore we could not use them to model the spring Chinook data. As such, we were unable to correct for any temporal correlation that may exist within the time series.

Tests of correlation with spawner abundance data indicated that the Naches River closely correlated with the Chiwawa population (Table 2). There was no difference in abundance trends between the potential reference populations and the Chiwawa population (Table 2; Figure 2). For NORs, all potential reference populations correlated with the Chiwawa population (Table 2). However, trends in NORs of all reference populations, except Naches, differed significantly from the Chiwawa population (Table 2; Figure 3). For productivity, the Naches, Sesech, and Little Wenatchee correlated with the Chiwawa population (Table 2). Only the Entiat productivity trend differed significantly from the Chiwawa population trend (Table 2; Figure 4).

Table 2. Pearson correlation coefficients and t-test results comparing slopes of trends between potential reference populations and the Chiwawa spring Chinook population; d.f. = degrees of freedom and for correlation coefficients, an asterisk (*) indicates significance at $P < 0.05$.

Reference populations	Pearson correlation coefficient	t-test on slopes		
		t-value	d.f.	P-value
Spawner Abundance Data				
Naches	0.684*	-0.659	8	0.528
Entiat	0.598*	-0.596	18	0.559
Marsh	0.147	-1.341	18	0.197
Sesech	0.274	-1.265	18	0.222
Little Wenatchee	0.399	-0.591	18	0.562
Natural-Origin Recruits				
Naches	0.803*	0.666	8	0.524
Entiat	0.795*	-7.495	18	0.000

Reference populations	Pearson correlation coefficient	t-test on slopes		
		t-value	d.f.	P-value
Marsh	0.605*	-5.786	18	0.000
Sesech	0.648*	-6.874	18	0.000
Little Wenatchee	0.880*	-7.206	18	0.000
Productivity Data				
Naches	0.960*	0.169	8	0.870
Entiat	0.272	-3.057	18	0.007
Marsh	0.320	0.605	18	0.553
Sesech	0.903*	-2.059	18	0.054
Little Wenatchee	0.848*	-2.065	18	0.054

We also ran correlation and trend analyses on natural-log transformed spawner abundance, NORs, and productivity data. These analyses indicated that the Naches, Entiat, and Little Wenatchee abundance data correlated with the Chiwawa population data (Table 3). None of the abundance trends of the potential reference populations differed significantly from the Chiwawa population trend (Table 3; Figure 5). For NORs, all potential reference populations correlated with the Chiwawa population (Table 3). Only trends in NORs of the Entiat and Sesech differed significantly from the Chiwawa population (Table 2; Figure 6). For productivity, the Naches, Marsh, Sesech, and Little Wenatchee correlated with the Chiwawa population data (Table 3). Only the Entiat productivity trend differed significantly from the Chiwawa population trend (Table 3; Figure 7).

Table 3. Pearson correlation coefficients and t-test results comparing slopes of trends between potential reference populations and the Chiwawa spring Chinook population; d.f. = degrees of freedom and for correlation coefficients, an asterisk (*) indicates significance at $P < 0.05$. Analyses were conducted on natural-log transformed abundance and productivity data.

Reference populations	Pearson correlation coefficient	t-test on slopes		
		t-value	d.f.	P-value
LN Spawner Abundance Data				
Naches	0.642*	-1.323	8	0.222
Entiat	0.652*	0.412	18	0.685
Marsh	0.294	-1.324	18	0.202
Sesech	0.149	-1.431	18	0.170
Little Wenatchee	0.670*	1.325	18	0.202
LN Natural-Origin Recruits				
Naches	0.824*	-1.985	8	0.082
Entiat	0.886*	-2.563	18	0.019
Marsh	0.830*	-1.038	18	0.313
Sesech	0.730*	-2.664	18	0.016
Little Wenatchee	0.927*	-1.150	18	0.265
LN Productivity Data				

Reference populations	Pearson correlation coefficient	t-test on slopes		
		t-value	d.f.	P-value
Naches	0.944*	-0.042	8	0.968
Entiat	0.373	-3.043	18	0.007
Marsh	0.610*	0.428	18	0.674
Sesech	0.913*	-2.050	18	0.055
Little Wenatchee	0.862*	-1.811	18	0.087

In summary, based on correlation, trend, and graphic analyses, the Naches, Entiat, and Little Wenatchee populations appear to be reasonable reference populations for comparing spawner abundance data with Chiwawa data. For NORs, the Naches, Marsh, and Little Wenatchee appear to be reasonable reference populations. For productivity, the Naches, Marsh, Sesech, and Little Wenatchee populations appear to be reasonable reference populations for the Chiwawa population.

Minimal Detectable Differences (MDD)

Given a suite of potential reference populations, it is important to conduct power analyses to determine the minimum differences that can be detected when comparing the reference populations to the supplemented population. As a final exercise under Step 2, we examined potential reference populations for the smallest minimal detectable differences. Before conducting power analyses, several decisions needed to be made, including what statistical procedures will be used to analyze the data, the desired level of statistical power (probability of rejecting a false null hypothesis), the size of the type-I error (the probability of rejecting a true null hypothesis of no difference), and the number of samples (i.e., years) included in the analysis. In this case, the number of samples represents the number of treatment (supplementation) years. The number of pre-treatment years (1981-1992) was based on the number of years of quality data available for Chiwawa spring Chinook and potential reference populations.

We designed the study as a modified BACI (Before-After, Control-Impact) design, which includes replication before and after supplementation in both the treated (T) population and the reference (R) populations. A common approach used to analyze data from BACI designs includes analysis of difference scores (Stewart-Oaten et al. 1992; Smith et al. 1993). Differences are calculated between paired treatment and reference population scores (i.e., T-R). Another approach is to calculate ratios (treatment/reference; T/R) for paired treatment and reference population scores (Skalski and Robson 1992). Finally, differences in annual changes in paired treatment and reference population scores can be calculated (i.e., ΔT-ΔR) (Murdoch and Peven 2005; Hays et al. 2006).[17] These derived difference and ratio scores are then analyzed for a before-after treatment effect with a two-sample t-test, Aspin-Welch modification of the t-test, or a randomization test. For power analyses, we calculated minimal detectable differences assuming the use of an independent two-sample t-test with a type-I error rate of 0.05, power of 0.80 (beta or type-II error rate of 0.20), and sample sizes (treatment years) of 5, 10, 15, 20, 25, and 50 years.

[17] The difference of annual difference scores was estimated by first subtracting the population parameter (e.g., spawner abundance) in year 2 from year 1. This continues for all years in the data series for both treatment ($T_{t+1} - T_t$) and reference populations ($R_{t+1} - R_t$). We then calculated differences between paired treatment and reference annual difference scores [$(T_{t+1} - T_t) - (R_{t+1} - R_t) = \Delta T - \Delta R$].

The power analysis calculated the minimal detectable difference between mean difference or ratio scores before and during supplementation. We used existing data to calculate variances for the pre-supplementation and supplementation periods. Thus, variances were known and unequal. For both spawner abundance and NORs, the null hypothesis tested was that the mean difference or ratio before supplementation equaled the mean difference or ratio during supplementation. The alternative hypothesis was that the mean difference or ratio before supplementation was less than the mean difference during supplementation (one-tail test; Difference < 0). For productivity, the null hypothesis tested was that the mean difference or ratio before supplementation equaled the mean difference or ratio during supplementation. The alternative hypothesis was that the mean difference or ratio before supplementation was greater than the mean difference during supplementation (one-tail test; Difference > 0).

Based on spawner abundance data, power analysis indicated that the Sesech-Chiwawa pairing consistently produced the smallest detectable differences (Table 4). However, when the abundance data were transformed using natural logs, the Entiat-Chiwawa pairing produced the smallest detectable difference (Table 5). Minimal detectable differences, based on mean difference scores on untransformed data and a treatment period of 20 years, ranged from 334 to 394 adult spawners; transformed data ranged from 0.479 to 1.010. These analyses indicate that the Naches, Entiat, Sesech, and Little Wenatchee populations appear to be reasonable reference populations for comparing spawner abundance data with Chiwawa data. The Marsh Creek population produced some of the largest detectable differences and based on these analyses may not be a reasonable reference population.

Table 4. Minimal detectable differences between mean difference and ratio scores before and during supplementation. Analyses were conducted on spawner abundance data.

Response variable	Treatment years	Minimal detectable differences by reference population				
		Naches	Entiat	Marsh	Sesech	Little Wenatchee
T-R	5	638	604	560	396	652
	10	464	448	444	354	481
	15	405	395	406	341	424
	20	376	368	387	334	394
	25	358	352	376	331	376
	50	322	319	354	323	340
T/R	5	0.600	2.084	39.251	1.569	5.498
	10	0.506	1.548	24.729	1.508	3.828
	15	0.478	1.367	19.646	1.490	3.256
	20	0.465	1.275	16.828	1.481	2.954
	25	0.458	1.219	14.974	1.475	2.765
	50	0.447	1.105	10.573	1.465	2.366
ΔT-ΔR	5	1,049	761	717	518	766
	10	750	542	539	411	547
	15	650	467	480	376	473
	20	598	429	450	359	434

Response variable	Treatment years	Minimal detectable differences by reference population				
		Naches	Entiat	Marsh	Sesech	Little Wenatchee
	25	567	405	431	348	410
	50	506	355	395	329	361

Table 5. Minimal detectable differences between mean difference and ratio scores before and during supplementation. Analyses were conducted on natural-log transformed spawner abundance data.

Response variable	Treatment years	Minimal detectable differences by reference population				
		Naches	Entiat	Marsh	Sesech	Little Wenatchee
T-R	5	0.975	0.871	2.061	0.828	1.013
	10	0.721	0.613	1.375	0.648	0.722
	15	0.637	0.525	1.138	0.588	0.623
	20	0.595	0.479	1.010	0.559	0.571
	25	0.569	0.450	0.928	0.541	0.539
	50	0.521	0.390	0.749	0.505	0.473
T/R	5	0.157	0.162	2.343	0.160	0.368
	10	0.116	0.115	1.474	0.125	0.247
	15	0.102	0.099	1.170	0.114	0.206
	20	0.095	0.090	1.001	0.108	0.183
	25	0.091	0.085	0.890	0.104	0.169
	50	0.082	0.075	0.625	0.098	0.138
ΔT-ΔR	5	1.261	1.288	3.076	1.160	1.467
	10	0.898	0.900	2.020	0.887	1.001
	15	0.776	0.768	1.653	0.797	0.840
	20	0.713	0.698	1.463	0.751	0.755
	25	0.675	0.655	1.325	0.724	0.701
	50	0.600	0.564	1.038	0.670	0.585

Based on NORs, power analysis indicated that the Entiat-Chiwawa, Marsh-Chiwawa, and Little Wenatchee-Chiwawa pairings produced the smallest detectable differences (Table 6). When NORs were transformed using natural logs, the Little Wenatchee-Chiwawa pairing produced the smallest detectable difference (Table 7). Minimal detectable differences, based on mean difference scores on untransformed data and a treatment period of 20 years, ranged from 483 to 640 NORs; transformed data ranged from 0.958 to 2.262. These analyses indicate that the Entiat, Marsh, and Little Wenatchee populations appear to be reasonable reference populations for comparing NORs with Chiwawa data.

Table 6. Minimal detectable differences between mean difference and ratio scores before and during supplementation. Analyses were conducted on natural-origin recruits.

Response variable	Treatment years	Minimal detectable differences by reference population				
		Naches	Entiat	Marsh	Sesech	Little Wenatchee
T-R	5	1,139	541	573	630	546
	10	809	511	515	550	503
	15	698	502	498	526	489
	20	640	497	489	514	483
	25	604	494	484	507	479
	50	534	489	474	493	472
T/R	5	0.469	2.538	5.196	1.976	6.973
	10	0.451	2.183	4.183	1.894	5.118
	15	0.446	2.072	3.854	1.869	4.492
	20	0.445	2.017	3.691	1.857	4.170
	25	0.444	1.986	3.594	1.850	3.973
	50	0.443	1.924	3.405	1.836	3.572
ΔT-ΔR	5	1,639	500	519	609	531
	10	1,239	386	409	433	396
	15	1,109	348	374	372	351
	20	1,046	329	356	341	328
	25	1,009	318	346	321	314
	50	943	295	325	281	285

Table 7. Minimal detectable differences between mean difference and ratio scores before and during supplementation. Analyses were conducted on natural-log transformed natural-origin recruits.

Response variable	Treatment years	Minimal detectable differences by reference population				
		Naches	Entiat	Marsh	Sesech	Little Wenatchee
T-R	5	2.380	1.646	1.967	2.247	1.174
	10	2.291	1.479	1.505	1.835	1.026
	15	2.270	1.428	1.351	1.702	0.980
	20	2.262	1.403	1.273	1.636	0.958
	25	2.258	1.389	1.227	1.597	0.945
	50	2.253	1.361	1.133	1.522	0.920
T/R	5	0.322	0.332	0.739	0.398	0.356
	10	0.301	0.289	0.581	0.334	0.322
	15	0.296	0.275	0.530	0.314	0.312
	20	0.294	0.269	0.504	0.305	0.307
	25	0.293	0.265	0.488	0.299	0.304

Response variable	Treatment years	Minimal detectable differences by reference population				
		Naches	Entiat	Marsh	Sesech	Little Wenatchee
	50	0.291	0.258	0.458	0.288	0.298
ΔT-ΔR	5	2.858	2.400	2.355	3.283	2.109
	10	2.560	1.714	1.881	2.311	1.552
	15	2.485	1.481	1.728	1.979	1.365
	20	2.456	1.360	1.652	1.805	1.269
	25	2.443	1.285	1.607	1.697	1.210
	50	2.430	1.130	1.519	1.471	1.092

Using untransformed productivity data, power analysis indicated that the Little Wenatchee-Chiwawa pairing consistently produced the smallest detectable differences (Table 8). The Marsh-Chiwawa pairings produced the largest detectable differences. When we analyzed natural-log transformed productivity data, the Naches-Chiwawa and Little Wenatchee-Chiwawa pairings produced the smallest detectable differences (Table 9). Minimal detectable differences, based on mean difference scores on untransformed data and a treatment period of 20 years, ranged from 0.754 to 1.839; transformed data ranged from 0.277 to 0.477. These analyses indicate that the Naches, Entiat, Sesech, and Little Wenatchee populations appear to be reasonable reference populations for comparing productivity data with Chiwawa data. The Marsh Creek population produced some of the largest detectable differences and based on these analyses may not be a reasonable reference population.

Table 8. Minimal detectable differences between mean difference and ratio scores before and during supplementation. Analyses were conducted on productivity data.

Response variable	Treatment years	Minimal detectable differences by reference population				
		Naches	Entiat	Marsh	Sesech	Little Wenatchee
T-R	5	2.181	1.382	2.033	3.517	1.192
	10	1.442	1.119	1.900	2.265	0.901
	15	1.186	1.033	1.859	1.828	0.804
	20	1.047	0.991	1.839	1.588	0.754
	25	0.959	0.966	1.828	1.432	0.724
	50	0.764	0.917	1.806	1.074	0.664
T/R	5	1.364	1.773	0.863	0.876	2.167
	10	1.095	1.359	0.831	0.687	1.587
	15	1.011	1.221	0.822	0.625	1.391
	20	0.971	1.152	0.817	0.594	1.290
	25	0.949	1.110	0.814	0.575	1.228
	50	0.910	1.027	0.908	0.538	1.102
ΔT-ΔR	5	3.298	1.864	3.211	4.420	1.942
	10	2.263	1.382	2.968	2.811	1.291

Response variable	Treatment years	Minimal detectable differences by reference population				
		Naches	Entiat	Marsh	Sesech	Little Wenatchee
	15	1.909	1.220	2.894	2.248	1.066
	20	1.723	1.137	2.859	1.938	0.944
	25	1.606	1.087	2.839	1.735	0.866
	50	1.365	0.986	2.800	1.259	0.695

Table 9. Minimal detectable differences between mean difference and ratio scores before and during supplementation. Analyses were conducted on natural-log transformed productivity data.

Response variable	Treatment years	Minimal detectable differences by reference population				
		Naches	Entiat	Marsh	Sesech	Little Wenatchee
T-R	5	0.540	0.551	0.674	0.890	0.585
	10	0.367	0.452	0.542	0.590	0.413
	15	0.308	0.421	0.499	0.486	0.355
	20	0.277	0.405	0.477	0.430	0.324
	25	0.257	0.396	0.465	0.393	0.305
	50	0.215	0.378	0.440	0.314	0.265
T/R	5	0.915	1.286	0.743	0.697	1.685
	10	0.744	0.973	0.704	0.541	1.227
	15	0.691	0.868	0.692	0.489	1.072
	20	0.666	0.815	0.687	0.463	0.993
	25	0.652	0.783	0.683	0.447	0.943
	50	0.628	0.719	0.677	0.416	0.843
ΔT-ΔR	5	0.885	0.810	1.028	1.252	0.971
	10	0.631	0.609	0.822	0.809	0.640
	15	0.546	0.542	0.755	0.655	0.525
	20	0.502	0.508	0.722	0.570	0.463
	25	0.475	0.487	0.702	0.516	0.423
	50	0.423	0.446	0.664	0.391	0.333

Step 3: Quantitative Method for Ranking Selection Criteria

Not surprisingly, different selection criteria produced different results (Table 10). Determining whether a given population is or is not a suitable reference population based on selection criteria such as graphic analysis can be subjective. In addition, treating each selection criterion as equally important may not be appropriate. For example, using the information in Table 10, is it appropriate to select a reference population that has two or three "Yes" entries, or should only populations with four "Yes" entries be selected as suitable reference populations? This approach does not allow certain selection criteria to carry more weight in the overall selection process. That is, correlation may be more important than graphic analysis in the overall selection process. In order to reduce

subjectivity, we developed a method of scoring and weighting each selection criterion. This method allows a more quantitative process for selecting suitable reference populations.

Table 10. Summary of results from graphic analysis, correlations, trend analysis, and power analysis (minimal detectable differences). "Yes" indicates that the population is a suitable reference population for the Chiwawa population; "No" indicates that it may not be a suitable reference population.

Potential reference populations	Graphic analysis	Correlation	Trends	Minimal detectable differences
Spawner Abundance				
Naches	Yes	Yes	Yes	Yes
Entiat	Yes	Yes	Yes	Yes
Marsh	No	No	Yes	No
Sesech	No	No	Yes	Yes
Little Wenatchee	Yes	Yes	Yes	Yes
Natural-Origin Recruits				
Naches	Yes	Yes	Yes	No
Entiat	No	Yes	No	Yes
Marsh	Yes	Yes	Yes	Yes
Sesech	No	Yes	No	No
Little Wenatchee	Yes	Yes	Yes	Yes
Productivity				
Naches	Yes	Yes	Yes	Yes
Entiat	No	No	No	Yes
Marsh	No	Yes	Yes	No
Sesech	Yes	Yes	Yes	Yes
Little Wenatchee	Yes	Yes	Yes	Yes

We developed scoring methods for each of the following five selection criteria:

(1) The proportion of natural-origin spawners (pNOS) in the reference population for the period before supplementation (pre-pNOS);

(2) pNOS in the reference population for the period following supplementation (post-pNOS);

(3) The correlation between the reference and supplemented populations before supplementation;

(4) The relative difference in slopes between the reference and supplemented populations before supplementation; and

(5) The coefficient of variation (CV) of the ratio of supplemented to reference populations before the period of supplementation.

Each selection criteria was scored from 0 to 1, with 0 being the worst possible score and 1 being the best.

The pre- and post-pNOS values were calculated as the average pNOS values before and after supplementation, respectively. Because pNOS values range from 0-1, we did not need to rescale

these values. When using reference populations to evaluate the effects of supplementation programs, it is important that the reference populations maintain high values of pNOS throughout the life of the monitoring program. Therefore, we heavily weighted the mean pNOS scores. We assigned weights of 30 and 40 to the mean pre- and post-pNOS scores, respectively. The relatively larger weight for the post-supplementation period is to reduce the likelihood of retaining a reference population that becomes influenced by hatchery fish during the supplementation period.

We assessed the association between the reference and supplemented populations during the pre-supplementation period by calculating the Pearson correlation coefficient, which ranges from -1 to 1. To scale the coefficient between 0 and 1, we took the absolute value of the coefficient. Thus, a coefficient of -0.92 would be reported as 0.92. For our analyses, we were not concerned with the direction of the relationship, only the strength of the relationship. The correlation coefficient was given a weight of 12.5.

As noted earlier, we used least squares to fit a linear trend to each of the reference populations and the supplemented population during the pre-supplementation period. Using the slope estimates for each trend line, we calculated the relative difference in slopes as the slope of the supplemented population minus the slope of the reference population, divided by the slope of the reference population. To scale this value between 0 and 1, we used absolute values, and depending on the direction of the slopes, we subtracted the relative difference from 1. The latter was needed to make sure a larger relative difference value indicated a small difference in slopes between the supplemented and reference populations. The relative difference score was given a weight of 7.5.

Finally, as a means to score effect size, we calculated the CV of the ratio of supplemented to reference population parameters (i.e., T/R). The CV was calculated as the standard deviation of the ratios divided by the absolute value of the mean ratios. The CV was subtracted from 1. This scaled the value from 0 to 1 with larger values representing the best condition. The CV was given a weight of 10, which is greater than the weight for trend, but less than the weight for correlation.

The total score for a reference population was calculated by multiplying the estimated value, which ranged from 0 to 1, by its weight. The sum of the five weighted values provided a total score, which ranged from 0 to 100. Based on several simulations, we set the cut-off score at 81. That is, if the total score for a given reference population equaled or exceeded 81, the population was included as a suitable reference population. If the total score fell below 81, the population was not considered a suitable reference. Based on the distribution of all scores possible, a score of 81 or greater represented only 3% of the total distribution. Thus, a cut-off of 81 is quite conservative.

Under Step 3, we used this method to select the final suite of suitable reference populations. Table 11 shows results from scoring each of the reference populations using the quantitative method. Using the cut-off criterion of 81, only the Naches, Marsh, and Sesech populations would be considered suitable reference populations for the Chiwawa supplementation program. Both the Entiat and Little Wenatchee populations failed to meet the minimum score, largely because of the influence of hatchery fish within those populations (i.e., relatively low pNOS values).

Table 11. Results from scoring potential reference populations using the selection criteria (pNOS, correlation, trend, and effect size). Populations with scores less than 81 were considered unsuitable as reference populations. Populations with scores equal to or greater than 81 were considered suitable references. These results were based on natural-log transformed data.

Potential reference populations	Population metric		
	Abundance	NORs	Productivity
Naches	85	88	91
Entiat	23	21	16
Marsh	79	91	87
Sesech	84	85	88
Little Wenatchee	51	53	49

An important benefit from scoring the different selection criteria is that the total scores can be used to weight the outcome of differing statistical results. For example, analyses may show that when three suitable reference populations are compared to the supplemented population, two of the reference populations may indicate a significant treatment effect, while the third indicates no effect. Under this scenario it is not clear if the supplementation program has or has not affected the abundance or productivity of the supplemented population. If, however, the two reference populations that produced a significant result had higher total scores than the reference population that did not indicate a significant result, one can place more weight on the results from populations with higher total scores.

Conclusions

The purpose of this exercise was to develop a method for selecting suitable reference populations that could be used to assess the effects of supplementation programs on spawner abundance, NORs, and productivity. The selection process included a three-step process (Figure 8). Step 1 identified populations with similar life-history characteristics, few or no hatchery spawners, a long time series of accurate abundance and productivity estimates, and similar freshwater habitat impairments and out-of-basin effects. Populations that met these criteria were then examined for their graphical and statistical relationship with the supplemented population (Step 2). The statistical analysis under Step 2 were converted to a quantitative model (Step 3) that was used to generate a weighted score for pNOS, correlation, trends, and effect sizes for each potential reference population. Reference populations with total scores of 81 or greater were selected as suitable reference populations.

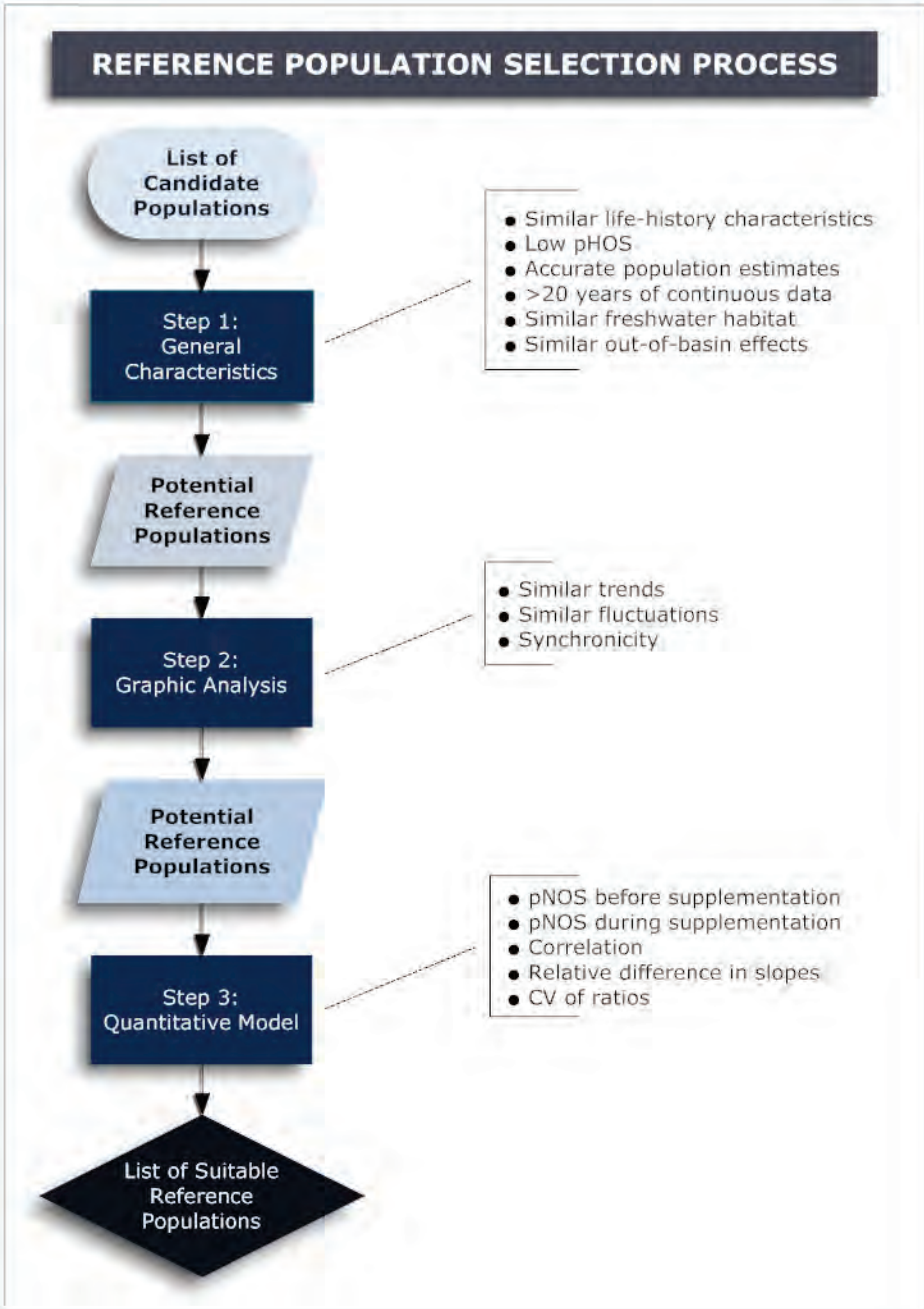

Figure 8. Three-step process for selecting suitable reference populations for supplemented populations.

We used this approach to select suitable reference populations for analyzing the effects of the Chiwawa spring Chinook supplementation program on fish abundance and productivity. The method indicated that the Naches, Marsh, and Sesech populations would serve as suitable reference populations for the Chiwawa spring Chinook supplementation program. Both the Entiat and Little Wenatchee populations failed to meet the minimum score, largely because of the influence of hatchery fish within those populations (i.e., relatively low pNOS values). However, because the presence of hatchery spring Chinook within those populations should decrease, they may serve as unique reference populations in which the comparisons change from all populations receiving

hatchery fish to only the Chiwawa population receiving hatchery fish. Therefore, we will continue to include both the Little Wenatchee and Entiat populations in future analyses.

An important assumption in the use of reference populations is that the supplemented and reference populations that tracked each other before supplementation would continue to track each other in the absence of supplementation. Given that the reference populations did not match the Chiwawa population on all criteria examined (Table 1) and some reference populations tracked the Chiwawa population more poorly than others (Figures 2-7; Tables 2-4), there may be some uncertainty as to whether differences observed between the Chiwawa and reference populations during the supplementation period are associated with the hatchery program, "nuisance" factors[18], or a combination of both. In addition, we have no ability to regulate or control activities in reference areas. Any large-scale change (man-made or natural) in reference areas could affect our ability to assess the effectiveness of the supplementation program.

Because we have no ability to maintain reference areas for long periods of time and may not be able to control all activities even within the supplemented populations, we propose the use of a "causal-comparative" approach to strengthen the certainty of our inferences (Pearsons and Temple 2010). The causal-comparative approach relies on correlative data to try and make a case for causal inference.[19] Correlation is used to rule out alternative hypotheses (note that we make our case as much if not more by disproving plausible alternatives as we do by showing that the data are consistent with a hypothesis). For example, large scale land-use activities or natural events can affect stream flows, fine sediment recruitment, and water temperatures. Changes in these factors can affect the freshwater survival and productivity of fish independently of supplementation programs. If changes in habitat, migratory, and ocean conditions do not affect reference and treatment populations similarly, inferences associated with supplementation programs may be confounded. By measuring and tracking these extraneous factors within reference and treatment areas, we can assess the effects of these state variables on population conditions independent of the supplementation programs. This allows us to more effectively assess the influence of supplementation programs on populations.

To that end, we recommend that the following state variables be measured and tracked within the Chiwawa Basin and each of the reference areas: mean annual precipitation, total and riparian forest cover, road density, impervious surface, and alluvium. These variables can be used to describe differences in water temperatures at different life stages (pre-spawning, egg incubation, and summer rearing) and substrate characteristics, including fine sediments and embeddedness (Jorgensen et al. 2009). They can be used to assess possible changes in spawner abundance, NORs, and productivity that are independent of supplementation.

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[18] A "nuisance" factor is any factor that is outside the control of the experimenter and can affect the response variable (spawner abundance or productivity). In this case, nuisance factors may include differences in freshwater habitat trends and conditions, out-of-basin effects (e.g., migration and ocean survival), and hatchery strays that affect the Chiwawa and reference populations differently.

[19] It is important to point out that correlation does not demonstrate cause-and-effect. It only suggests a relationship between variables. Thus, inferences based on correlation lack the certainty that is associated with a design-based approach.

Analyses with Reference Populations

Once suitable reference populations are selected, methods for analyzing the supplemented and reference populations need to be identified. What follows is a description of different analyses that can be used to assess the effects of supplementation programs on spawner abundance, NORs, and productivity using reference populations. Later in this report we describe methods for assessing supplementation effects when reference populations are not available.

We used some of the reference populations selected for the Chiwawa program to illustrate the different methods for evaluating the effects of the supplementation program on spawner abundance, NORs, and productivity. For abundance, we selected the Naches, Entiat, Little Wenatchee, and Sesech populations as suitable references for the Chiwawa population. For NORs, we selected the Naches, Entiat, Marsh, and Little Wenatchee populations as suitable references. For productivity, we selected the Naches, Sesech, Little Wenatchee, and Marsh Creek as suitable references for the Chiwawa. As noted earlier, we included the Little Wenatchee and Entiat populations, even though they did not meet all the criteria for suitable reference populations.

Analysis of Trends

As a first step, we used trend analyses to assess the effects of the Chiwawa supplementation program on spring Chinook spawner abundance, NORs, and productivity. Here, we compared the slopes of the trends between each treatment/reference pair before and during supplementation using t-tests. If the hatchery program is successfully supplementing the natural spring Chinook population, trends in spawner abundance and NORs should deviate significantly (i.e., the slope of the supplemented population should be greater than the slopes of the reference populations during the supplementation period). For productivity, the slope of the supplemented population, relative to the reference population, should increase or remain the same.

Trend analysis indicated that the relationship of slopes of spawner abundance between the Chiwawa and reference populations did not change significantly after the initiation of supplementation (Figure 9; Table 12). This was true for both transformed and untransformed abundance data. Before supplementation, spawner abundances trended down in both the Chiwawa and reference populations (Figure 9). During the period of supplementation, abundances in both the Chiwawa and reference populations trended upward. Interestingly, in nearly all treatment/reference comparisons, the Pearson correlation coefficient was greater in the supplementation period than in the pre-supplementation period (Table 12). This was most evident in the transformed abundance data (Figure 9).

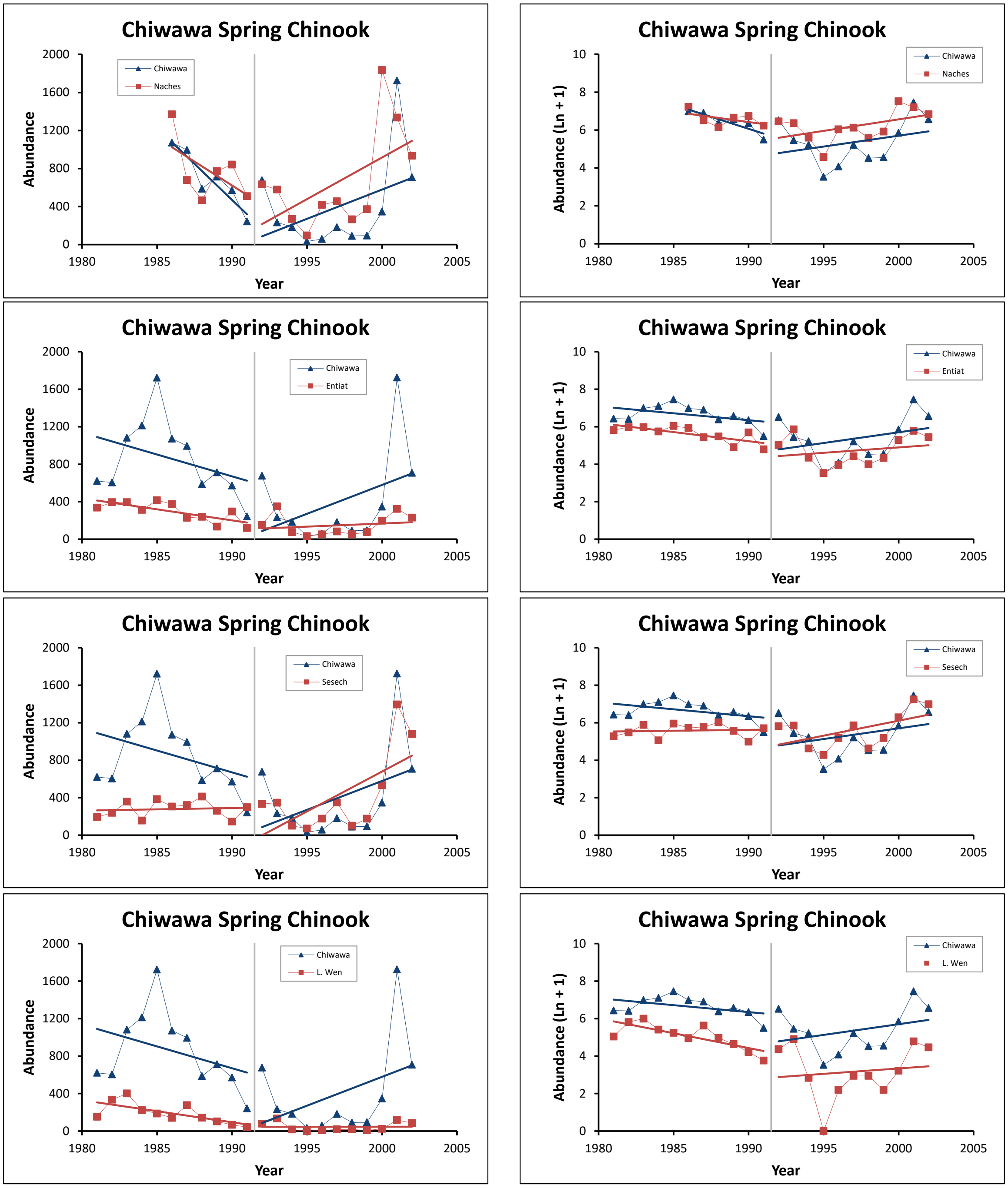

Figure 9. Trends in spring Chinook spawner abundance in the Chiwawa and reference populations. The vertical lines in the figures separate the pre- and post-supplementation periods. Figures on the left include untransformed spawner abundance data; those on the right include natural-log transformed data.

Table 12. Pearson correlation coefficients and t-test results comparing slopes of spawner abundance trends between reference populations and the Chiwawa spring Chinook population before and during the supplementation periods; for correlation coefficients, an asterisk (*) indicates significance at P < 0.05. Analyses include both untransformed and natural-log transformed spawner abundance data.

Reference population	Pearson correlation coefficient		Test on slopes			
			t-value		P-value	
	Before	During	Before	During	Before	During
Spawner Abundance						
Naches	0.684*	0.595	-0.659	-0.414	0.528	0.684
Entiat	0.598*	0.672*	-0.596	1.162	0.559	0.260
Sesech	0.274	0.904*	-1.265	-0.418	0.222	0.681
Little Wenatchee	0.399	0.685*	-0.591	1.330	0.562	0.200
LN Spawner Abundance						
Naches	0.642*	0.813*	-1.323	-0.047	0.222	0.963
Entiat	0.652*	0.860*	0.412	0.422	0.685	0.678
Sesech	0.149	0.878*	-1.431	-0.333	0.170	0.743
Little Wenatchee	0.670*	0.861*	1.325	0.316	0.202	0.756

Trend analysis indicated that the relationship of slopes of NORs between the Chiwawa and reference populations did not change significantly after the initiation of supplementation (Figure 10; Table 13). Before supplementation, Chiwawa NORs trended downward more strongly than the reference populations (Figure 10). However, during the supplementation period, both the Chiwawa and reference population NORs trended upward in parallel. In nearly all treatment/reference comparisons, the Pearson correlation coefficient was greater in the pre-supplementation period than in the supplementation period (Table 13).

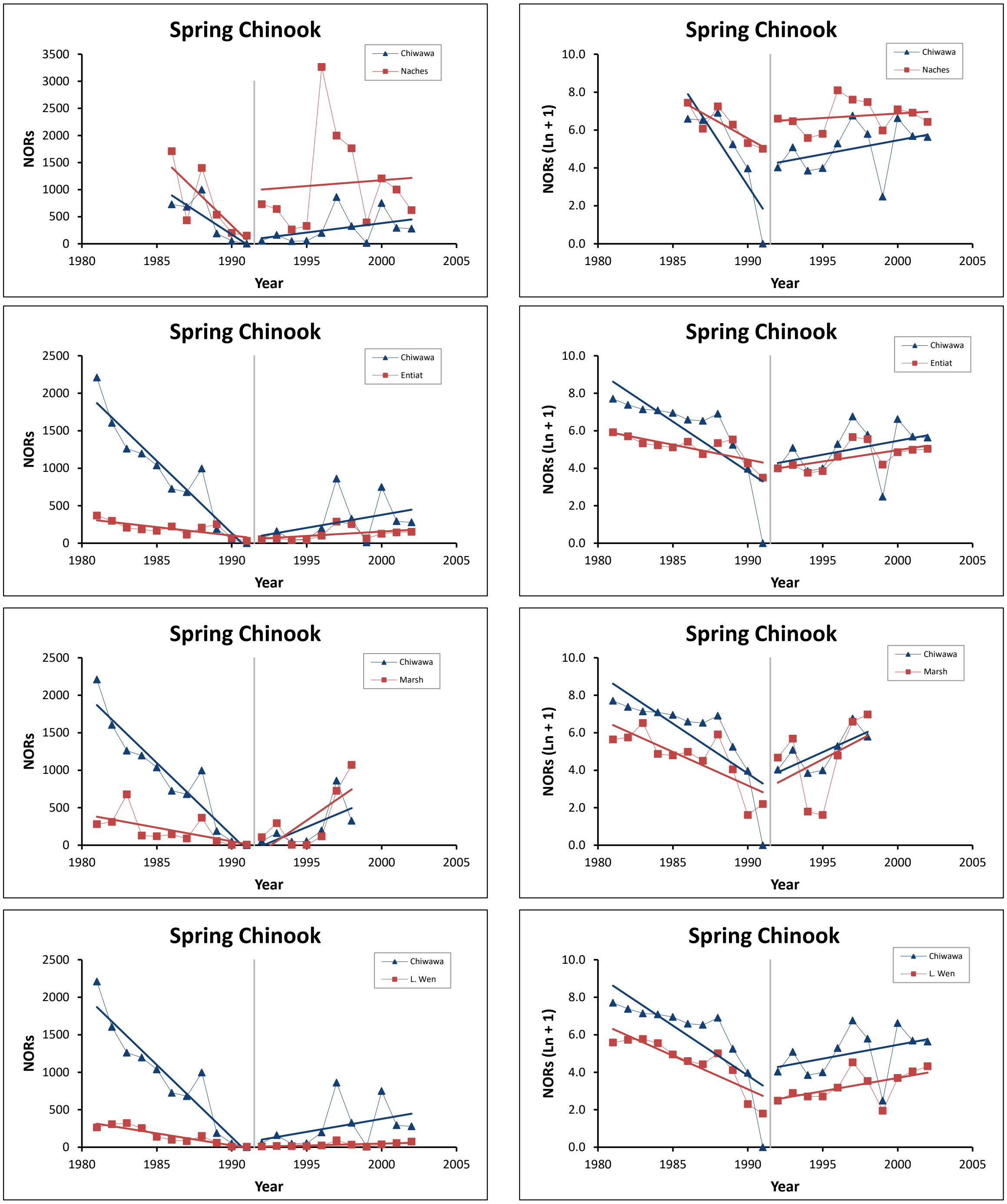

Figure 10. Trends in spring Chinook natural-origin recruits (NORs) in the Chiwawa and reference populations. The vertical lines in the figures separate the pre- and post-supplementation periods. Figures on the left include untransformed NORs; those on the right include natural-log transformed data.

Table 13. Pearson correlation coefficients and t-test results comparing slopes of natural-origin recruits trends between reference populations and the Chiwawa spring Chinook population before and during the supplementation periods; for correlation coefficients, an asterisk (*) indicates significance at $P < 0.05$. Analyses include both untransformed and natural-log transformed natural-origin recruits.

Reference population	Pearson correlation coefficient		Test on slopes			
			t-value		P-value	
	Before	During	Before	During	Before	During
Natural-Origin Recruits						
Naches	0.803*	0.432	0.666	0.140	0.524	0.890
Entiat	0.795*	0.754*	-7.495	0.847	0.000	0.408
Marsh	0.605*	0.677*	-5.786	-0.718	0.000	0.489
Little Wenatchee	0.880*	0.758*	-7.206	1.128	0.000	0.274
LN Natural-Origin Recruits						
Naches	0.824*	0.710*	-1.985	0.693	0.082	0.497
Entiat	0.886*	0.796*	-2.563	0.202	0.019	0.842
Marsh	0.830*	0.835*	-1.038	-0.134	0.313	0.896
Little Wenatchee	0.927*	0.898*	-1.150	0.046	0.265	0.964

As with NORs and spawner abundance data, trend analysis indicated that the relationship of slopes of productivity (recruits/spawner) between the Chiwawa and reference populations did not change significantly after the initiation of supplementation (Figure 11; Table 14). This was true for both transformed and untransformed productivity data. Before supplementation, productivities trended down in both the Chiwawa and reference populations (Figure 11). During the period of supplementation, productivities fluctuated widely in both the Chiwawa and reference populations. Nevertheless, during the supplementation period, productivities generally increased in both the reference and Chiwawa populations. Unlike with spawner abundance, the Pearson correlation coefficients resulting from analysis of productivity data were generally higher in the pre-supplementation period than during the supplementation period (Table 14).

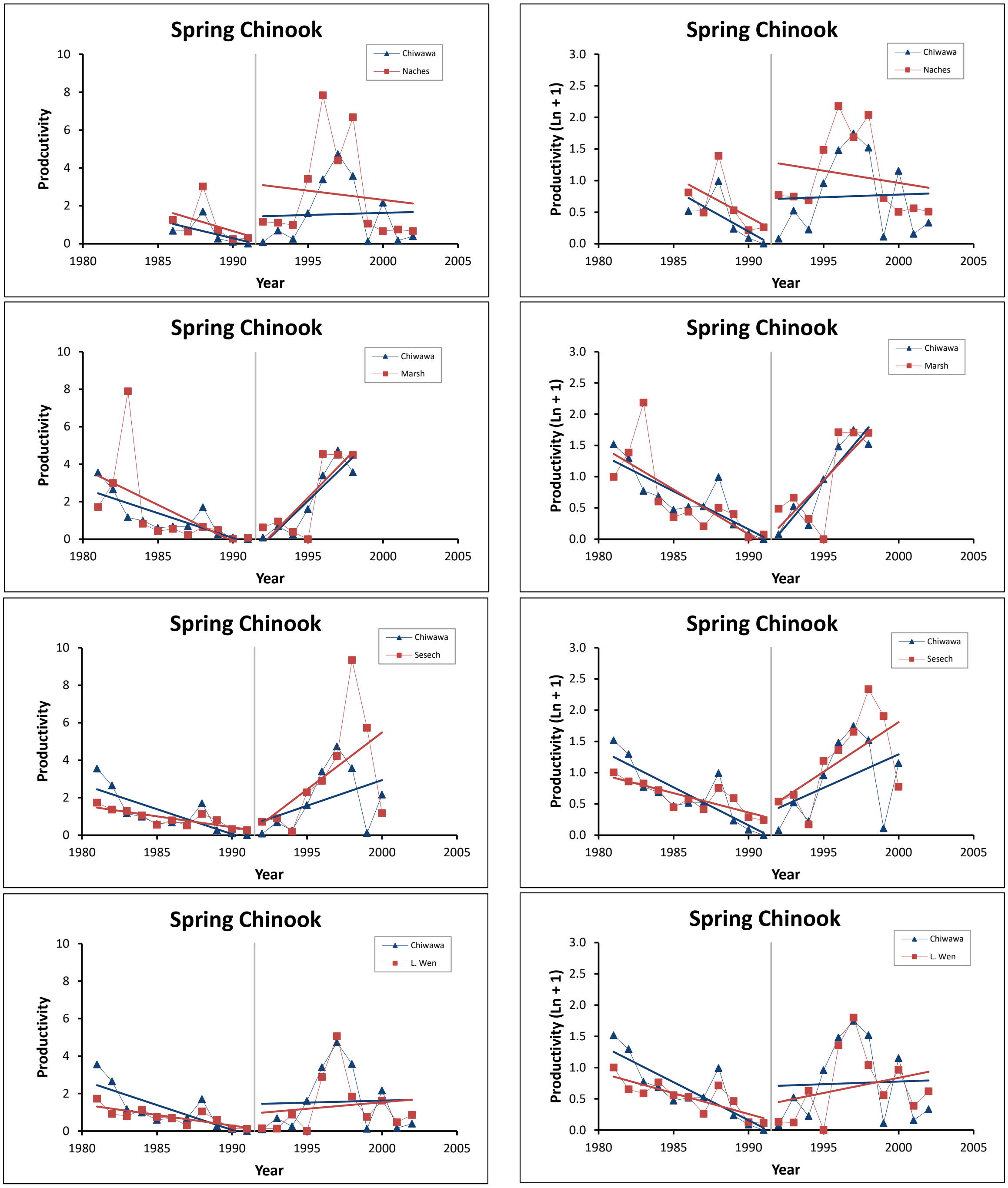

Figure 11. Trends in spring Chinook productivity (recruits/spawner) in the Chiwawa (supplemented) and reference populations. The vertical lines in the figures separate the pre- and post-supplementation periods. Figures on the left include untransformed productivity data; those on the right include natural-log transformed data.

Table 14. Pearson correlation coefficients and t-test results comparing slopes of productivity (recruits/spawner) trends between reference populations and the Chiwawa spring Chinook population before and during the supplementation periods; for correlation coefficients, an asterisk (*) indicates significance at $P < 0.05$. Analyses include both untransformed and natural-log transformed productivity data.

Reference population	Pearson correlation coefficient		Test on slopes			
			t-value		P-value	
	Before	During	Before	During	Before	During
Productivity						
Naches	0.960*	0.802*	0.169	0.387	0.870	0.703
Marsh	0.320	0.910*	0.605	-0.132	0.553	0.898
Sesech	0.903*	0.491	-2.059	-0.837	0.054	0.417
Little Wenatchee	0.848*	0.864*	-2.065	-0.213	0.054	0.834
LN Productivity						
Naches	0.944*	0.805*	-0.042	0.526	0.968	0.605
Marsh	0.610*	0.804*	0.428	0.281	0.674	0.784
Sesech	0.913*	0.531	-2.050	-0.463	0.055	0.651
Little Wenatchee	0.862*	0.751*	-1.811	-0.480	0.087	0.637

Using trend analysis, we found no evidence that the supplementation program has significantly increased the spawner abundance and NORs of spring Chinook in the Chiwawa Basin. Even though we documented an increasing trend in spawner abundance and NORs during the supplementation period, a similar increase in spawner abundance and NORs was observed in the reference populations. In addition, we found no evidence that the supplementation program has increased the productivity of spring Chinook in the Chiwawa Basin. Importantly, the productivity of spring Chinook in the Chiwawa Basin did not trend downward during the supplementation period. Thus, based on trend analysis, it appears that the supplementation program has not increased or decreased the abundance and productivity of spring Chinook in the Chiwawa Basin.

We note that this exercise only tests the slopes of the trend lines. It does not test for differences in elevations of the trend lines. A supplementation program could increase spawner abundance, NORs, and productivity of the target population without changing the slopes of the trend lines. That is, supplementation could cause the elevation of the trend line to be greater during the supplementation period than during the pre-supplementation period. In the next section we evaluate elevation differences by testing mean differences before and after supplementation.

Analysis of Mean Differences, Ratios, and Rates

For assessing mean differences between supplemented and reference populations, we derived three different response variables using transformed and untransformed spawner abundance, NORs, and productivity data. The first included difference scores, which were calculated as the difference between paired treatment and reference data (T-R). The second included ratios, which were calculated as the ratio of paired treatment and reference data (T/R). Finally, we calculated the differences in annual changes in paired treatment and reference population data (ΔT-ΔR; see footnote #2).

If the hatchery program is successfully supplementing the natural spring Chinook population, the mean difference or ratio score of paired spawner abundance data and NORs during the supplementation period should be greater than the pre-supplementation period. For productivity, the mean difference or ratio score during the supplementation period should be equal to or higher than the pre-supplementation period. We tested the following statistical hypotheses.

Spawner Abundance and NORs:

> Ho: Mean Difference (or Ratio) before supplementation ≥ Mean Difference (or Ratio) during supplementation.
>
> Ha: Mean Difference (or Ratio) before supplementation < Mean Difference (or Ratio) during supplementation (i.e., $\mu_{pre} - \mu_{post} < 0$).

Productivity (Recruits/Spawner):

> Ho: Mean Difference (or Ratio) before supplementation ≤ Mean Difference (or Ratio) during supplementation.
>
> Ha: Mean Difference (or Ratio) before supplementation > Mean Difference (or Ratio) during supplementation (i.e., $\mu_{pre} - \mu_{post} > 0$).[20]

For each set of response variables, we tested before/after supplementation effects using a one-tailed Aspin-Welch unequal-variance test. We used the Aspin-Welch unequal-variance test instead of Student's t-test, because in nearly every case, the variances of response variables in the pre-treatment and supplementation periods were unequal.[21] This was true even for natural-log transformed variables. We used the modified Levene equal-variance test to assess the equality of variance. In some cases, the distributions of response variables were not normal (based on the Omnibus Normality test and examination of histograms, normal probability plots, and box plots). Therefore, we also used a randomization test, based on 10,000 Monte Carlo simulations, to assess differences in response variables before and during supplementation. The randomization procedure only allowed the testing of two-tailed hypotheses. Therefore, we generated 95% confidence intervals on the mean difference ($\mu_{pre} - \mu_{post}$) using bootstrapping methods to determine the direction of the difference. We generated 5,000 bootstrap samples to calculate confidence intervals.

All these statistical methods assume that the samples of derived difference or ratio scores from the pre-supplementation and supplementation periods were independent. However, BACI designs, like time-series trend analysis, are repeated-measures designs and therefore are susceptible to temporal correlations in the data. This means that the two samples of difference or ratio scores may not be independent. Under this scenario, ARIMA models can be used to describe the correlation structure in temporal data (Gotelli and Ellison 2004). ARIMA models can be fit individually to the reference and supplemented time series data, or to a derived data series created by taking the ratio or difference of the supplemented/reference data at each time step. ARIMA models, however, require a long time series (N > 40) and therefore we could not use them to model

20 Because of the logic of null hypothesis testing, the rejection of the null hypothesis of no difference in productivity would mean that the supplementation program has reduced the productivity of the target population (here rejection of the null indicates "harm"). Notice that the rejection of the null hypothesis of no difference in spawner abundance means that the supplementation program has improved the spawner abundance in the target population (here rejection of the null indicates "benefit").

21 In cases in which the variances were equal, both the Aspin-Welch test and Student's t-test gave the same result.

the spring Chinook data. Thus, we acknowledge that our analyses may be confounded if the samples are not independent.

Difference Scores (T-R)

Analysis of supplementation effects on spawner abundance using difference scores indicated that supplementation did not significantly increase spawning abundance in the Chiwawa Basin (Table 15; Figure 12). Only the Little Wenatchee-Chiwawa pairing using transformed abundance data indicated a significant increase in spawning abundance following supplementation. The randomization test indicated significant differences in several of the treatment-reference pairs; however, the bootstrap CIs indicated that those differences were in the wrong direction (i.e., CIs > 0). That is, compared to the reference populations, spawner abundance decreased in the Chiwawa Basin during the supplementation period (Figure 12).

Table 15. Results of the Aspin-Welch unequal-variance test, randomization test (based on 10,000 Monte Carlo samples), and 95% CI (based on 5,000 bootstrap samples) on transformed and untransformed spawner abundance data. Tests determined if the mean difference scores during the supplementation period were greater than mean difference scores during the pre-supplementation period.

Reference population	Aspin-Welch unequal-variance test			Randomization test P-value	Bootstrap 95% CI
	t-value	P-value	Effect size		
Spawner Abundance					
Naches	1.066	0.848	184	0.322	-162 – 472
Entiat	1.872	0.962	316	0.078	17 – 633
Sesech	4.502	0.999	607	0.000	349 – 851
Little Wenatchee	1.773	0.954	321	0.093	0 – 690
LN Spawner Abundance					
Naches	2.603	0.990	0.701	0.026	0.210 – 1.214
Entiat	1.701	0.946	0.388	0.108	-0.033 – 0.811
Sesech	5.394	0.999	1.327	0.000	0.891 – 1.805
Little Wenatchee	-2.259	0.018	0.609	0.034	-1.125 – -0.097

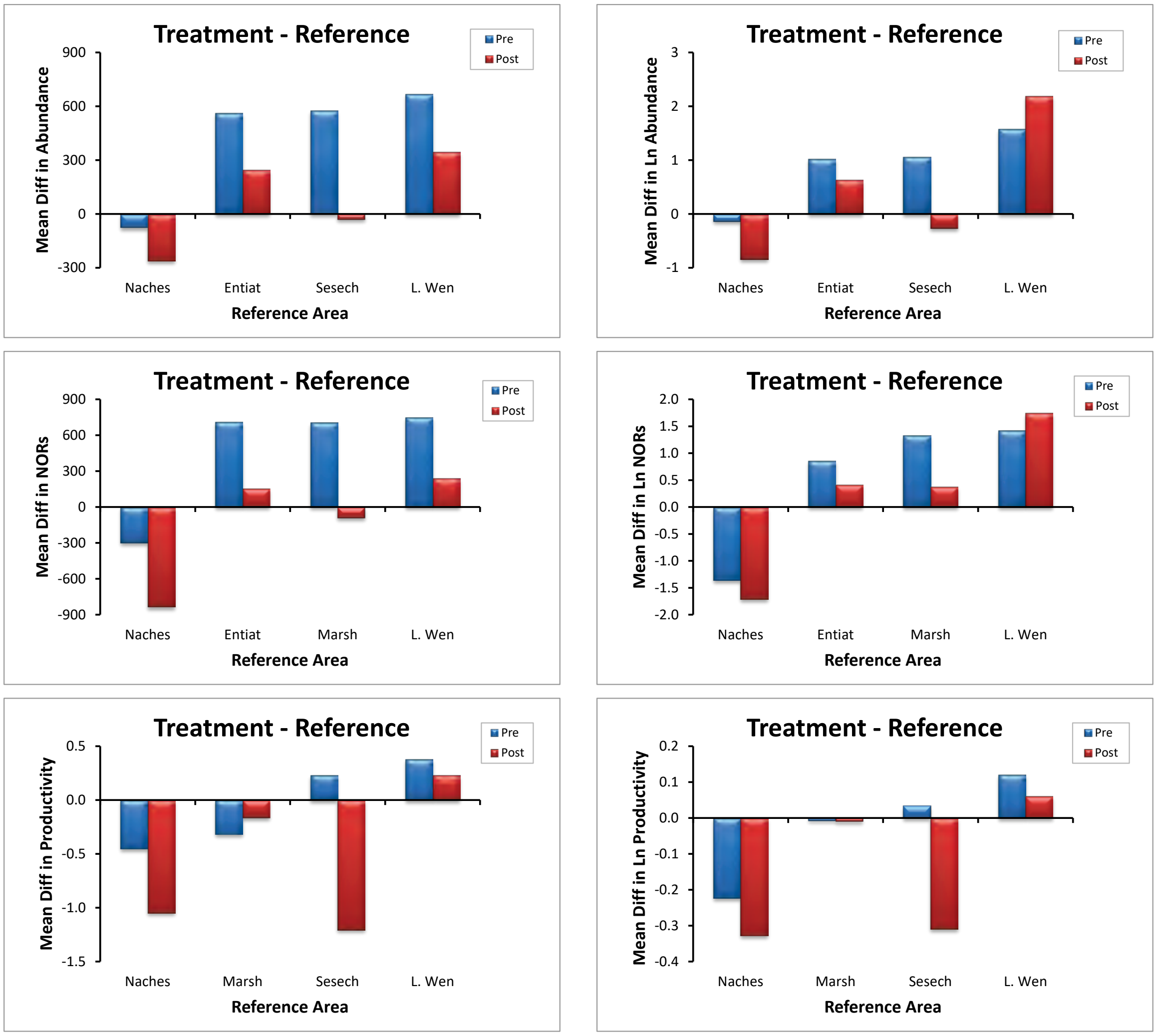

Figure 12. Mean difference (Treatment – Reference) scores of untransformed (figures on the left) and transformed (figures on the right) spawner abundance, natural-origin recruits (NORs), and productivity data before (pre) and after (post) spring Chinook supplementation in the Chiwawa Basin. Positive effects of supplementation on spawner abundance and NORs are indicated when the post-supplementation (red) bars are greater than their corresponding pre-supplementation (blue) bars. Negative effects of supplementation on productivity are indicated when the pre-supplementation (blue) bars are greater than their corresponding post-supplementation (red) bars.

Analysis of supplementation effects on NORs using difference scores indicated that supplementation did not significantly increase NORs in the Chiwawa Basin (Table 16; Figure 12). The randomization test indicated significant differences in several of the treatment-reference pairs; however, the bootstrap CIs indicated that those differences were in the wrong direction. That is, compared to the reference populations, NORs decreased in the Chiwawa Basin during the supplementation period (Figure 12).

Table 16. Results of the Aspin-Welch unequal-variance test, randomization test (based on 10,000 Monte Carlo samples), and 95% CI (based on 5,000 bootstrap samples) on transformed and untransformed natural-origin recruits. Tests determined if the mean difference scores during the supplementation period were greater than mean difference scores during the pre-supplementation period.

Reference population	Aspin-Welch unequal-variance test			Randomization test P-value	Bootstrap 95% CI
	t-value	P-value	Effect size		
Natural-Origin Recruits					
Naches	1.787	0.953	537	0.081	-60 – 1039
Entiat	2.879	0.993	558	0.007	201 – 916
Marsh	3.817	0.999	795	0.001	381 – 1153
Little Wenatchee	2.668	0.991	510	0.013	145 – 863
LN Natural-Origin Recruits					
Naches	0.430	0.659	0.354	0.686	-0.948 – 1.975
Entiat	0.788	0.779	0.445	0.465	-0.504 – 1.583
Marsh	1.45	0.916	0.953	0.168	-0.169 – 2.243
Little Wenatchee	-0.813	0.214	-0.319	0.506	-0.948 – 0.484

Analysis of supplementation effects on productivity (adult recruits/spawner) using difference scores indicated that supplementation did not significantly decrease productivity in the Chiwawa Basin (Table 17; Figure 12). All tests, regardless of treatment-reference pairs, indicated that productivity did not change significantly during the supplementation period. These tests indicate that supplementation has not negatively affected the productivity of spring Chinook salmon in the Chiwawa Basin.

Table 17. Results of the Aspin-Welch unequal-variance test, randomization test (based on 10,000 Monte Carlo samples), and 95% CI (based on 5,000 bootstrap samples) on transformed and untransformed productivity data. Tests determined if the mean difference scores during the supplementation period were less than mean difference scores during the pre-supplementation period.

Reference population	Aspin-Welch unequal-variance test			Randomization test P-value	Bootstrap 95% CI
	t-value	P-value	Effect size		
Productivity					
Naches	1.134	0.139	0.594	0.296	-0.427 – 1.540
Marsh	-0.203	0.579	0.152	0.932	-0.304 – 1.381
Sesech	1.607	0.071	1.435	0.151	-0.403 – 2.917
Little Wenatchee	0.431	0.335	0.147	0.665	-0.498 – 0.762
LN Productivity					
Naches	0.770	0.227	0.104	0.480	-0.125 – 0.378
Marsh	0.012	0.495	0.003	0.992	-0.375 – 0.493
Sesech	1.463	0.087	0.343	0.161	-0.135 – 0.732
Little Wenatchee	0.390	0.351	0.060	0.701	-0.229 – 0.347

Ratio Scores (T/R)

As with difference scores, analysis of supplementation effects on spawner abundance using ratios indicated that supplementation did not significantly increase spawning abundance in the Chiwawa Basin (Table 18; Figure 13). Only the Little Wenatchee-Chiwawa pairing indicated a significant increase in spawning abundance following supplementation. Analysis with both transformed and untransformed Little Wenatchee-Chiwawa data indicated a significant effect. In contrast, only difference scores derived from transformed data indicated a significant effect. The randomization test indicated significant differences in several of the treatment-reference pairs; however, the bootstrap CIs indicated that those differences were in the wrong direction. That is, compared to the reference populations, spawner abundance decreased in the Chiwawa Basin during the supplementation period (Figure 13).

Table 18. Results of the Aspin-Welch unequal-variance test, randomization test (based on 10,000 Monte Carlo samples), and 95% CI (based on 5,000 bootstrap samples) on transformed and untransformed spawner abundance data. Tests determined if the mean ratios during the supplementation period were greater than mean ratios during the pre-supplementation period.

Reference population	Aspin-Welch unequal-variance test			Randomization test P-value	Bootstrap 95% CI
	t-value	P-value	Effect size		
Spawner Abundance					
Naches	2.110	0.970	0.398	0.065	0.056 – 0.737
Entiat	1.254	0.888	0.731	0.223	-0.365 – 1.834
Sesech	4.251	0.999	2.428	0.000	1.278 – 3.435
Little Wenatchee	-2.649	0.009	3.897	0.018	-6.579 – -1.202
LN Spawner Abundance					
Naches	2.783	0.993	0.120	0.021	0.045 – 0.199
Entiat	1.273	0.890	0.055	0.220	-0.026 – 0.135
Sesech	5.143	0.999	0.244	0.000	0.160 – 0.335
Little Wenatchee	-3.462	0.002	0.327	0.003	-0.516 – -0.154

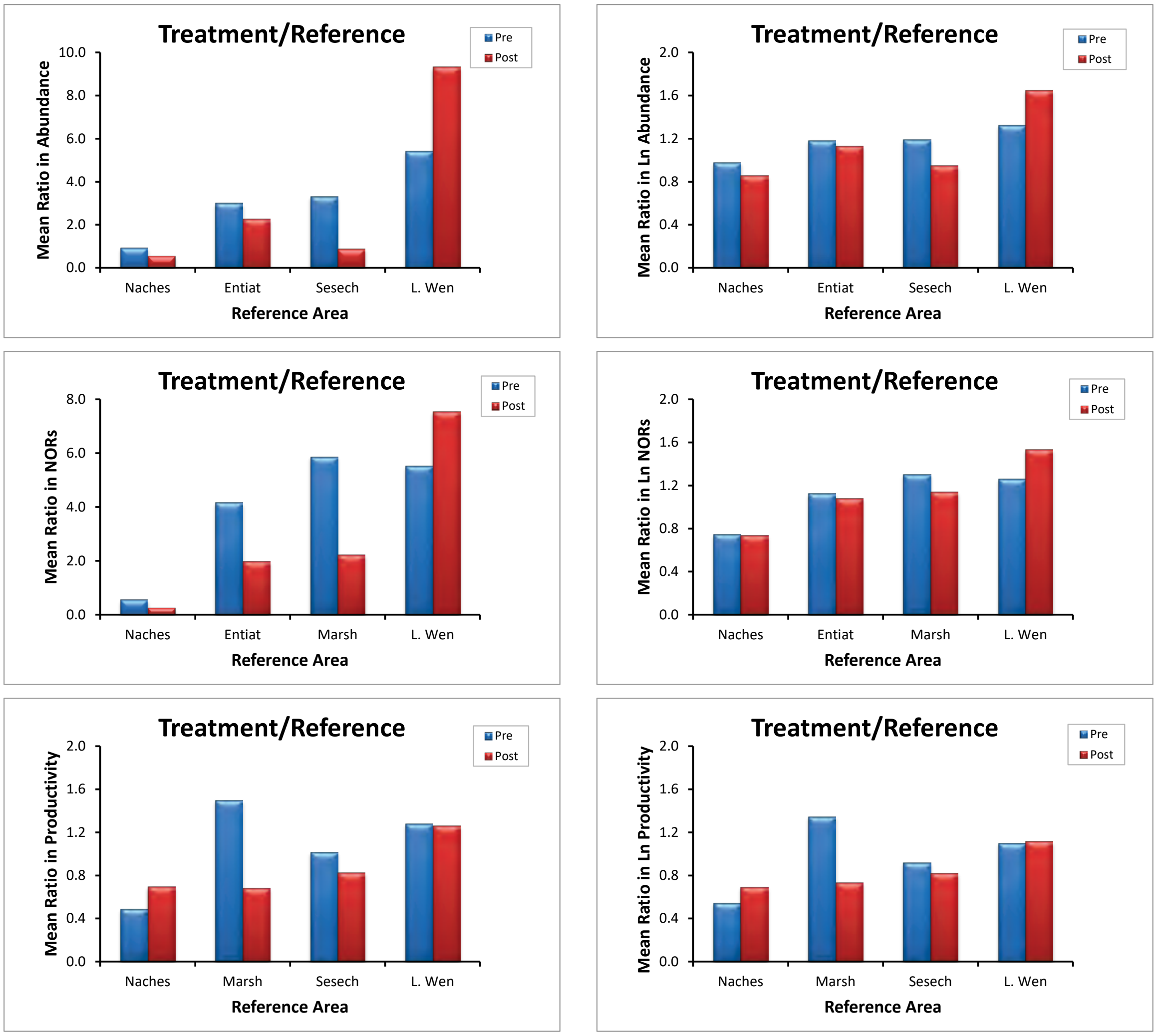

Figure 13. Mean ratios (Treatment/Reference) scores of untransformed (figures on the left) and transformed (figures on the right) spawner abundance, natural-origin recruits (NORs), and productivity data before (pre) and after (post) spring Chinook supplementation in the Chiwawa Basin. Positive effects of supplementation on spawner abundance and NORs are indicated when the post-supplementation (red) bars are greater than their corresponding pre-supplementation (blue) bars. Negative effects of supplementation on productivity are indicated when the pre-supplementation (blue) bars are greater than their corresponding post-supplementation (red) bars.

Analysis of supplementation effects on NORs using ratios indicated that supplementation did not significantly increase NORs in the Chiwawa Basin (Table 19; Figure 13). Only the Little Wenatchee-Chiwawa pairing indicated a significant increase in transformed NORs following supplementation. The randomization test indicated significant differences in several of the treatment-reference pairs; however, the bootstrap CIs indicated that those differences were in the wrong direction. That is, compared to the reference populations, NORs decreased in the Chiwawa Basin during the supplementation period (Figure 13).

Table 19. Results of the Aspin-Welch unequal-variance test, randomization test (based on 10,000 Monte Carlo samples), and 95% CI (based on 5,000 bootstrap samples) on transformed and untransformed natural-origin recruits. Tests determined if the mean ratios during the supplementation period were greater than mean ratios during the pre-supplementation period.

Reference population	Aspin-Welch unequal-variance test			Randomization test P-value	Bootstrap 95% CI
	t-value	P-value	Effect size		
Natural-Origin Recruits					
Naches	1.318	0.881	0.306	0.219	-0.157 – 0.670
Entiat	2.447	0.987	2.172	0.028	0.593 – 3.871
Marsh	2.001	0.965	3.638	0.075	0.532 – 7.201
Little Wenatchee	-1.148	0.136	2.020	0.284	-5.055 – 1.516
LN Natural-Origin Recruits					
Naches	0.057	0.522	0.009	0.967	-0.230 – 0.351
Entiat	0.359	0.638	0.049	0.759	-0.173 – 0.336
Marsh	0.603	0.721	0.161	0.579	-0.272 – 0.681
Little Wenatchee	-1.914	0.038	0.277	0.027	-0.504 – 0.031

Analysis of supplementation effects on productivity (adult recruits/spawner) using ratios indicated that supplementation did not significantly decrease productivity in the Chiwawa Basin (Table 20; Figure 13). Although the Aspin-Welch test indicated a significant effect when comparing the Chiwawa to the Marsh Creek population, both the randomization test and the bootstrap CI did not indicate a significant effect. These tests indicate that supplementation has probably not negatively affected the productivity of spring Chinook salmon in the Chiwawa Basin.

Table 20. Results of the Aspin-Welch unequal-variance test, randomization test (based on 10,000 Monte Carlo samples), and 95% CI (based on 5,000 bootstrap samples) on transformed and untransformed productivity data. Tests determined if the mean ratios during the supplementation period were less than mean ratios during the pre-supplementation period.

Reference population	Aspin-Welch unequal-variance test			Randomization test P-value	Bootstrap 95% CI
	t-value	P-value	Effect size		
Productivity					
Naches	-0.677	0.745	0.209	0.688	-0.700 – 0.425
Marsh	2.236	0.022	0.814	0.054	0.112 – 1.459
Sesech	0.677	0.253	0.191	0.515	-0.356 – 0.718
Little Wenatchee	0.033	0.487	0.018	0.979	-0.879 – 1.162
LN Productivity					
Naches	-0.639	0.734	0.148	0.616	-0.548 – 0.316
Marsh	1.952	0.036	0.613	0.081	-0.003 – 1.170
Sesech	0.447	0.330	0.098	0.663	-0.301 – 0.515
Little Wenatchee	-0.034	0.513	0.015	0.982	-0.692 – 0.861

Difference of Annual Difference Scores (ΔT-ΔR)

Analysis of supplementation effects on spawner abundance using difference scores of annual changes indicated that supplementation did not significantly increase spawning abundance in the Chiwawa Basin (Table 21; Figure 14). None of the statistical analyses detected a significant increase in annual change in the Chiwawa Basin relative to the reference populations.

Table 21. Results of the Aspin-Welch unequal-variance test, randomization test (based on 10,000 Monte Carlo samples), and 95% CI (based on 5,000 bootstrap samples) on transformed and untransformed spawner abundance data. Tests determined if mean difference scores of annual change during the supplementation period were greater than mean difference scores of annual change during the pre-supplementation period.

Reference population	Aspin-Welch unequal-variance test			Randomization test P-value	Bootstrap 95% CI
	t-value	P-value	Effect size		
Spawner Abundance					
Naches	0.009	0.503	2	0.995	-502 – 539
Entiat	-0.239	0.407	48	0.826	-414 – 327
Sesech	-0.126	0.451	20	0.902	-311 – 266
Little Wenatchee	-0.318	0.377	65	0.761	-452 – 311
LN Spawner Abundance					
Naches	-0.425	0.339	0.142	0.698	-0.744 – 0.466
Entiat	-0.084	0.467	0.028	0.933	-0.681 – 0.593
Sesech	-0.349	0.366	0.117	0.740	-0.741 – 0.515
Little Wenatchee	0.001	0.500	0.000	0.999	-0.663 – 0.687

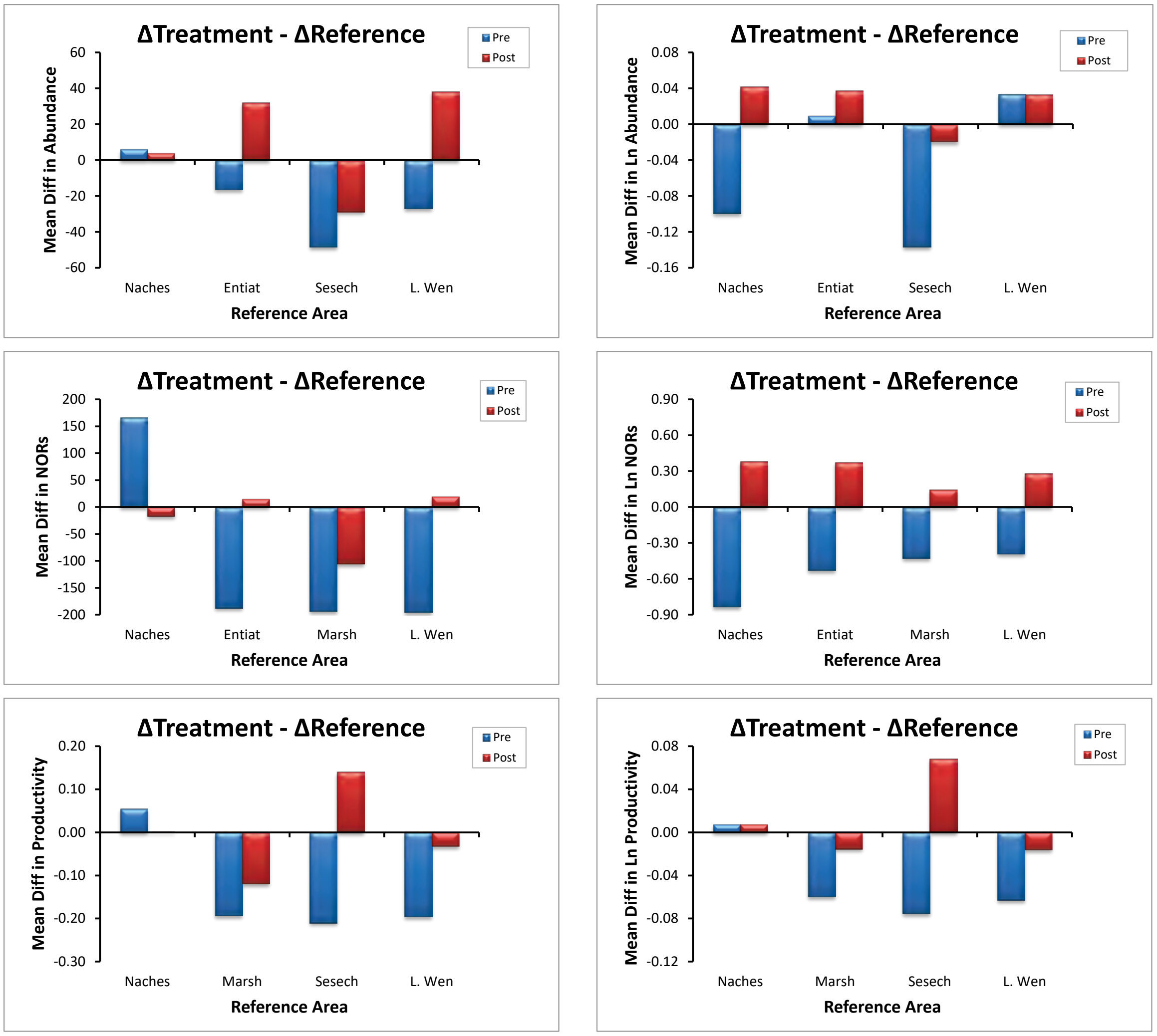

Figure 14. Mean difference scores of annual changes (ΔTreatment – ΔReference) of untransformed (figures on the left) and transformed (figures on the right) spawner abundance and productivity data before (pre) and after (post) spring Chinook supplementation in the Chiwawa Basin.

Analysis of supplementation effects on NORs using difference scores of annual changes indicated that supplementation did not significantly increase NORs in the Chiwawa Basin (Table 22; Figure 14). None of the statistical analyses detected a significant increase in annual change in the Chiwawa Basin relative to the reference populations.

Table 22. Results of the Aspin-Welch unequal-variance test, randomization test (based on 10,000 Monte Carlo samples), and 95% CI (based on 5,000 bootstrap samples) on transformed and untransformed natural-origin recruits. Tests determined if mean difference scores of annual change during the supplementation period were greater than mean difference scores of annual change during the pre-supplementation period.

Reference population	Aspin-Welch unequal-variance test			Randomization test P-value	Bootstrap 95% CI
	t-value	P-value	Effect size		
Natural-Origin Recruits					
Naches	0.399	0.652	184	0.741	-699 – 989
Entiat	-1.381	0.092	202	0.194	-471 – 86
Marsh	-0.505	0.311	88	0.624	-425 – 206
Little Wenatchee	-1.437	0.084	214	0.179	-481 – 64
LN Natural-Origin Recruits					
Naches	-1.301	0.118	1.214	0.224	-2.783 – 0.531
Entiat	-1.408	0.088	0.901	0.188	-1.977 – 0.387
Marsh	-0.712	0.244	0.570	0.517	-1.952 – 0.975
Little Wenatchee	-1.154	0.132	0.674	0.274	-1.706 – 0.497

Analysis of supplementation effects on productivity (adult recruits/spawner) using difference scores of annual changes indicated that supplementation did not significantly decrease productivity in the Chiwawa Basin (Table 23; Figure 14). All tests, regardless of treatment-reference pairs, indicated that productivity did not change significantly during the supplementation period.

Table 23. Results of the Aspin-Welch unequal-variance test, randomization test (based on 10,000 Monte Carlo samples), and 95% CI (based on 5,000 bootstrap samples) on transformed and untransformed productivity data. Tests determined if the mean difference scores of annual change during the supplementation period were less than mean difference scores of annual change during the pre-supplementation period.

Reference population	Aspin-Welch unequal-variance test			Randomization test P-value	Bootstrap 95% CI
	t-value	P-value	Effect size		
Productivity					
Naches	0.002	0.475	0.054	0.952	-1.464 – 1.583
Marsh	-0.063	0.525	0.074	0.948	-2.395 – 2.031
Sesech	-0.317	0.621	0.350	0.628	-2.387 – 1.695
Little Wenatchee	-0.347	0.633	0.163	0.728	-1.023 – 0.725
LN Productivity					
Naches	0.000	0.500	0.000	0.999	-0.408 – 0.445
Marsh	-0.126	0.549	0.044	0.904	-0.715 – 0.595
Sesech	-0.449	0.668	0.144	0.727	-0.685 – 0.509
Little Wenatchee	-0.200	0.578	0.047	0.842	-0.466 – 0.391

We believe results from analysis of mean differences of annual change (ΔT-ΔR) in spawning abundance, NORs, and productivity are difficult to interpret and may be insensitive to treatment effects. A simpler analysis, which is also easier to interpret, is the use of trend analysis. Therefore, we recommend that analyses using differences of annual change be replaced with trend analysis.

Corrections for Density Dependence and Carrying Capacity

The analyses described above assume that the density of spawners or recruits does not affect the survival and productivity of fish. However, it is well known that the density of fish can affect the number of recruits as well as the productivity of the population. This occurs through the relationship between density and mortality. Mortality of fish can be generally classified as density independent and density dependent. In general, when densities are low, the mortality is density independent, but as densities increase, the amount of density-dependent mortality increases. Monitoring programs can make use of this information to derive density-corrected estimates of productivity. In this section, we describe two different methods for deriving density-corrected estimates of productivity.

The first method controlled the effects of density on productivity (adult recruits/spawner; R/S) by partitioning observed productivities into density-independent and density-dependent productivity. When abundance is below the minimum number of spawners (S) needed to produce the maximum number of recruits (K_{sp}), the observed productivity is used in statistical tests. However, when the abundance is equal to or above K_{sp}, the modeled value of productivity (R/K_{sp}) is used in statistical tests.

$$\boldsymbol{Adj\ R/S} = \begin{cases} \boldsymbol{R/S,} & \boldsymbol{if\ S < K_{sp}} \\ \boldsymbol{R/K_{sp},} & \boldsymbol{if\ S \geq K_{sp}} \end{cases}$$

The density-independent and density-dependent productivities were then combined in a single test.

The second method was based on one of the goals of supplementation, which is to fill the capacity of the environment with fish. This method corrects for differences in carrying capacities between the supplemented and reference populations. We did this by calculating the percent saturation of NORs. That is, we calculated the fraction of the habitat (τ) that was filled with NORs by dividing the observed NOR by the modeled maximum number of NORs (K_R) that the habitat could support.

$$\boldsymbol{\tau} = \frac{\boldsymbol{NOR_{obs}}}{\boldsymbol{K_R}}$$

Note that 1-τ represents the unused portion of the carrying capacity and is the term that is multiplied by the exponential growth equation to derive the logistic growth equation. We included τ in the statistical analyses.

These two methods require the estimation of carrying capacity (K_R) and the spawning abundance that produces the maximum number of recruits (K_{sp}). We estimated these parameters for both reference populations and the supplemented population using Ricker, Beverton-Holt, and smooth hockey stick stock-recruitment models. We used only spawner abundance as a predictor of subsequent brood recruitment. We made the following assumptions in proceeding with the analysis:

- Density-dependent mortality—For some time period before recruitment, the brood instantaneous mortality rate is proportional to the number of parent spawners (Ricker 1954).
- Lognormal variation—At any particular spawning stock size, the variation in recruitment is log-normally distributed about its average, and acts multiplicatively (Quinn and Deriso 1999).
- Measurement error—Error in spawning stock size estimates (measurement error) is small relative to the range of spawning stock sizes observed (Hilborn and Walters 1992). Variation in realized recruitment at any particular spawning stock size (process error) dominates recruitment measurement error.
- Stationarity—The average stock-recruitment relationship is constant over time (Hilborn and Walters 1992). That is, environmental conditions randomly affect survival independent of stock size or time.

In general, the methods we used to fit the models to the data followed those outlined in Hilborn and Walters (1992) and Froese (2008). The Ricker model, which assumes that the number of recruits increases to a maximum and then declines as the number of spawners increases, takes the form:

$$\boldsymbol{E(R) = \alpha S e^{-\beta S}}$$

where E(R) is the expected recruitment, S is spawner abundance, α is the number of recruits per spawner at low spawning levels, and β describes how quickly the recruits per spawner drop as the number of spawners increases. We estimated K_R as:

$$\boldsymbol{K_R = \left(\frac{\alpha}{\beta}\right) e^{-1}}$$

and K_{sp} as:

$$\boldsymbol{K_{sp} = \frac{1}{\beta}}$$

The Beverton-Holt model assumes that the number of recruits increases constantly toward an asymptote as the number of spawners increases. After the asymptote is reached, the number of recruits neither increases nor decreases. The asymptote represents the maximum number of recruits the system can support (i.e., carrying capacity for the system; K_R). The Beverton-Holt curve takes the form:

$$\boldsymbol{E(R) = \frac{(\alpha S)}{(\beta + S)}}$$

where E(R) and S are as above, α is the maximum number of recruits produced (K_R), and β is the number of spawners needed to produce (on average) recruits equal to one-half the maximum number of recruits. Because $K_{sp} = \infty$ in the Beverton-Holt model, we estimated K_{sp} as the number of spawners needed to produce 0.99(K_R).

Like the Beverton-Holt model, the smooth hockey stick model assumes that the number of recruits increases toward an asymptote (carrying capacity; K_R) as the number of spawners increases. After the carrying capacity is reached, the number of recruits neither increases nor decreases. The carrying capacity represents the maximum number of recruits the system can support. This curve

takes the form (Froese 2008):

$$\boldsymbol{E(R) = R_{\infty}\left(1 - e^{-\left(\frac{\alpha}{R_{\infty}}\right)S}\right)}$$

where E(R) and S are as above, α is the slope at the origin of the spawner-recruitment curve, and R_{∞} is the carrying capacity of recruits (note that $R_{\infty} = K_R$). As with the Beverton-Holt model, we estimated K_{sp} as the number of spawners needed to produce 0.99(K_R).

We used non-linear regression to fit the three models to spawner-recruitment data. Before fitting the models, we transformed recruitment data using natural logs. We estimated bias and uncertainty measures (95% CI) for the model parameters using bootstrap procedures, which assumed that the {R, S} sample represented or approximated the population. The number of bootstrap samples was 3,000. We computed and stored the non-linear regression results for each bootstrap sample. We then calculated the bootstrap 95% CI by arranging the 3,000 bootstrap parameter values in sorted order and selected the 2.5 and 97.5 percentiles from the list.

We used Akaike's Information Criterion for small sample size (AIC_c) to determine which model(s) best explained the relationship between spawners and recruitment in the supplemented and reference populations. AIC_c was estimated as:

$$\boldsymbol{AIC_c = -2log\left(£(\theta|data)\right) + 2K + \left(\frac{2K(K+1)}{n-K-1}\right)}$$

where *log(£(θ|data))* is the maximum likelihood estimate, *K* is the number of estimable parameters (structural parameters plus the residual variance parameter), and *n* is the sample size (Burnham and Anderson 2002). We used least-squares methods to estimate *log(£(θ|data))*, which was calculated as $log(\sigma^2)$, where σ^2 = residual sum of squares divided by the sample size ($\sigma^2 = RSS/n$). AIC_c assessed model fit in relation to model complexity (number of parameters). The model with the smallest AIC_c value represented the "best approximating" model within the model set. Remaining models were ranked relative to the best model using AIC_c difference scores (ΔAIC_c), Akaike weights (w_i), and evidence ratios. Models with ΔAIC_c values less than 2 indicated that there is substantial support for these models as being the best-fitting models within the set (Burnham and Anderson 2002). Models with values greater than 2 had less support. Akaike weights are probabilities estimating the strength of the evidence supporting a particular model as being the best model within the model set. Models with small w_i values are less plausible as competing models (Burnham and Anderson 2002). If no single model could be specified as the best model, a "best subset" of competing models was identified using (1) AIC_c differences to indicate the level of empirical support each model had as being the best model, (2) evidence ratios based on Akaike weights to indicate the relative probability that any model is the best model, and (3) coefficients of determination (R^2) assessing the explanatory power of each model.

Stock-Recruitment Analysis

We successfully fit stock-recruitment models to the Chiwawa and reference population data. The span of spawner data for the Chiwawa and reference populations was greater than 14 times the minimum observed spawners, which should provide sufficient contrast for estimation of model parameters. In addition, the span of recruitment data was greater than 12 times the minimum observed recruitment, again providing sufficient contrast for estimation of parameters. The relationship between natural log R/S and spawners indicated that some of the highest productivities occurred at the lower spawner levels and the lowest productivities generally occurred at the highest spawner levels (Figure 15). This is consistent with the assumption of density-dependent mortality.

Although model fits were generally poor, explaining less than 40% of the residual variation in natural-log recruitment data, we were able to estimate average maximum recruitment levels (K_R) and the spawning levels needed to produce maximum recruitment (K_{sp}) (Table 24; Figure 15). For all populations examined, Akaike information criterion was unable to identify a best approximating model (i.e., ΔAIC_c values were less than 2, indicating support for all three models). However, evaluation of 95% CIs and the asymptotic correlation coefficients indicated that the smooth hockey stick model may be the best approximating model for each population. Therefore, we used estimates of K_R and K_{sp} derived from the smooth hockey stick model to correct for density dependence and different carrying capacities in treatment-reference comparisons.

As part of the regression diagnostics, we examined the dependence of the model residuals on time and found a significant ($P < 0.05$), positive, one-year-lag autocorrelation for the Entiat (0.562), Marsh (0.551), Sesech (0.564), and Little Wenatchee (0.629) populations. For the purposes of our work here, we did not attempt to correct for this one-year-lag correlation in the residuals. Future analyses will explore the use of autoregressive models (e.g., AR1; Noakes et al. 1987) to correct for autocorrelation.

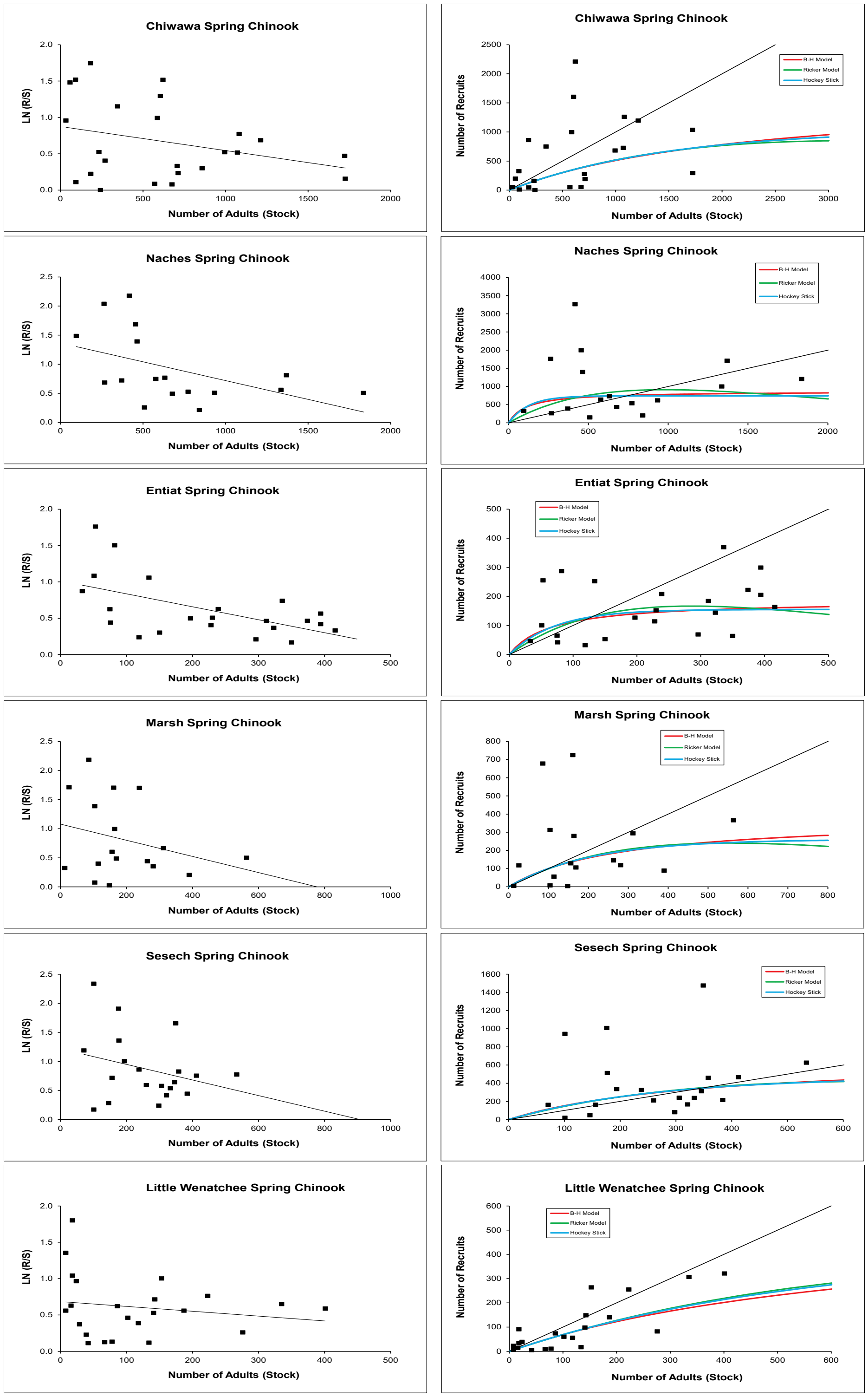

Figure 15. Relationships between natural log recruits/spawner (LN R/S) and spawners (Stock) in the Chiwawa and reference populations (figures on the left) and relationships between numbers of untransformed recruits and spawners in the Chiwawa and reference populations (figures on the right). Figures on the right also show the fit of the Ricker, Beverton-Holt, and the smooth hockey stick models to the data (black straight line represents R=S).

Table 24. Results from fitting Ricker, Beverton-Holt, and smooth hockey stick models to stock-recruitment data from the Chiwawa and reference populations. 95% CI on parameter estimates are based on 3,000 bootstrap trials; Corr coef = asymptotic correlation of the parameter estimates; K_R = maximum natural origin recruits (recruits at carrying capacity); K_{sp} = number of spawners needed to produce K_R; AICc = Akaike's Information Criterion for small sample size; Adj R^2 = coefficient of determination that is adjusted for the number of parameters in the model.

Model	Parameter	Parameter value	Bootstrap 95% CI	Corr coef	K_R	K_{sp}	AICc	Adj R^2
Chiwawa Population								
Ricker	α	0.7048	-0.6197 1.1055	0.791	852	3,285	-47.949	0.125
	β	0.000304	-0.000668 0.000609					
Beverton-Holt	α	1687.4	-65654539 3062.1	0.989	1,687	43,760	-47.962	0.125
	β	2308.5	-99999538 4526.1					
Smooth hockey stick	α	6.956	-41.313 8.2270	-0.708	1,049	6,847	-47.949	0.125
	β	0.7118	-2.397 1.122					
Naches Population								
Ricker	α	2.5223	-2.0003 3.9672	0.844	912	983	-45.063	-0.143
	β	0.001018	-0.000752 0.001717					
Beverton-Holt	α	869.4	97.4 1641.4	0.858	869	11,455	-46.801	-0.097
	β	111.8	-346.2 569.8					
Smooth hockey stick	α	6.612	5.9223 7.006	-0.399	744	565	-46.831	-0.095
	β	6.013	-89.071 12.026					
Entiat Population								
Ricker	α	1.5843	0.1609 2.4178	0.867	167	286	-68.365	-0.049
	β	0.003496	0.001141 0.005906					
Beverton-Holt	α	186.1	67.9 304.3	0.880	186	1,277	-69.895	0.029
	β	65.0	-59.1 189.2					
Smooth hockey stick	α	5.045	4.381 5.378	-0.450	155	344	-69.379	0.003
	β	2.180	-89.369 3.704					
Marsh Creek Population								
Ricker	α	1.1852	-1.8268 1.9269	0.823	241	552	-32.237	0.218

Model	Parameter	Parameter value	Bootstrap 95% CI	Corr coef	K_R	K_{sp}	AICc	Adj R^2
	β	0.001810	-0.003063 0.003625					
Beverton-Holt	α	383.3	-85109314 665.4	0.970	383	5,310	-32.291	0.234
	β	282.4	-99999944 564.9					
Smooth hockey stick	α	5.565	-22.631 6.584	-0.694	261	984	-32.264	0.227
	β	1.265	-108.574 2.531					
Sesech Population								
Ricker	α	1.6835	-2.9253 2.5951	0.912	421	680	-54.589	-0.005
	β	0.001470	-0.002951 0.002941					
Beverton-Holt	α	689.9	-986.8 2366.7	0.981	690	6,591	-54.678	0.000
	β	351.7	-1059.0 1762.5					
Smooth hockey stick	α	6.1528	-22.851 6.815	-0.821	470	1,185	-54.633	-0.002
	β	0.8000	-119.370 2.909					
Little Wenatchee Population								
Ricker	α	0.7447	0.0828 1.0280	0.735	356	1,298	-66.978	0.357
	β	0.000770	-0.003052 0.001541					
Beverton-Holt	α	564.7	-74423355 1067.6	0.994	565	13,400	-67.055	0.358
	β	719.7	-99999856 1413.4					
Smooth hockey stick	α	6.0181	-49.5620 8.1122	-0.683	411	2,544	-67.000	0.357
	β	0.7550	-0.9539 1.0452					

Method 1: Productivity Data Adjusted for Density Dependence

Analysis of supplementation effects on productivity (adult recruits/spawner adjusted for density-dependent effects based on the smooth hockey stick model) using difference scores indicated that supplementation did not significantly decrease productivity in the Chiwawa Basin (Table 25; Figure 16). All tests, regardless of treatment-reference pairs, indicated that productivity did not change significantly during the supplementation period, even though productivity did decrease during the supplementation period (Figure 16). These results are consistent with those based on unadjusted productivity data (Table 17). This is because most abundance estimates were below the level of assumed density dependence.

Table 25. Results of the Aspin-Welch unequal-variance test, randomization test (based on 10,000 Monte Carlo samples), and 95% CI (based on 5,000 bootstrap samples) on transformed and untransformed productivity data corrected for density dependence. Tests determined if the mean difference scores during the supplementation period were greater than mean difference scores during the pre-supplementation period.

Reference population	Aspin-Welch unequal-variance test			Randomization test P-value	Bootstrap 95% CI
	t-value	P-value	Effect size		
Productivity					
Naches	0.904	0.190	0.496	0.412	-0.511 – 1.497
Marsh	-0.203	0.579	0.152	0.927	-1.298 – 1.372
Sesech	1.607	0.071	1.435	0.146	-0.359 – 2.911
Little Wenatchee	0.431	0.335	0.147	0.668	-0.487 – 0.781
LN Productivity					
Naches	0.570	0.290	0.083	0.568	-0.168 – 0.362
Marsh	0.012	0.495	0.003	0.991	-0.373 – 0.480
Sesech	1.463	0.087	0.343	0.171	-0.125 – 0.732
Little Wenatchee	0.390	0.351	0.060	0.709	-0.218 – 0.365

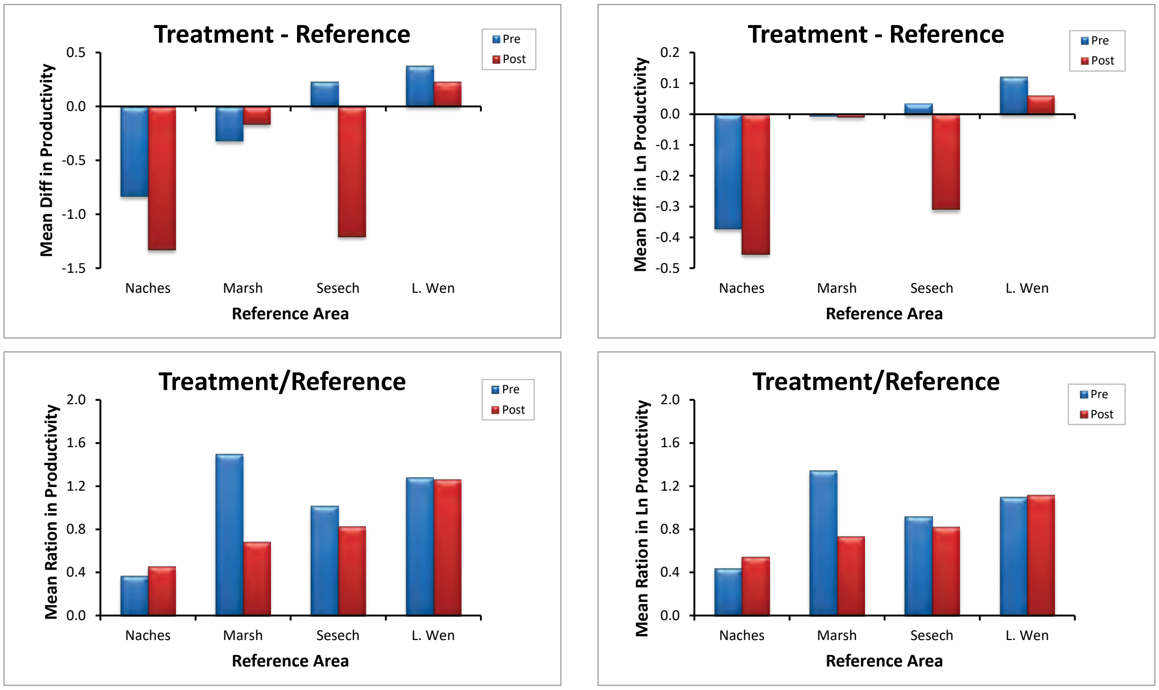

Figure 16. Mean differences (Treatment – Reference; figures on the top) and mean ratios (Treatment/Reference; figures on the bottom) of transformed and untransformed productivity data (adjusted for density dependence) before (pre) and after (post) spring Chinook supplementation in the Chiwawa Basin. Negative effects of supplementation on productivity are indicated when the pre-supplementation (blue) bars are greater than their corresponding post-supplementation (red) bars.

Analysis of supplementation effects on productivity (adult recruits/spawner adjusted for density-dependent effects) using ratios indicated that supplementation did not significantly decrease productivity in the Chiwawa Basin (Table 26; Figure 16). The Aspin-Welch test and the 95% CIs did indicate a significant effect when comparing the Chiwawa to the Marsh Creek population. These results are consistent with those using unadjusted productivity data (Table 20). Again, this is because most abundance estimates were below the level of assumed density dependence.

Table 26. Results of the Aspin-Welch unequal-variance test, randomization test (based on 10,000 Monte Carlo samples), and 95% CI (based on 5,000 bootstrap samples) on transformed and untransformed productivity data corrected for density dependence. Tests determined if the mean ratios during the supplementation period were less than mean ratios during the pre-supplementation period.

Reference population	Aspin-Welch unequal-variance test			Randomization test P-value	Bootstrap 95% CI
	t-value	P-value	Effect size		
Productivity					
Naches	-0.529	0.696	0.087	0.597	-0.394 – 0.214
Marsh	2.236	0.022	0.814	0.056	0.140 – 1.470
Sesech	0.677	0.253	0.191	0.496	-0.343 – 0.727
Little Wenatchee	0.033	0.487	0.018	0.978	-0.902 – 1.181
LN Productivity					
Naches	-0.621	0.726	0.104	0.536	-0.406 – 0.191

Reference population	Aspin-Welch unequal-variance test			Randomization test P-value	Bootstrap 95% CI
	t-value	P-value	Effect size		
Marsh	1.952	0.036	0.613	0.076	0.005 – 1.163
Sesech	0.447	0.330	0.098	0.649	-0.312 – 0.498
Little Wenatchee	-0.034	0.513	0.015	0.980	-0.697 – 0.852

Our analyses assume that there is a spawner abundance (K_{sp}) at which density-independent effects end and density-dependent effects begin. In reality, density-dependent effects occur at low spawning abundance and intensify as spawning abundance increases (evident in the changing slope of the three stock-recruitment curves used in our analyses). We did not account for these increasing density-dependent effects at spawner abundances less than K_{sp}. If we accounted for the increasing effects of density dependence at spawning abundances less than K_{sp}, the analysis with and without productivity adjustments may give different results.

Method 2: Fraction of Carrying Capacity Filled with NORs

We analyzed the effects of supplementation on filling the capacity of the habitat with natural-origin recruits. The smooth hockey stick model derived the carrying capacity (K_R) estimates for the Chiwawa and reference populations. The fraction of the carrying capacity filled with Chinook recruits before and during supplementation for the Chiwawa and reference populations is provided in Table 27. These data indicate that for the Chiwawa population, the mean fraction of the K_R filled with fish decreased significantly from the pre-supplementation period through the supplementation period (Table 27). Likewise, the Entiat and Little Wenatchee populations showed a significant decline in the mean fraction of K_R filled with adult recruits. In contrast, the mean fraction of K_R in the Naches and Marsh Creek populations increased during the same period (Table 27).[22] Interestingly, the fraction of K_R filled with adult recruits for all populations trended downward during the pre-supplementation period (Figure 17). During the supplementation period, however, the fraction of K_R filled with adult recruits trended upward for all populations. These results suggest that agents of mortality outside the Chiwawa and reference populations were reducing recruitment to the populations.

22 Although we do not show the results here, statistical analysis of the mean fraction of carrying capacity filled by adult recruits using natural-log transformed data produced the same result as using untransformed data. This was true for all populations.

Table 27. Fraction of the carrying capacity that was filled with Chinook salmon adult recruits in the Chiwawa and reference populations before (pre) and during (post) supplementation in Chiwawa Basin. The smooth hockey stick model estimated carrying capacity for each population. Statistical results from comparing the pre and post mean scores using the Aspin-Welch unequal-variance test are provided at the bottom of the table.

Supplementation period	Chiwawa	Reference populations			
		Naches	Entiat	Marsh	L. Wenatchee
Pre-supplementation period (1981-1992)	2.11		2.38	1.07	0.64
	1.53		1.93	1.20	0.75
	1.20		1.32	2.60	0.78
	1.14		1.19	0.49	0.62
	0.99		1.06	0.46	0.34
	0.70	2.30	1.43	0.56	0.24
	0.65	0.58	0.74	0.34	0.20
	0.95	1.88	1.34	1.40	0.36
	0.18	0.72	1.63	0.22	0.15
	0.05	0.27	0.45	0.02	0.02
	0.00	0.20	0.21	0.03	0.01
Pre-Mean:	0.86	0.99	1.24	0.76	0.37
Pre-Range:	0.00 – 2.11	0.20 – 2.30	0.21 – 2.38	0.02 – 2.60	0.01 – 0.78
Post-supplementation period (1992-2002)	0.05	0.98	0.34	0.41	0.03
	0.15	0.86	0.41	1.13	0.04
	0.04	0.35	0.27	0.02	0.03
	0.05	0.44	0.30	0.02	0.03
	0.19	4.39	0.65	0.45	0.06
	0.82	2.68	1.85	2.78	0.22
	0.31	2.37	1.65	4.10	0.08
	0.01	0.53	0.42		0.02
	0.71	1.62	0.82		0.10
	0.28	1.35	0.93		0.14
	0.27	0.83	0.98		0.18
Post-Mean:	0.26	1.49	0.78	1.27	0.08
Post-Range:	0.04 – 0.82	0.35 – 4.39	0.30 – 1.85	0.02 – 4.10	0.02 – 0.22
One-sided Aspin-Welch t-test of pre and post means	t = 2.846; P = 0.007	t = -0.967; P = 0.825	t = 1.833; P = 0.041	t = -0.799; P = 0.776	t = 3.321; P = 0.003

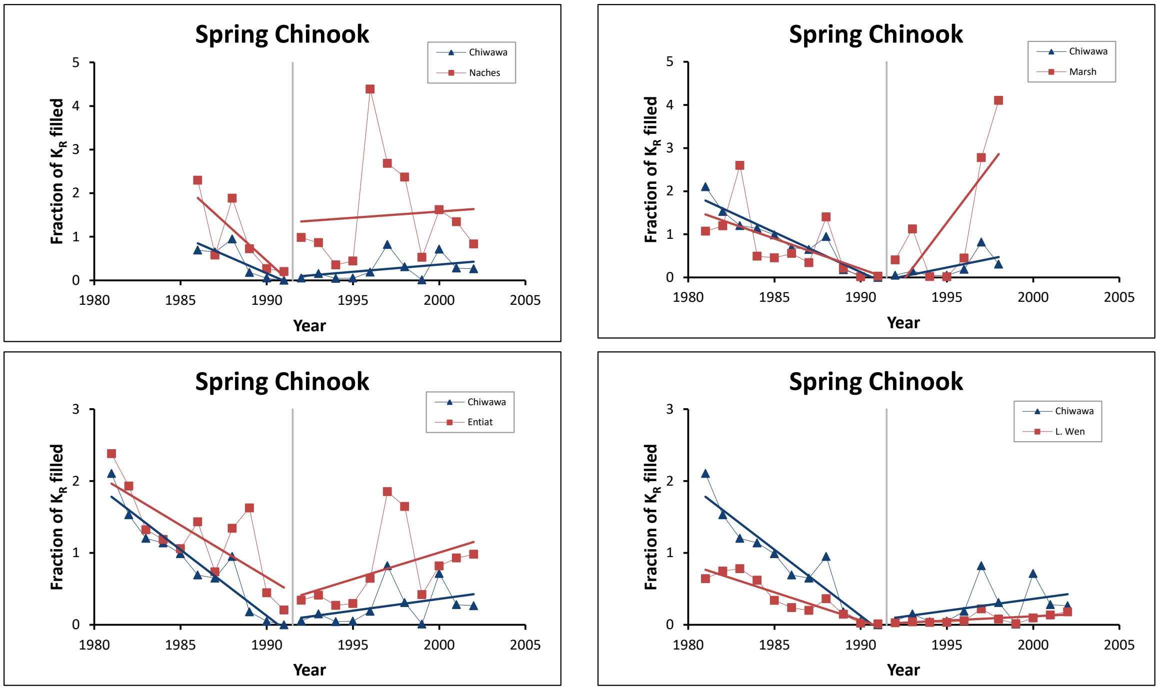

Figure 17. Trends in the fraction of the carrying capacity that was filled with Chinook salmon adult recruits in the Chiwawa and reference populations before (pre) and during (post) supplementation in Chiwawa Basin. The vertical lines in the figures separate the pre- and post-supplementation periods. The smooth hockey stick model estimated carrying capacity for each population.

We then compared the mean difference scores and ratios between the Chiwawa and reference populations before and during supplementation using data representing the fraction of K_R filled with adult recruits. In most of the Chiwawa-reference population comparisons, the absolute value of the mean difference between the fraction of K_R filled with recruits was greater in the supplementation period than during the pre-supplementation period; two of the four pairings were significant (Table 28; Figure 18). Analysis of difference scores using natural-log transformed data indicated that three of the four pairings were significant (Table 28).

Results from analyses using ratios were similar to results using difference scores. Mean ratio scores were generally smaller during the supplementation period than during the pre-supplementation period (Figure 18). This indicated that the mean fraction of K_R filled by adult recruits in most reference populations was greater during the supplementation period than during the pre-supplementation period (i.e., the denominator in the ratio increased between the pre- and post-supplementation periods). In contrast, the fraction of K_R filled by adult recruits in the Chiwawa decreased from the pre- to post-supplementation period (i.e., the numerator in the ratio decreased between the pre- and post-supplementation periods). Thus, unlike the Chiwawa population, the capacity of most reference populations was becoming more saturated during the period when the Chiwawa was being supplemented. Statistical analysis with mean ratios indicated that two of the four pairings were significant (Table 29).

Analyses comparing the Little Wenatchee with the Chiwawa indicate that adult recruits to the Little Wenatchee have been well below its carrying capacity. During the pre-supplementation period, the capacity of the Little Wenatchee was on average 37% saturated with adult recruits. During the supplementation period, the capacity of the Little Wenatchee declined to 8% saturation

with adult recruits (a 22% decline). The Chiwawa, during the pre-supplementation period, was on average 86% saturated. During the supplementation period, percent saturation in the Chiwawa decreased to 26% (a 30% decrease). During the same time periods, the capacity of the Entiat population, which until recently has been supplemented, declined from 124% to 78% saturation (a 63% decline).

Table 28. Results of the Aspin-Welch unequal-variance test, randomization test (based on 10,000 Monte Carlo samples), and 95% CI (based on 5,000 bootstrap samples) on the fraction of the habitat capacity (K_R) that is filled with natural origin recruits. Analyses include both transformed and untransformed data. Tests determined if the mean difference scores during the supplementation period were greater than mean difference scores during the pre-supplementation period.

Reference population	Aspin-Welch unequal-variance test			Randomization test P-value	Bootstrap 95% CI
	t-value	P-value	Effect size		
Fraction of Capacity Filled					
Naches	1.550	0.071	0.657	0.145	-0.173 – 1.378
Entiat	0.835	0.207	0.141	0.422	-0.167 – 0.475
Marsh	2.026	0.040	1.141	0.055	0.064 – 2.054
Little Wenatchee	2.166	0.023	0.310	0.031	0.035 – 0.569
LN Fraction of Capacity Filled					
Naches	2.123	0.026	0.311	0.039	0.031 – 0.575
Entiat	1.405	0.087	0.122	0.176	-0.034 – 0.289
Marsh	2.547	0.017	0.519	0.017	0.125 – 0.864
Little Wenatchee	1.744	0.049	0.130	0.100	-0.004 – 0.273

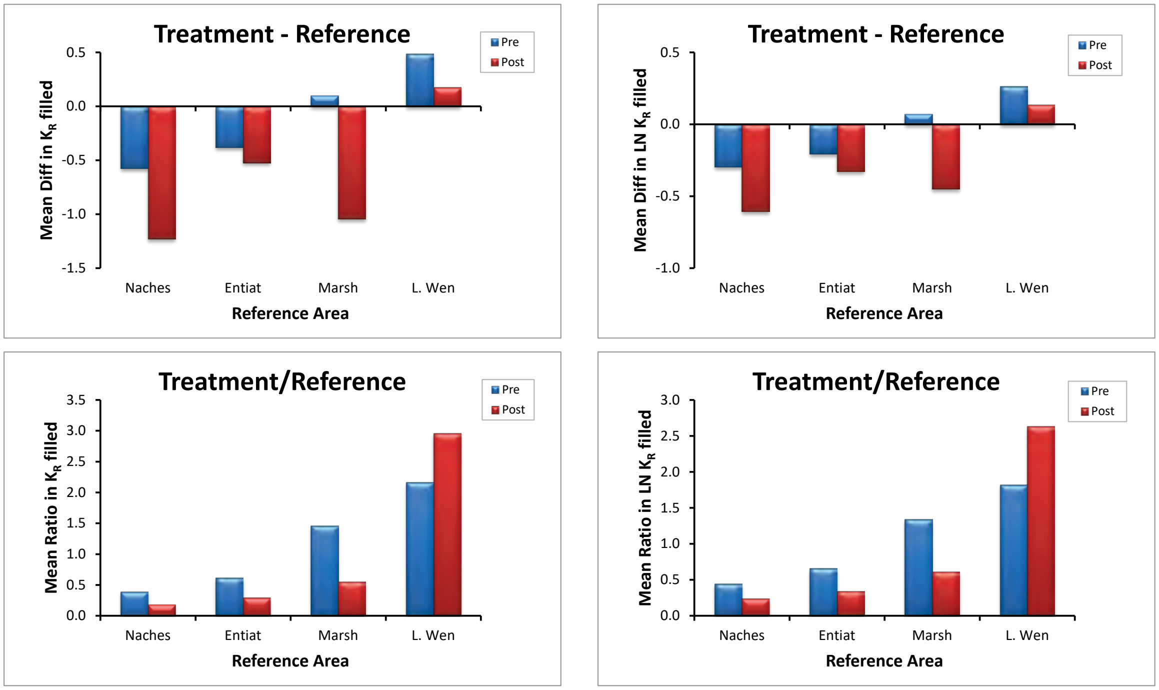

Figure 18. Mean differences (Treatment – Reference; figures on the top) and mean ratios (Treatment/Reference; figures on the bottom) of transformed and untransformed fractions of carrying capacity filled with adult recruits before (pre) and after (post) spring Chinook supplementation in the Chiwawa Basin.

Table 29. Results of the Aspin-Welch unequal-variance test, randomization test (based on 10,000 Monte Carlo samples), and 95% CI (based on 5,000 bootstrap samples) on the fraction of the habitat capacity (K_R) that is filled with natural origin recruits. Analyses include both transformed and untransformed data. Tests determined if the mean ratios during the supplementation period were less than mean ratios during the pre-supplementation period.

Reference population	Aspin-Welch unequal-variance test			Randomization test	Bootstrap 95% CI
	t-value	P-value	Effect size	P-value	
Fraction of Capacity Filled					
Naches	1.317	0.119	0.217	0.219	-0.103 – 0.482
Entiat	2.449	0.013	0.321	0.028	0.085 – 0.577
Marsh	2.001	0.035	0.905	0.070	0.138 – 1.788
Little Wenatchee	-1.148	0.864	0.791	0.278	-1.979 – 0.578
LN Fraction of Capacity Filled					
Naches	1.257	0.127	0.207	0.249	-0.099 – 0.484
Entiat	2.346	0.016	0.313	0.031	0.072 – 0.583
Marsh	1.737	0.056	0.729	0.111	0.028 – 1.531
Little Wenatchee	-1.525	0.924	0.815	0.142	-1.751 – 0.195

Comparing Stock-Recruitment Curves

As a final set of treatment and reference population comparisons, we compared the stock-recruitment curves of the Chiwawa population (using {R, S} data only from the supplementation period) to the reference populations (using all available {R, S} data). Specifically, we tested whether the regression parameters were equal between the Chiwawa population and the reference populations, and whether the fitted curves coincided between populations. Earlier in this report we described the data, methods, and results of fitting the Ricker, Beverton-Holt, and smooth hockey stick curves to the data. Because AIC_c was unable to identify a best approximating model, here we included all three models in our analyses. We tested the following hypotheses.

Parameter equivalence:

Ho: Stock-recruitment parameters (α and β) of the Chiwawa population = Stock-recruitment parameters of the reference populations.

Ha: Stock-recruitment parameters (α and β) of the Chiwawa population $\neq$ Stock-recruitment parameters of the reference populations.

Curve equivalence:

Ho: Modeled stock-recruitment curves of the Chiwawa population = Modeled stock-recruitment curves of the reference populations.

Ha: Modeled stock-recruitment curves of the Chiwawa population $\neq$ Modeled stock-recruitment curves of the reference populations.

We used two-sided randomization tests to test the null hypotheses of equal model parameters and that fitted curves coincided. Because the total number of permutations was in the millions, we used a Monte Carlo approach to randomly select 10,000 permutations. The test statistic for comparing the model parameters was formed by summing the difference between the population parameter estimates for each pair of populations. The test statistic for comparing the whole curve was formed by summing the difference between the estimated predicted values for each pair of populations at 500 equally spaced points along the curve.

<u>*Ricker Relationships*</u>

Ricker curves differed significantly between the Chiwawa and reference populations (Figure 19; Table 30). Interestingly, however, the parameters in the Ricker model did not differ significantly among most populations (Table 30). Only the β parameter differed significantly between the Chiwawa and Entiat populations.

In the Ricker model, the α parameter represents intrinsic productivity (i.e., recruits per spawner at low spawner densities). In this analysis, there was not enough evidence in the stock-recruitment data to reject the hypothesis of inequality in intrinsic productivity. Thus, this test was unable to demonstrate that supplementation, based on the Ricker curve, affected productivity in the Chiwawa population.

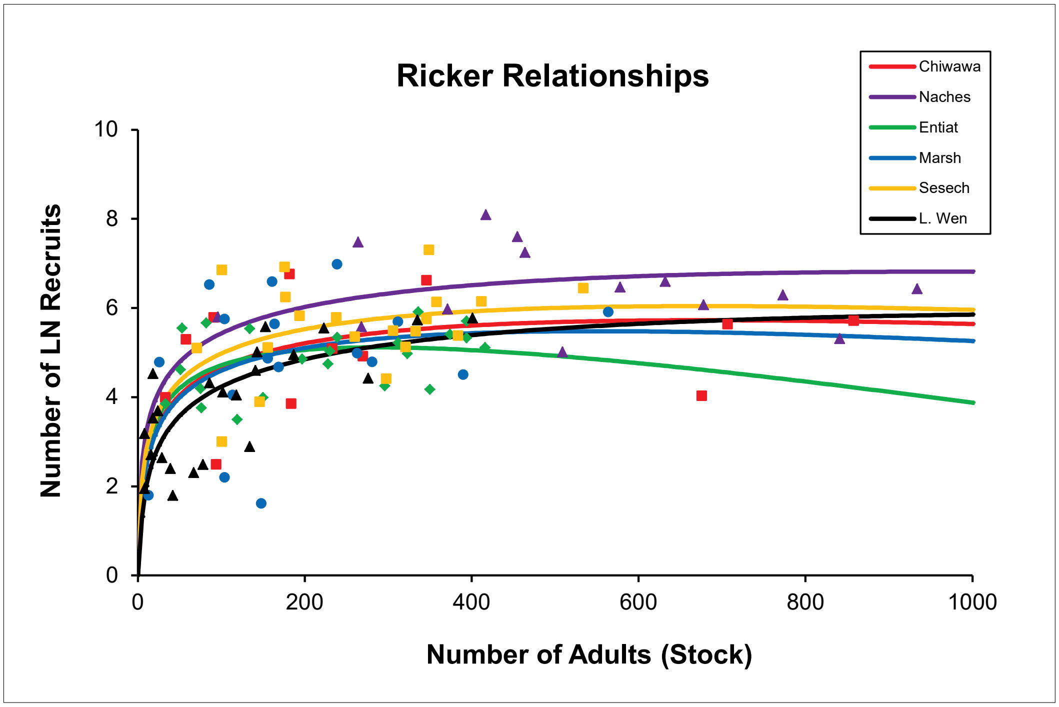

Figure 19. Scatter plot of the number of spawners and natural log adult recruits and fitted Ricker curves to the Chiwawa (supplemented population) and reference (un-supplemented) populations.

Table 30. Randomization test results comparing the equality of Ricker curves and equality of parameter values (α and β). Randomization tests were based on 10,000 Monte Carlo samples. Equality or curves was based on 500 points along the x-axis (spawner abundance axis).

Curves tested	Curve inequality randomization P-value	Parameter inequality		
		Model Parameter		Randomization P-value
		Chiwawa	Reference	
Chiwawa v. Naches	0.008	α = 1.2247	α = 2.5267	0.236
		β = 0.0015	β = 0.0010	0.600
Chiwawa v. Entiat	0.004	α = 1.2247	α = 1.5836	0.978
		β = 0.0015	β = 0.0035	0.025
Chiwawa v. Marsh	0.034	α = 1.2247	α = 1.1855	0.997
		β = 0.0015	β = 0.0018	0.688
Chiwawa v. Sesech	0.036	α = 1.2247	α = 1.6818	0.972
		β = 0.0015	β = 0.0015	0.997
Chiwawa v. L. Wenatchee	0.034	α = 1.2247	α = 0.7439	0.969
		β = 0.0015	β = 0.0008	0.203

Beverton-Holt Relationships

Beverton-Holt curves differed significantly only between the Chiwawa and Naches populations (Figure 20; Table 31). There was no significant difference in curves between the Chiwawa and the other reference populations. The parameters in the Beverton-Holt model did not differ significantly among any of the populations (Table 31). This was true even for the Chiwawa and Naches populations.

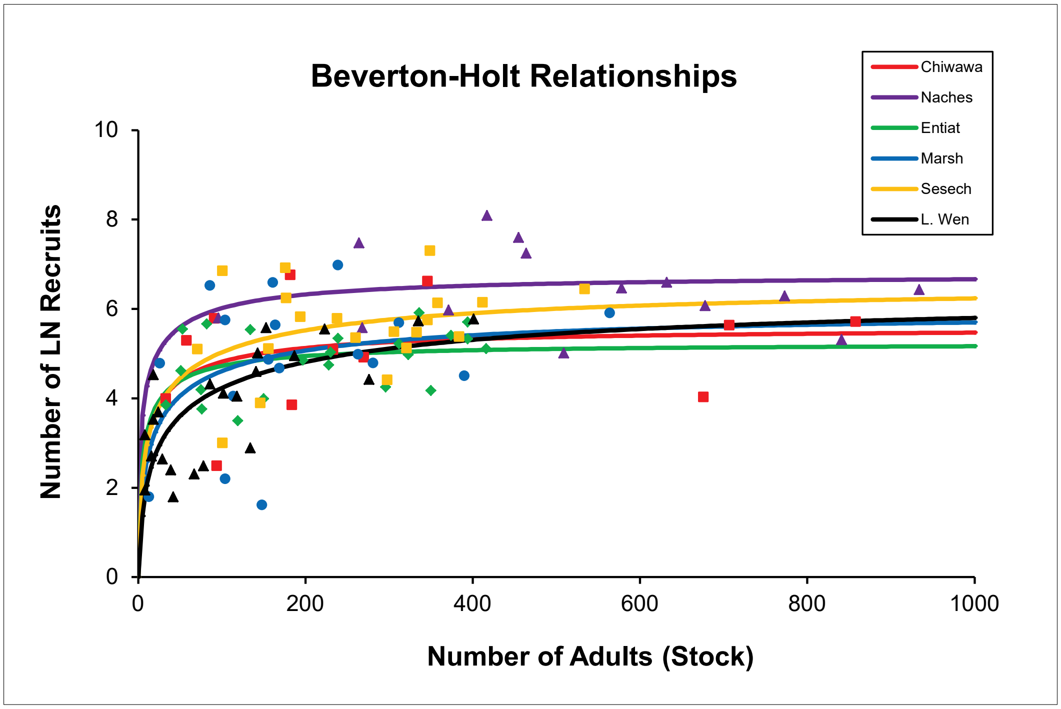

Figure 20. Scatter plot of the number of spawners and natural log adult recruits and fitted Beverton-Holt curves to the Chiwawa (supplemented population) and reference (un-supplemented) populations.

Table 31. Randomization test results comparing the equality of Beverton-Holt curves and equality of parameter values (α and β). Randomization tests were based on 10,000 Monte Carlo samples. Equality or curves was based on 500 points along the x-axis (spawner abundance axis).

Curves tested	Curve inequality randomization P-value	Parameter inequality		
		Model Parameter		Randomization P-value
		Chiwawa	Reference	
Chiwawa v. Naches	0.036	α = 264.25	α = 870.62	0.777
		β = 113.79	β = 112.24	0.963
Chiwawa v. Entiat	0.746	α = 264.25	α = 186.34	0.960
		β = 113.79	β = 65.33	0.954
Chiwawa v. Marsh	0.850	α = 264.25	α = 381.79	0.944
		β = 113.79	β = 281.04	0.891

Curves tested	Curve inequality randomization P-value	Parameter inequality		
		Model Parameter		Randomization P-value
		Chiwawa	Reference	
Chiwawa v. Sesech	0.272	α = 264.25	α = 689.31	0.821
		β = 113.79	β = 351.59	0.869
Chiwawa v. L. Wenatchee	0.654	α = 264.25	α = 568.69	0.864
		β = 113.79	β = 725.87	0.751

Smooth Hockey Stick Relationships

Smooth hockey stick curves differed significantly between the Chiwawa and Naches populations and the Chiwawa and Sesech populations (Figure 21; Table 32). There was no significant difference in curves between the Chiwawa and the other reference populations. Most of the parameters in the smooth hockey stick model did not differ significantly among the populations (Table 32). However, the productivity parameter β did differ significantly between the Chiwawa and the Naches and the Chiwawa and Little Wenatchee populations. The β parameter for the Naches was significantly greater than the Chiwawa, while the β parameter for the Little Wenatchee was significantly less than the Chiwawa.

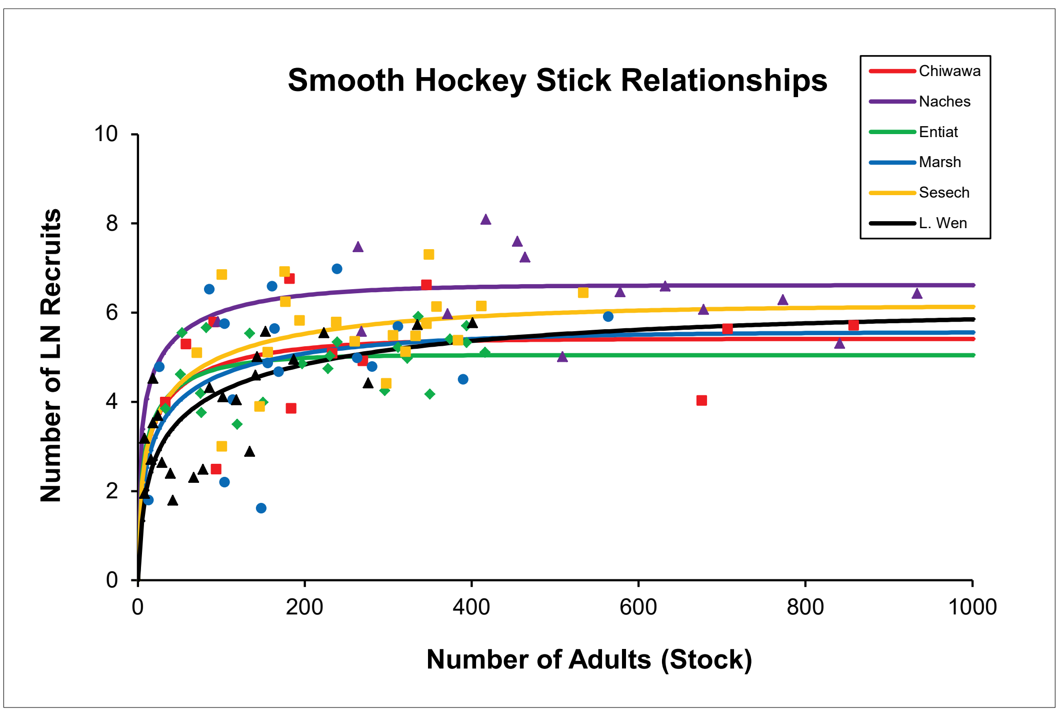

Figure 21. Scatter plot of the number of spawners and natural log adult recruits and fitted smooth hockey stick curves to the Chiwawa (supplemented population) and reference (un-supplemented) populations.

Table 32. Randomization test results comparing the equality of smooth hockey stick curves and equality of parameter values (α and β). Randomization tests were based on 10,000 Monte Carlo samples. Equality or curves was based on 500 points along the x-axis (spawner abundance axis).

Curves tested	Curve inequality randomization P-value	Parameter inequality		
		Model Parameter		Randomization P-value
		Chiwawa	Reference	
Chiwawa v. Naches	0.000	$\alpha = 5.41$	$\alpha = 6.61$	0.000
		$\beta = 1.84$	$\beta = 5.99$	0.000
Chiwawa v. Entiat	0.999	$\alpha = 5.41$	$\alpha = 5.05$	0.999
		$\beta = 1.84$	$\beta = 2.17$	0.999
Chiwawa v. Marsh	0.999	$\alpha = 5.41$	$\alpha = 5.56$	0.999
		$\beta = 1.84$	$\beta = 1.27$	0.999
Chiwawa v. Sesech	0.000	$\alpha = 5.41$	$\alpha = 6.15$	0.000
		$\beta = 1.84$	$\beta = 1.80$	0.999
Chiwawa v. L. Wenatchee	0.990	$\alpha = 5.41$	$\alpha = 6.02$	0.999
		$\beta = 1.84$	$\beta = 0.75$	0.000

Comparing different stock-recruitment curves and their parameters did not provide strong evidence that the supplementation program has negatively affected the productivity of the Chiwawa population.

Analysis without Reference Populations

In some cases, suitable reference populations may not exist to compare with supplemented populations. It is therefore important to have alternative analyses to assess supplementation effects. In this section, we describe methods that can be used to assess supplementation effects when suitable reference populations are not available. We discuss before-after comparisons, correlation analysis, and comparisons to standards as alternatives when reference populations are unavailable.

Before-After Comparisons

Before-after analyses compare population metrics (spawner abundance, NORs, and productivity) before supplementation to those during supplementation. In this case, data collected before supplementation represent the reference condition. The assumption is that population trajectories measured during the pre-supplementation period would continue in the absence of supplementation. We compared trends in abundance and productivity, mean abundance and productivity, and stock-recruitment relationships before and after supplementation.

Trend Analysis

Comparing trends before and after supplementation can be used to assess the effects of supplementation. Here, we compared the slopes of trends of spawner abundance, NORs, and productivity before and during supplementation using t-tests. If the hatchery program is successfully supplementing the natural spring Chinook population, the trend for spawner abundance and NORs during supplementation should be greater than the slope during the pre-supplementation period. For productivity, the slope during the supplementation period should increase or remain the same as that during the pre-supplementation period.

Visual examination of trends of Chiwawa data indicates that spawner abundance, NORs, and productivity decreased during the pre-supplementation period, but increased during the supplementation period (Figure 22). Only the changes in NOR trends were significant (Figure 22). This was true for both transformed and untransformed data.

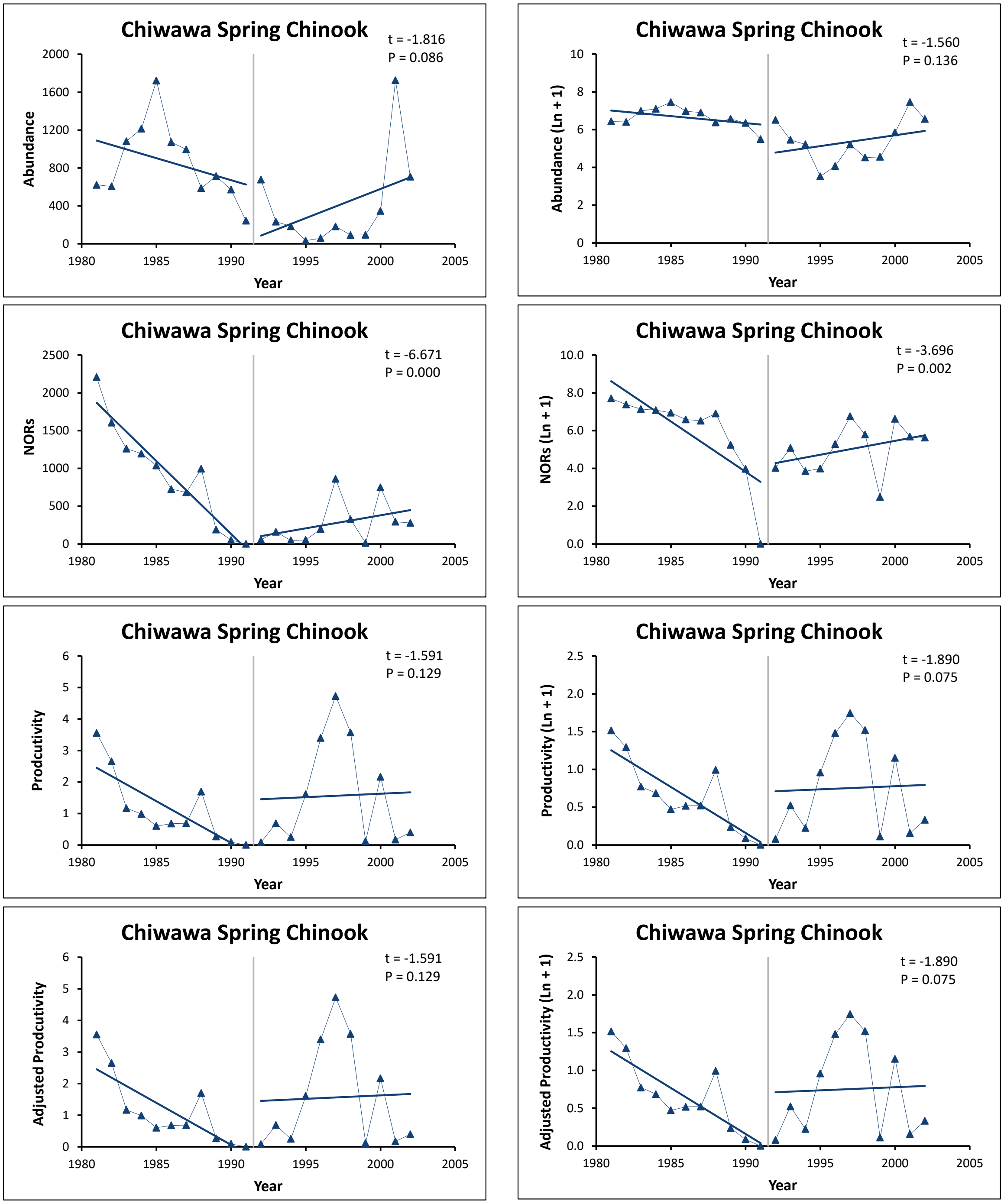

Figure 22. Trends in Chiwawa spring Chinook spawner abundance, natural-origin recruits (NORs), productivity (adults recruits per spawner), and adjusted productivity (adjusted for density dependence) before and during supplementation. The vertical lines in the figures separate the pre- and post-supplementation periods. Figures on the left show untransformed data; figures on the right include natural-log transformed data. Figures include results of t-tests comparing slope of trends before and during supplementation.

Analysis of Mean Scores

We also compared mean spawner abundance, NORs, and productivity data before and after supplementation. If the hatchery program is successfully supplementing the natural spring Chinook population, mean spawner abundance and NORs during the supplementation period should be greater than the pre-supplementation period. For productivity, the mean productivity during the supplementation period should be equal to or higher than the pre-supplementation period. We tested the following statistical hypotheses.

Spawner Abundance and NORs:

Ho: Mean spawner abundance and NORs before supplementation ≥ Mean spawner abundance and NORs during supplementation.

Ha: Mean spawner abundance and NORs before supplementation < Mean spawner abundance and NORs during supplementation.

Productivity (Recruits/Spawner):

Ho: Mean productivity before supplementation ≤ Mean productivity during supplementation.

Ha: Mean productivity before supplementation > Mean productivity during supplementation.

We tested before-after supplementation effects using a one-tailed Aspin-Welch unequal-variance test. We also used a randomization test, based on 10,000 Monte Carlo simulations, to assess differences in spawner abundance and productivity before and during supplementation. The randomization procedure only allowed the testing of two-tailed hypotheses. Therefore, we generated 95% confidence intervals on the mean difference (μ_{pre} - μ_{post}) using bootstrapping methods to determine if the significant result from the randomization test was in the right direction. We generated 5,000 bootstrap samples to calculate confidence intervals.

Mean spawner abundance during the supplementation period was significantly less than the pre-supplementation spawner abundance (Table 33). Mean spawner abundance decreased 46% between the pre- and post-supplementation periods. Likewise, mean NORs decreased significantly between the two periods (Table 33). On the other hand, productivity increased slightly, but not significantly, between the pre- and post-supplementation periods (Table 33). This was true for both adjusted and transformed productivity data.

Table 33. Statistical results comparing mean scores of spawner abundance, natural-origin recruits (NORs), and productivity (using both untransformed and natural-log transformed) before and during supplementation of Chiwawa spring Chinook. Randomization tests were based on 10,000 Monte Carlo samples and 95% CI were based on 5,000 bootstrap samples.

Population metric	Mean scores		Test on means			
			Aspin-Welch test		Random test P-value	Bootstrap 95% CI
	Before	During	t-value	P-value		
Abundance	856	393	2.383	0.986	0.028	112 - 843
LN Abundance	6.6	5.4	3.304	0.997	0.004	0.56 – 1.99
NORs	905	275	2.846	0.993	0.009	214 – 1034
LN NORs	6.0	5.0	1.197	0.876	0.250	-0.40 – 2.54
Productivity	1.13	1.56	-0.721	0.759	0.479	-1.55 – 0.73
LN Productivity	0.64	0.75	-0.450	0.671	0.649	-0.55 – 0.35
Adj Productivity	1.12	1.56	-0.721	0.759	0.477	-1.54 – 0.71
LN Adj Productivity	0.64	0.75	-0.450	0.671	0.652	-0.57 – 0.34

Analysis of Stock-Recruitment Curves

The third method compared stock-recruitment curves of the Chiwawa population during supplementation with those generated before supplementation. Specifically, we tested whether the regression parameters were equal between the pre- and post-supplementation periods, and whether the fitted curves coincided between the two time periods. We used the methods described earlier to fit the Ricker, Beverton-Holt, and smooth hockey stick curves to the two data sets. We tested the following hypotheses.

Parameter equivalence:

Ho: Stock-recruitment parameters (α and β) of the pre-supplementation period = Stock-recruitment parameters of the supplementation period.

Ha: Stock-recruitment parameters (α and β) of the pre-supplementation period ≠ Stock-recruitment parameters of the supplementation period.

Curve equivalence:

Ho: Modeled stock-recruitment curves from the pre-supplementation period = Modeled stock-recruitment curves from the pre-supplementation period.

Ha: Modeled stock-recruitment curves from the pre-supplementation period ≠ Modeled stock-recruitment curves from the pre-supplementation period.

We were only able to fit stock-recruitment curves to the post-supplementation data. Non-linear regression was unable to converge on a solution using only pre-supplementation data. Therefore, we were unable to use this method to test supplementation effects on the Chiwawa spring Chinook population. If we could have fit curves to both the pre- and post-supplementation periods, we would have used two-sided randomization tests to evaluate the null hypotheses of equal model parameters and that fitted curves coincided.

Before describing correlation approaches, it is important to note that comparing before-after data can sometimes be misleading. For example, the spawner abundance, NORs, and productivity data presented in Figure 22 suggest that supplementation is increasing the abundance and productivity of spring Chinook in the Chiwawa Basin. However, when we compared these trends to those from reference populations during the same time periods (Figures 9-11), it becomes clear that supplementation was not responsible for increasing the trends in spawner abundance, NORs, and productivity of the Chiwawa population. Thus, whenever possible, it is wise to compare before-after data with a reference population.

Correlation Analyses

A simple way to see if the supplementation program is increasing or decreasing productivity is to assess the association between the proportion of adult spawners that are made up of hatchery adults (pHOS) and productivity (recruits/spawner). If the supplementation program is working as planned, the increase in hatchery fish spawning naturally should increase the productivity of the population. It should not decrease the productivity of the population.

We tested the association between pHOS and adult productivity[23] using Pearson correlation. During the pre-supplementation period, productivity averaged 1.13 recruits/spawner; during the supplementation period, productivity averaged 1.39 recruits/spawner. This increase in productivity did not appear to be strongly correlated to pHOS (Figure 23). Correlation analysis showed that there was no significant association between pHOS and productivity, even though productivity increased with increasing pHOS.

[23] Note that the analysis could also include juvenile productivity (e.g., smolts/spawner).

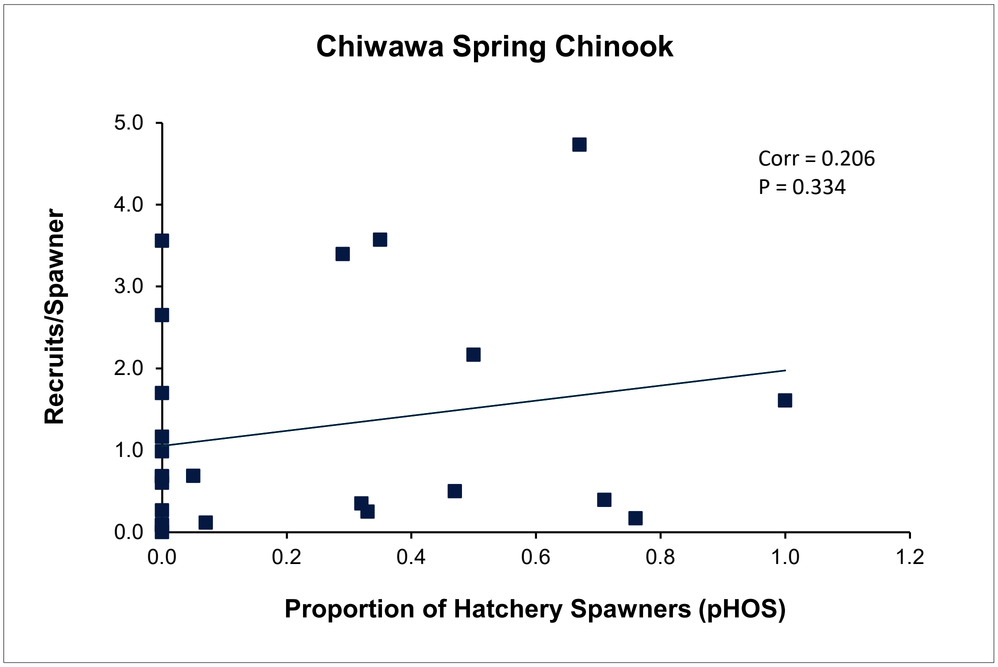

Figure 23. Association between the proportion of spawners that are made up of hatchery adults (pHOS) and the number of natural-origin recruits. The Pearson correlation coefficient (Corr) and its P-value (P) are shown in the figure.

The association between pHOS and productivity can also be assessed by testing the correlation between pHOS and the residuals from stock-recruitment curves fitted to the Chiwawa spawner and natural-origin recruitment data. This approach removes the effects of density dependence on the relationship between pHOS and productivity. A significant negative association provides evidence that hatchery-origin spawners may not be as productive as natural-origin spawners.

The Ricker, Beverton-Holt, and smooth hockey stick models were fit to the Chiwawa stock and recruitment data (including {S, R} data from both the pre- and post-supplementation period, 1981-2004) using methods described earlier. Residuals were calculated by subtracting the predicted recruitment values from the observed (modeled) values. Pearson correlation then tested the association between pHOS and the residuals from each model.

Although there was a negative trend in residuals with increasing pHOS, suggesting that hatchery-origin spawners may not be as productive as natural-origin spawners, the association was not significant (Figure 24). Thus, based on these analyses, there is no strong evidence that the supplementation program has significantly benefited or harmed the natural spring Chinook population.

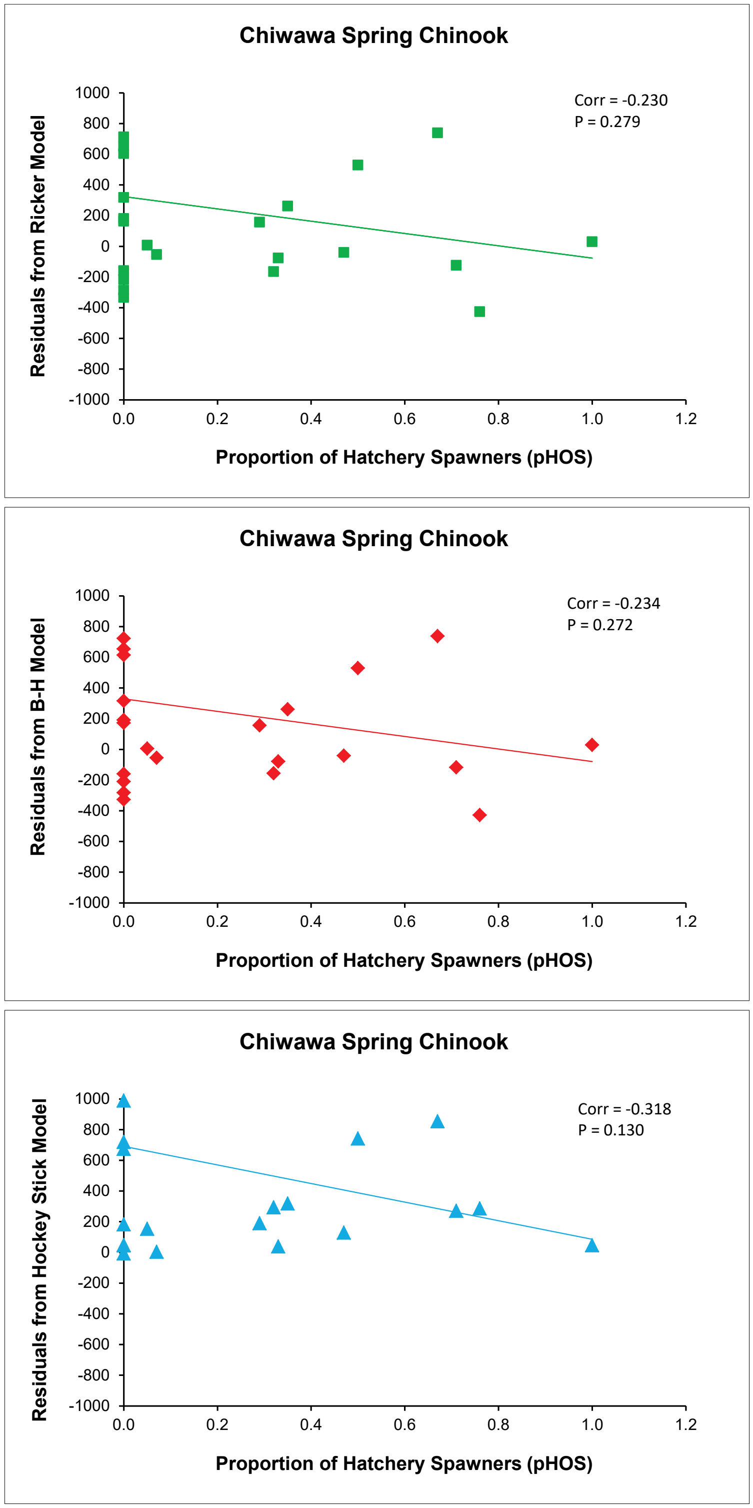

Figure 24. Association between the proportion of spawners that are made up of hatchery adults (pHOS) and the residuals from Ricker, Beverton-Holt (B-H), and smooth hockey stick stock-recruitment models. The Pearson correlation coefficient (Corr) and its P-value (P) are shown in the figures.

Comparison to Standards

In those cases in which suitable reference populations are not available and there are no pre-supplementation data, the investigator is left with comparing population parameters to relevant standards. Standards can include performance of natural-origin fish in similar environments (a type of reference condition), mitigation requirements, quantitative objectives of the program, Biological Assessment and Management Plan (BAMP) values, or other appropriate standards. An example of a statistical hypothesis would be:

Ho: Productivity (Recruits/Spawner) of the supplemented population ≥ standard productivity.

Ha: Productivity (Recruits/Spawner) of the supplemented population < standard productivity.

For these analyses to be useful, the standards must be based on biological reality.

Conclusions and Recommendations

Hatcheries are an important component of fish production within the Upper Columbia Basin. The goal of some of these programs is to supplement natural production in declining populations. The supplementation programs generally use both hatchery and natural (spawned and reared in nature from either wild or hatchery parents) adults for hatchery broodstock. These programs are designed to supplement natural populations by increasing natural reproduction while preventing the establishment of a domesticated hatchery stock. Thus, the programs should increase total spawning escapement and NORs, and not reduce the productivity of the natural population. Measuring the success of these programs is challenging and expensive.

In this paper, we described methods that can be used to determine if supplementation programs are achieving some of their goals. This paper focused on the use of reference populations to determine if the supplementation programs increase total spawning escapement, NORs, and maintain or increase productivities. In some cases, suitable reference populations may not be available (e.g., we found no suitable reference populations for Upper Columbia steelhead and sockeye). In these cases, alternative methods are needed to assess supplementation effects. We also described these alternative methods in this paper.

Identification of Reference Populations

Finding suitable reference populations that match well with supplemented populations is a difficult and time-consuming process. Our three-step selection process included identification of populations with similar life-history characteristics, few or no hatchery spawners, a long time series of accurate abundance and productivity estimates, and similar freshwater habitat impairments and out-of-basin effects. Those populations that met these criteria were then examined for their relationship with the supplemented population (in this case, the Chiwawa spring Chinook population). Several criteria were scored, including pNOS, correlation, trend, and effect size. Reference populations with total weighed scores of 81 or greater were selected as suitable reference populations.

This selection process provided a valuable framework for selecting suitable reference populations for supplemented populations. Interestingly, we found that a given reference population may match well with one parameter of the supplemented population (e.g., spawning escapement), but not for all parameters (e.g., not NORs or productivity). The reason for this may be related to errors

in the estimation of population parameters and/or differential factors limiting population parameters of supplemented and reference populations. Therefore, depending on the parameter analyzed, a different suite of reference populations may be needed.

An important assumption in the use of reference populations is that the supplemented and reference populations that tracked each other before supplementation would continue to track each other in the absence of supplementation. Given that the reference populations did not match the Chiwawa population on all criteria examined, and some reference populations tracked the Chiwawa population more poorly than others, there may be some uncertainty as to whether differences observed between the supplemented and reference populations during the supplementation period are associated with the hatchery program, or other unaccounted factors. For example, any large-scale change (man-made or natural) within the reference or supplemented population could affect our ability to assess the effectiveness of the supplementation program.

To account for some of these uncontrollable factors, we recommend the use of a "causal-comparative" approach to strengthen the certainty of our inferences. This approach relies on correlative data to try and make a case for causal inference. We recommend that the following state variables be measured and tracked within the supplemented and reference populations: mean annual precipitation, total and riparian forest cover, road density, impervious surface, and alluvium. These variables can be used to describe differences in water temperatures at different life stages (pre-spawning, egg incubation, and summer rearing) and substrate characteristics, including fine sediments and embeddedness. These state variables can be used to help explain possible changes in spawner abundance, NORs, and productivity that are independent of supplementation. In addition, the use of multiple reference streams reduces the possibility that man-made changes to a single reference stream will influence the interpretation of the results.

Analyses with Reference Populations

Using reference populations, we evaluated the effects of supplementation on natural-log transformed and untransformed total spawning escapement, NORs, and productivity by comparing trends, analyzing mean differences, ratios, and rates, and comparing stock-recruitment curves and their parameters. For trend analysis, we compared the slopes of the trends between each supplemented/reference pair before and during supplementation. If the hatchery program is successfully supplementing the natural population, trends in spawner abundance and NORs should deviate significantly during the supplementation period (i.e., the slope of the supplemented population should be greater than the slopes of the reference populations during the supplementation period), but not during the pre-supplementation period. For productivity, the slope of the supplemented population, relative to the reference population, should increase or remain the same.

Because trend analysis only tests the slopes of the trend lines, it does not test for differences in elevations of the trend lines, additional analyses were needed to determine if supplementation increased spawner abundance, NORs, and productivity of the target population without changing the slopes of the trend lines. To do this, we derived three different response variables using natural-log transformed and untransformed spawner abundance, NORs, and productivity data. The first derived variable included difference scores, which were calculated as the difference between paired treatment and reference data (T-R). The second included ratios, which were calculated as the ratio of paired treatment and reference data (T/R). Finally, we calculated the differences in annual changes in paired treatment and reference population data (ΔT-ΔR). If the hatchery

program is successfully supplementing the natural population, the mean difference or ratio score of paired spawner abundance data and NORs during the supplementation period should be greater than the pre-supplementation period. For productivity, the mean difference or ratio score during the supplementation period should be equal to or higher than the pre-supplementation period.

As a final set of analyses, we compared the stock-recruitment curves of the supplemented population (using stock and recruitment data only from the supplementation period) to the reference populations (using all available stock and recruitment data). Specifically, we tested whether the regression parameters were equal between the supplemented population and the reference populations, and whether the fitted curves coincided between populations. Here, we were most interested in comparing the productivity parameters in the models.

Surprisingly, these different analyses yielded similar results when they were applied to the Chiwawa spring Chinook and reference population data. Trend analysis was unable to detect a significant difference in trends between the supplemented and reference populations during the supplementation period. Even though we measured an increasing trend in spawner abundance, NORs, and productivity in the supplemented population during the supplementation period, these same parameters trended upward in the reference populations. Likewise, we were unable to detect a significant supplementation effect using difference scores, ratios, and differences in annual changes. However, we found the results from analysis of mean differences of annual change difficult to interpret and they may be insensitive to treatment effects. A simpler analysis, which is also easier to interpret, is to use trend analysis. Finally, comparing stock-recruitment curves and their parameters did not provide strong evidence that supplementation has affected the productivity of the natural population.

Based on these results, we do not recommend using difference scores of annual change (ΔT-ΔR), nor do we recommend comparing stock-recruitment curves and their parameters. As noted above, difference scores of annual change are difficult to interpret and may be redundant with trend analysis. Testing stock-recruitment curves and their parameters appears redundant with testing differences in productivity using difference scores or ratios. In addition, the analyses are computer intensive and do not appear to be very sensitive to changes.

There was little difference in results using difference scores and ratios. It appears that ratios may be more sensitive to change than difference scores (e.g., we found significant differences in some comparisons using ratios but not with difference scores), but ratios can be more difficult to interpret than difference scores. Nevertheless, we recommend the use of ratios in future analyses.

Correcting for Density Dependence and Carrying Capacity

The analyses described so far assumed that the density of spawners or recruits did not affect the survival and productivity of fish. However, without controlling for density effects, productivity of the population would continue to decline with increasing abundance. This scenario could occur in supplementation programs that increase the number of spawners, and could result in lower productivities relative to reference populations. In addition, lower productivities may be caused by differential environmental carrying capacities rather than the capacity of the supplemented fish to produce offspring. Therefore, we described two different methods for deriving density-corrected estimates of productivity. The first controlled the effects of density on productivity by partitioning observed productivities into density-independent and density-dependent productivity. These productivities were then combined in a single test. The second method corrected for differences in carrying capacities between the supplemented and reference populations. This was accomplished

by calculating the percent saturation of NORs, which was estimated as the ratio of observed NORs to the maximum number of NORs that the habitat could support.

We fit Ricker, Beverton-Holt, and smooth hockey stick models to stock and recruitment data to estimate the maximum number of NORs (NORs at carrying capacity) and the maximum number of spawners needed to produce maximum NORs. We fit models to the supplemented and reference populations. Using information-theoretic criterion and evaluating the precision of estimated parameters, we found that the smooth hockey stick model provided the best estimates of maximum NORs and spawners. We used these modeled values to estimate density-independent and density-dependent productivities, and saturation of NORs.

Statistical analyses, using difference scores and ratios of adjusted Chiwawa spring Chinook productivity data, found no significant effects of supplementation on the productivity of the supplemented population. Indeed, the results from correcting for density dependence were similar to those without correcting for density dependence. This is in part because the abundance of the supplemented and reference populations has been below their respective carrying capacities in most years. This was clearly demonstrated in the analyses of NORs corrected for carrying capacity. In the supplemented population, the mean fraction of the carrying capacity filled with NORs decreased significantly during the supplementation period. In other words, the carrying capacity was filled with more NORs during the pre-supplementation period than during the supplementation period, which is contrary to the goal of supplementation. By comparison, two of the reference populations showed a similar decrease in saturation, while the other two reference populations actually increased in saturation. Analyzing the saturation scores using BACI-design analyses indicated that two of the four pairings differed significantly. That is, the percent saturation of the supplemented population decreased significantly relative to two reference populations.

Because productivity can be affected by the abundance of spawners and recruits, we recommend that future analyses comparing supplemented and reference populations adjust for density-dependent effects and differential carrying capacities. Although we detected only slight differences between adjusted and unadjusted results, as supplemented stocks recover, it will become more important to adjust productivities to account for density dependence. Importantly, the analyses using percent saturation placed NORs in the context of the carrying capacity of the environment. This will help managers determine if supplementation programs are filling or over-filling the capacity of the habitat with NORs.

As we noted earlier, analyses using productivities adjusted for density dependence assume that there is a spawner abundance at which density-independent effects end and density-dependent effects begin. In reality, density-dependent effects occur at low spawning abundance and intensify as spawning abundance increases. We did not account for these increasing density-dependent effects at lower spawner abundances. This is an area that needs additional attention.

Analyses without Reference Populations

Because of the rigorous criteria we used to select reference populations, it is likely that reference populations may not exist for making comparisons with supplemented populations. For example, we used the criteria described in this paper to identify reference populations for supplemented steelhead and sockeye populations in the Upper Columbia Basin. We were unsuccessful in identifying any suitable reference populations. Therefore, in the absence of suitable reference populations, it is important to have alternative methods for assessing supplementation effects. We described three different types of analyses one can use to assess supplementation effects in the

absence of reference populations. They include before-after comparisons, correlation analysis, and comparisons to standards.

Before-after analyses compare population metrics before supplementation with those during supplementation. In this case, data collected before supplementation represent the reference condition. The assumption is that population trajectories measured during the pre-supplementation period would continue in the absence of supplementation. We compared trends in spawner abundance, NORs, and productivity before and after supplementation. In addition, we compared mean scores in these three parameters before and after supplementation. Finally, we attempted to compare stock-recruitment parameters before and after supplementation. The hypotheses examined were that the spawner abundance and NORs would be greater during the supplementation period, and that productivities would not decline during the supplementation period.

Trend analysis indicated that the all three Chiwawa spring Chinook population parameters trended downward during the pre-supplementation period, but trended upward during supplementation. On the other hand, mean spawner abundance and NORs were lower during the supplementation period than during the pre-supplementation period. Mean productivities increased, but not significantly, during the supplementation period. We were unable to compare pre- and post-supplementation stock-recruitment curves because we were unable to fit stock-recruitment models to the pre-supplementation data.

We used correlation analyses to determine if the proportion of hatchery-origin fish that spawn naturally on the spawning grounds (pHOS) increased productivity. In addition, we used correlation to assess the association between pHOS and the residuals from stock-recruitment relationships. A significant negative association provides evidence that hatchery-origin spawners may not be as productive as natural-origin spawners. The analysis indicated that the productivity of Chiwawa spring Chinook increased with increasing pHOS, but the association was not significant. In contrast, there was a negative association between pHOS and the stock-recruitment residuals, but again the association was not significant. The latter analysis accounts for density-dependent effects.

In concert, the before-after comparisons and correlation analyses do not provide conclusive evidence that the supplementation program has increased spawner abundance and NORs, or that it has significantly reduced the productivity of the supplemented population. Although increasing the number of hatchery fish on the spawning grounds appears to reduce NORs and productivity, mean productivity actually increased during the supplementation period compared to the pre-supplementation period.

It is important to note that relying on only one set of analysis could result in drawing a wrong conclusion. For example, if we had only conducted trend analysis, we may have concluded wrongly that the Chiwawa spring Chinook supplementation program significantly increased spawner abundance, NORs, and productivity in the supplemented population. The analysis of mean scores and correlations indicates that the supplementation program has not increased spawner abundance or NORs in the supplemented population. Therefore, in the absence of suitable reference populations, we recommend that analyses include the evaluation of trends, means scores, and correlations. By conducting more than one set of analyses, one can use weight-of-evidence to assess the effects of supplementation programs.

Under the scenario that there are no reference populations or pre-supplementation data, one is left with comparing population parameters to relevant standards. These standards could come from mitigation requirements, quantitative objectives, or published or unpublished standards. One could also use correlation to evaluate the association between productivity and pHOS, but this requires a wide range in pHOS values to be most effective. A more extreme approach, which probably would not gain much traction with managers, is to shutoff the supplementation program for some time and then evaluate the effects of the program in a before-after design. The Entiat spring Chinook hatchery program provides a unique opportunity to evaluate this type of management decision.

Some Concerns and Limitations

No matter how hard we try to explain different sources of variation in population data, we are limited by the quality of the data. Teasing out the effects of supplementation requires long time series of population data. Because funding levels and methods change over time, the quality (i.e., accuracy and precision) of the data also changes over time. Importantly, the population parameters examined in this paper (spawner abundance, NORs, and productivity) are rarely measured directly in the field. That is, other population metrics, such as numbers of redds, number of fish counted at weirs or dams, scales, tags, etc., are sampled in the field. These metrics are then used to calculate spawner abundance[24], NORs, and productivity, often based on assumptions about fish/redd, pre-spawning loss, marking rates, and sampling rates. This has a tendency to increase the variability in the data independent of supplementation programs. In our studies, we can only control sampling within the supplemented populations, and even that is limited by available funding. We have no control over the sampling within reference populations. Thus, we have to assume that sampling within the reference populations will continue and that sampling effort will remain comparable to that in the supplemented populations.

In our analyses, we included both the Entiat and Little Wenatchee populations as references for the Chiwawa population. In the analyses, we treated them as equivalent to the other reference populations. That is, the statistical procedures used to compare the supplemented population to each reference population were identical. This is appropriate. However, the interpretation of the results must be different when comparing the Entiat and Little Wenatchee to the supplemented population, because they are populations that were influenced by hatchery fish. As noted earlier, the Entiat spring Chinook hatchery program has been discontinued. Therefore, it provides a unique type of reference where the comparison changes from both populations being supplemented to only one population being supplemented. For the Little Wenatchee, nearly all the strays came from the Chiwawa program. Straying should stop or be greatly reduced with the change in water supply to the Chiwawa Rearing Ponds. In sum, one must be careful in how they interpret these test-reference results.

Finally, it is important to point out that for this paper, we conducted 463 statistical tests. Because we set our Type I error rate at 0.05, by random chance alone, we may have incorrectly rejected about 23 null hypotheses. Inasmuch as this work was designed to evaluate different ways to analyze test-reference data, the number of future analyses will be greatly reduced based on the results from this work. However, if the Type I error rate is a concern to managers, researchers can

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24 The smooth hockey stick model, which we used to estimate density-dependent correction factors for productivity and NORs, is sensitive to errors in spawner escapement estimates. Therefore, it is important to use accurate and precise estimates of spawner escapement.

use a lower error rate, such as $\alpha = 0.01$. Another option is to analyze test-reference data graphically. Although this is subjective, there are no statistical analyses and therefore no concerns with violating assumptions of statistical tests, including temporal correlation. We believe researchers should use the statistical procedures recommended in this report to support graphic analysis.

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Appendix Q
Monitoring and Evaluation of the Chelan and Grant County PUDs Hatchery Programs: 2016 Annual Report

MONITORING AND EVALUATION OF THE CHELAN AND GRANT COUNTY PUDs HATCHERY PROGRAMS

2016 ANNUAL REPORT

September 15, 2017

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Citation: Hillman, T., M. Miller, M. Johnson, C. Moran, J. Williams, M. Tonseth, C. Willard, S. Hopkins, B. Ishida, C. Kamphaus, T. Pearsons, and P. Graf. 2017. Monitoring and evaluation of the Chelan and Grant County PUDs hatchery programs: 2016 annual report. Report to the HCP and PRCC Hatchery Committees, Wenatchee and Ephrata, WA.

TABLE OF CONTENTS

SECTION 1: INTRODUCTION 1

SECTION 2: SUMMARY OF METHODS 7
2.1 Broodstock Collection and Sampling 7
2.2 Within Hatchery Monitoring 9
2.3 Juvenile Sampling 10
2.4 Spawning/Carcass Surveys 12

SECTION 3: WENATCHEE STEELHEAD 19
3.1 Broodstock Sampling 20
3.2 Hatchery Rearing 25
3.3 Disease Monitoring 37
3.4 Natural Juvenile Productivity 37
3.5 Spawning Surveys 44
3.6 Life History Monitoring 48
3.7 ESA/HCP Compliance 66

SECTION 4: WENATCHEE SOCKEYE SALMON 69
4.1 Broodstock Sampling 69
4.2 Hatchery Rearing 75
4.3 Disease Monitoring 80
4.4 Natural Juvenile Productivity 80
4.5 Spawning Escapement 85
4.6 Carcass Surveys 86
4.7 Life History Monitoring 89
4.8 ESA/HCP Compliance 105

SECTION 5: WENATCHEE (CHIWAWA) SPRING CHINOOK 107
5.1 Broodstock Sampling 108
5.2 Hatchery Rearing 115
5.3 Disease Monitoring 122
5.4 Natural Juvenile Productivity 123
5.5 Spawning Surveys 142
5.6 Carcass Surveys 149
5.7 Life History Monitoring 155
5.8 ESA/HCP Compliance 173

SECTION 6: NASON CREEK SPRING CHINOOK 177
6.1 Broodstock Sampling 177
6.2 Hatchery Rearing 180
6.3 Disease Monitoring 183
6.4 Natural Juvenile Productivity 183
6.5 Spawning Surveys 192
6.6 Carcass Surveys 194
6.7 Life History Monitoring 196
6.8 ESA/HCP Compliance 204

SECTION 7: WHITE RIVER SPRING CHINOOK 207
7.1 Captive Brood Collection 207
7.2 Hatchery Spawning and Release 209
7.3 Disease Monitoring 214
7.4 Natural Juvenile Productivity 215
7.5 Spawning Surveys 223
7.6 Carcass Surveys 225
7.7 Life History Monitoring 227
7.8 ESA/HCP Compliance 240

SECTION 8: WENATCHEE SUMMER CHINOOK 243
8.1 Broodstock Sampling 243
8.2 Hatchery Rearing 250
8.3 Disease Monitoring 257
8.4 Natural Juvenile Productivity 258
8.5 Spawning Surveys 261
8.6 Carcass Surveys 265
8.7 Life History Monitoring 270
8.8 ESA/HCP Compliance 284

SECTION 9: METHOW SUMMER CHINOOK 287
9.1 Broodstock Sampling 287
9.2 Hatchery Rearing 294
9.3 Disease Monitoring 300
9.4 Natural Juvenile Productivity 301
9.5 Spawning Surveys 304
9.6 Carcass Surveys 308
9.7 Life History Monitoring 313
9.8 ESA/HCP Compliance 326

SECTION 10: OKANOGAN/SIMILKAMEEN SUMMER CHINOOK 329
10.1 Broodstock Sampling 329
10.2 Hatchery Rearing 330
10.3 Disease Monitoring 336
10.4 Spawning Surveys 336
10.5 Carcass Surveys 338
10.6 Life History Monitoring 341
10.7 ESA/HCP Compliance 353

SECTION 11: CHELAN FALLS SUMMER CHINOOK 355
11.1 Broodstock Sampling 356
11.2 Hatchery Rearing 358
11.3 Spawning Surveys 366
11.4 Carcass Surveys 369
11.5 Life History Monitoring 372
11.6 ESA/HCP Compliance 384

SECTION 12: REFERENCES 385

SECTION 13: APPENDICES 389

LIST OF APPENDICES

Appendix A: **Abundance and Total Numbers of Chinook Salmon and Trout in the Chiwawa River Basin, Washington, 2016.**

Appendix B: **Fish Trapping at the Chiwawa and Wenatchee Smolt Traps during 2016.**

Appendix C: **Summary of CSS PIT-Tagging Activities in the Wenatchee River Basin, 2016.**

Appendix D: **Wenatchee Steelhead Spawning Escapement Estimates, 2016.**

Appendix E: **Examining the Genetic Structure of Wenatchee River Basin Steelhead and Evaluating the Effects of the Supplementation Program.**

Appendix F: **NPDES Hatchery Effluent Monitoring, 2016.**

Appendix G: **Steelhead Stock Assessment at Priest Rapids Dam, 2016.**

Appendix H: **Wenatchee Sockeye Salmon Spawning Escapement, 2016.**

Appendix I: **Genetic Diversity of Wenatchee Sockeye Salmon.**

Appendix J: **Wenatchee Spring Chinook Redd Estimates, 2016.**

Appendix K: **Genetic Diversity of Natural Chiwawa River Spring Chinook Salmon.**

Appendix L: **Fish Trapping at the Nason Creek Smolt Trap during 2016.**

Appendix M: **Fish Trapping at the White River Smolt Trap during 2016.**

Appendix N: **Genetic Diversity of Upper Columbia Summer Chinook Salmon.**

Appendix O: **Summer Chinook Spawning Ground Surveys in the Methow and Chelan Rivers, 2016.**

PREFACE

This annual report is the result of coordinated field efforts conducted by Washington Department of Fish and Wildlife (WDFW), the Confederated Tribes and Bands of the Yakama Nation (Yakama Nation), Chelan County Public Utility District (Chelan PUD), the Confederated Tribes of the Colville Reservation (Colville Tribes), the U.S. Fish and Wildlife Service (USFWS), and BioAnalysts, Inc. An extensive amount of work was conducted in 2006 through 2016 to collect the data needed to monitor the effects of the Chelan and Grant County PUD Hatchery Programs. This work was directed and coordinated by the Habitat Conservation Plans (HCP) Hatchery Committees, consisting of the following members: Bill Gale and Matt Cooper, USFWS; Justin Yeager and Craig Busach, National Marine Fisheries Service (NMFS); Catherine Willard and Alene Underwood, Chelan PUD; Tom Scribner and Keely Murdoch, the Yakama Nation; Mike Tonseth, WDFW; Kirk Truscott, Colville Tribes; and Tracy Hillman, BioAnalysts (Chair). This report also includes monitoring efforts funded by Grant County Public Utility District (Grant PUD). Grant PUD helps fund the spring and summer Chinook monitoring programs. Work funded by Grant PUD was directed and coordinated by the Priest Rapids Coordinating Committee (PRCC) Hatchery Sub-Committee, which consists of the same agency and tribal representatives listed for the HCP Hatchery Committee and replaces Chelan PUD representatives with Grant PUD representatives, Todd Pearsons, Peter Graf, and Deanne Pavlik-Kunkel.

The approach to monitoring the hatchery programs was guided by the updated monitoring and evaluation plan for PUD hatchery programs (Hillman et al. 2013). Technical aspects of the updated monitoring and evaluation program were developed by the Hatchery Evaluation Technical Team (HETT), which consisted of the following scientists: Matt Cooper, USFWS; Tracy Hillman, BioAnalysts; Tom Kahler, Douglas PUD; Greg Mackey, Douglas PUD; Andrew Murdoch, WDFW; Keely Murdoch, Yakama Nation; Todd Pearsons, Grant PUD; Mike Tonseth, WDFW; and Catherine Willard, Chelan PUD. The updated plan also directs the analyses of hypotheses developed by the HETT. Most of the analyses outlined in the updated plan will be conducted in the comprehensive reports.

Most of the work reported in this document was funded by Chelan and Grant PUDs. Bonneville Power Administration purchased some of the Passive Integrated Transponder (PIT) tags that were used to mark juvenile Chinook and steelhead captured in tributaries and also helped fund a portion of the screw trap efforts in Nason Creek. We thank Charlie Paulsen for analyzing PIT-tag data for each program. This is the 11^{th} annual report written under the direction of the HCP.

"I often say that when you can measure something and express it in numbers, you know something about it. When you cannot measure it, when you cannot express it in numbers, your knowledge is of a meager and unsatisfactory kind. It may be the beginning of knowledge, but you have scarcely in your thoughts advanced to the stage of science, whatever it may be."

Lord Kelvin

SECTION 1: INTRODUCTION

Chelan and Grant PUDs implement hatchery programs as part of their respective agreements related to the operation of Rocky Reach, Rock Island, Wanapum, and Priest Rapids Hydroelectric Projects. The fish resource management agencies developed the following general goal statements for the hatchery programs, which were adopted by the HCP Hatchery Committees and PRCC Hatchery Sub-Committee (hereafter, Hatchery Committees):

1. *Support the recovery of ESA-listed species by increasing the abundance of the natural adult population, while ensuring appropriate spatial distribution, genetic stock integrity, and adult spawner productivity.*

   Includes the Wenatchee spring Chinook, Wenatchee summer steelhead, and Methow spring Chinook programs.

2. *Increase the abundance of the natural adult population of unlisted plan species, while ensuring appropriate spatial distribution, genetic stock integrity, and adult spawner productivity. In addition, provide harvest opportunities in years when spawning escapement is sufficient to support harvest.*

   Includes the Wenatchee sockeye, Wenatchee summer/fall Chinook, Methow summer/fall Chinook, Okanogan summer/fall Chinook, and Okanogan sockeye programs.

3. *Provide salmon for harvest and increase harvest opportunities, while segregating returning adults from natural tributary spawning populations.*

   Includes the Chelan Falls summer Chinook program.

Following the development of the Hatchery and Genetic Management Plans (HGMPs), artificial propagation programs are now characterized into three categories. The first type, integrated conservation programs, are intended to support or restore natural populations. These programs focus on increasing the natural production of targeted fish populations. A fundamental assumption of this strategy is that adults spawned in the hatchery will produce more adult offspring than if they were left to spawn in the river and ultimately provide a demographic boost to the natural population. The second type, safety-net programs, are extensions of conservation programs, but are intended to function as reserve capacity for conservation programs in years of low returns. The safety-net provides a demographic and genetic reserve for the natural population. That is, in years of abundant returns, they function like segregated programs, and in years of low returns, they can be managed as conservation programs. Lastly, harvest augmentation programs are intended to increase harvest opportunities while limiting interactions with wild-origin counterparts.

Monitoring is needed to determine if the hatchery programs are meeting the intended management objectives of conservation, safety-net, or harvest augmentation programs. Objectives for hatchery programs are generally grouped into three categories of performance indicators:

1. In-Hatchery Indicators: Are the programs meeting the hatchery production objectives?

2. In-Nature Indicators: How do hatchery fish from the programs perform after release?

a. Conservation Programs:
   - How do the programs affect target population abundance and productivity?
   - How do the programs affect target population long-term fitness?

b. Safety-Net Programs:
   - How do the programs affect target population long-term fitness?

c. Harvest Augmentation Programs:
   - Do the programs provide harvest opportunities?

3. Risk Assessment Indicators: Do the programs pose risks to other populations?

The specific objectives identified in the updated monitoring and evaluation plan are as follows:

1. *Determine if conservation programs have increased the number of naturally spawning and naturally produced adults of the target population and if the program has reduced the natural replacement rate (NRR) of the supplemented population.*
2. *Determine if the proportion of hatchery fish on the spawning grounds affects the freshwater productivity of supplemented stocks.*
3. *Determine if the hatchery adult-to-adult survival (i.e., hatchery replacement rate, HRR) is greater than the natural adult-to-adult survival (i.e., natural replacement rate, NRR) and the target hatchery survival rate.*
4. *Determine if the proportion of hatchery-origin spawners (pHOS or PNI) is meeting management target.*
5. *Determine if the run timing, spawn timing, and spawning distribution of both the hatchery component is similar to the natural component of the target population or is meeting program-specific objectives.*
6. *Determine if stray rate of hatchery fish is below the acceptable levels to maintain genetic variation among stocks.*
7. *Determine if genetic diversity, population structure, and effective population size have changed in natural spawning populations as a result of the hatchery program.*
8. *Determine if hatchery programs have caused changes in phenotypic characteristics of natural populations.*
9. *Determine if hatchery fish were released at the programmed size and number.*
10. *Determine if appropriate harvest rates have been applied to conservation, safety-net, and segregated harvest programs to meet the HCP/SSSA goal of providing harvest opportunities while also contributing to population management and minimizing risk to natural populations*

Two additional regional objectives that were not explicit in the goals specified above but were included in the updated monitoring and evaluation plan because they relate to goals and concerns of all artificial production programs include:

11. *Determine if the incidence of disease has increased in the natural and hatchery populations.*
12. *Determine if the release of hatchery fish affects non-target taxa of concern (NTTOC) within acceptable limits.*

Objective 12 was completed using an extensive risk assessment that concluded risks from the PUD hatchery programs were within containment objectives approved by the Hatchery Committees (Mackey et al. 2014; Pearsons et al. 2012).

Objectives in the updated plan have been organized in a hierarchy where productivity indicators are the primary metrics used to assess if conservation and safety-net program goals have been met; harvest rates and effects on non-targeted populations are used for harvest programs. In cases where productivity indicators are not available, or results are equivocal, monitoring indicators may be used to help evaluate the performance of the program. Evaluations of monitoring indicators may not provide sufficiently powerful conclusions on which to base management actions; although they may provide insight as to why a productivity indicator did or did not meet the program goal. Therefore, the relationship between hatchery programs and indicators can be viewed in a chain-of-causation: management actions within the hatchery programs affect the status of monitoring indicators, which in turn influence productivity indicators (Figure 1.1).

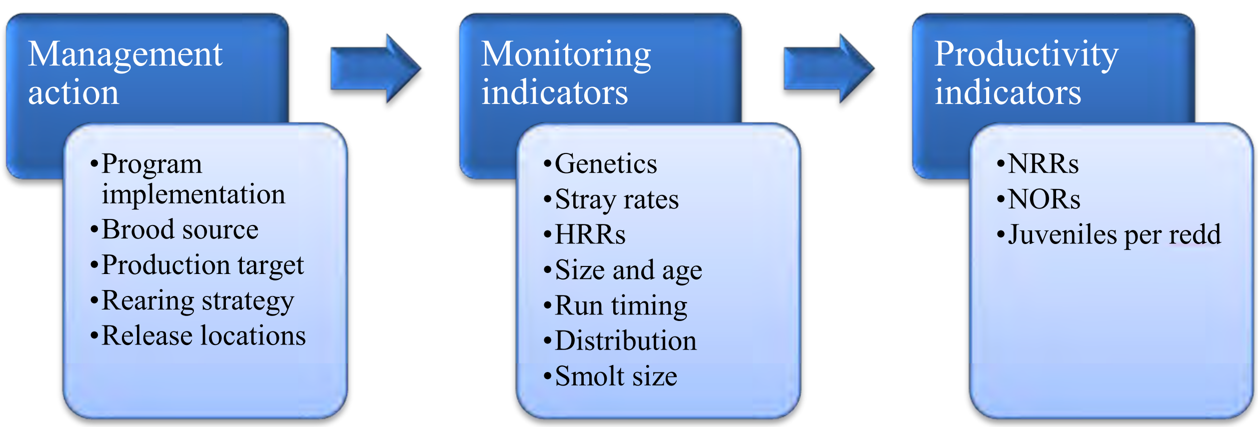

Figure 1.1. Relationship of indicators to the assessment of propagation programs. Management actions affect monitoring indicators, which influence productivity indicators. Monitoring indicators may be used to hypothesize the magnitude of influence on productivity.

Attending each objective is one or more testable hypotheses (see Hillman et al. 2013). Each hypothesis will be tested statistically following the routines identified in the updated monitoring and evaluation plan. Most of these analytical routines will be conducted at the end of five-year monitoring blocks, as outlined in the updated plan.

Both monitoring and productivity indicators will be used to evaluate the success of the hatchery programs. If the statistical power of tests that involve productivity indicators is insufficient to inform sound management decisions, some of the monitoring indicators may be used to guide management. Figure 1.2 shows the categories of indicators associated with each component of monitoring.

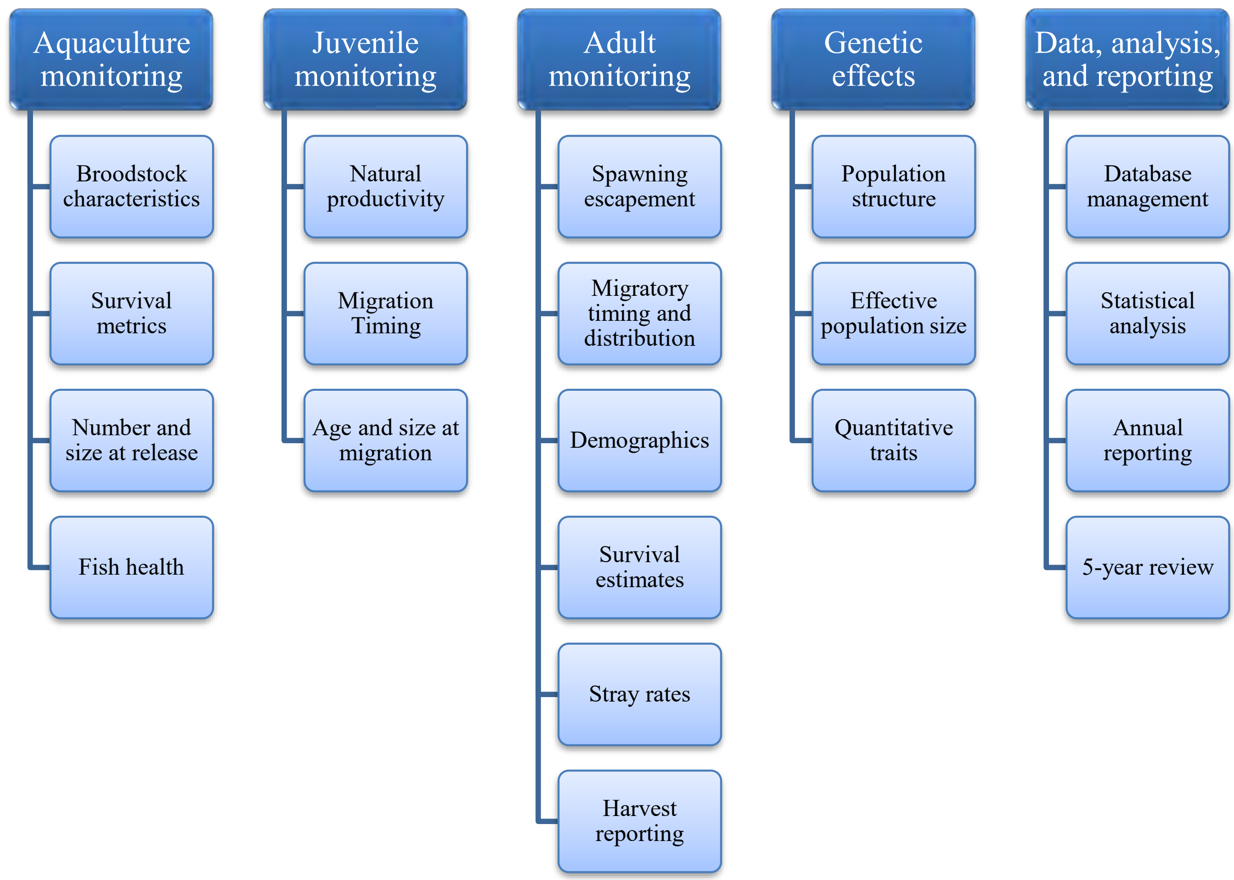

Figure 1.2. Overview of monitoring and evaluation plan categories and components (not including regional objectives).

Throughout each five-year monitoring period, annual reports will be generated that describe the monitoring and evaluation data collected during a specific year. This is the 11th annual report developed under the direction of the Hatchery Committees. The purpose of this report is to describe monitoring activities conducted in 2016. Activities included broodstock collection, collection of life-history information, within hatchery spawning and rearing activities, juvenile monitoring within streams, and redd and carcass surveys. Data from reference areas are not included in this annual report (reference data are in the five-year reports). To the extent currently possible, we have included information collected before 2016.

This report is divided into several sections, each representing a different species, stock, or spawning aggregate (i.e., steelhead, sockeye salmon, spring Chinook salmon, and summer Chinook salmon). For all species, we provide annual broodstock information; hatchery rearing history, release data, and survival estimates; disease information; juvenile migration and productivity estimates; redd counts, distribution, and spawn timing; spawning escapements; and life-history characteristics. For salmon species, we also provide information on carcasses. Brood year 2011 was the final sockeye salmon hatchery release, and beginning in 2013, only natural adult and juvenile sockeye productivity monitoring results are reported. Beginning in 2013, we added a separate section on Nason Creek spring Chinook salmon and in 2014 we added a separate section on White River spring Chinook salmon. The Colville Tribes began conducting monitoring of

Okanogan summer Chinook in 2013; however, we retained the Okanogan summer Chinook section in this report because the PUDs have summer Chinook mitigation obligations in the Okanogan River basin. The Okanogan summer Chinook section includes monitoring information up to the return of brood year 2013 Chinook. Monitoring results for brood years 2013 to present can be found in annual reports prepared by the Colville Tribes to Bonneville Power Administration (BPA). Monitoring results of Grant PUD's fall Chinook salmon mitigation produced at Priest Rapids Hatchery can be found in annual reports written by WDFW and Grant PUD.

Finally, we end each section by addressing compliance issues with ESA/HCP mandates. For each Hatchery Program, WDFW and the PUDs are authorized annual take of ESA-listed spring Chinook and steelhead through Section 10 of the Endangered Species Act (ESA), including:

1. ESA Section 10(a)(1)(A) Permit No. 1395, which authorizes the annual take of adult and juvenile endangered upper Columbia River (UCR) spring Chinook and endangered UCR steelhead associated with implementing artificial propagation programs for the enhancement of UCR steelhead. The authorization includes takes associated with adult broodstock collection, hatchery operations, juvenile fish releases, monitoring and evaluation activities, and management of adult returns related to UCR steelhead artificial propagation programs in the UCR region (NMFS 2003a).
2. ESA Section 10(a)(1)(A) Amended Permit No. 18121, which authorizes the annual take of adult and juvenile endangered UCR spring Chinook and endangered UCR steelhead associated with implementing artificial propagation programs in the Chiwawa River for the enhancement of UCR spring Chinook. The authorization includes takes associated with adult broodstock collection, hatchery operations, juvenile fish releases, and monitoring and evaluation activities supporting UCR spring Chinook artificial propagation programs in the UCR region (NMFS 2003, amended in 2015).
3. ESA Section 10(a)(1)(A) Permit No. 18118, which authorizes the annual take of adult and juvenile endangered UCR spring Chinook and endangered UCR steelhead associated with implementing artificial propagation programs in Nason Creek for the enhancement of UCR spring Chinook. The authorization includes takes associated with adult broodstock collection, hatchery operations, juvenile fish releases, and monitoring and evaluation activities supporting UCR spring Chinook artificial propagation programs in the UCR region (NMFS 2003, amended in 2015).
4. ESA Section 10(a)(1)(A) Permit No. 18119, which authorizes the annual take of adult and juvenile endangered UCR spring Chinook and endangered UCR steelhead associated with implementing artificial propagation programs in the White River for the enhancement of UCR spring Chinook. The authorization includes takes associated with adult broodstock collection, hatchery operations, juvenile fish releases, and monitoring and evaluation activities supporting UCR spring Chinook artificial propagation programs in the UCR region (NMFS 2003, amended in 2015).
5. ESA Section 10(a)(1)(A) Permit No. 1347, which authorizes the annual incidental take of adult and juvenile endangered UCR spring Chinook and endangered UCR steelhead through actions associated with implementing artificial propagation programs for the enhancement of non-listed anadromous fish populations in the UCR. The authorization includes incidental takes associated with adult broodstock collection, hatchery operations, juvenile fish releases, and monitoring and evaluation activities associated with non-listed

summer Chinook, fall Chinook, and sockeye salmon artificial propagation programs in the UCR region (NMFS 2003b).

SECTION 2: SUMMARY OF METHODS

Sampling in 2016 followed the methods and protocols described in Hillman et al. (2013). In this section, we only briefly review the methods and protocols. More detailed information can be found in the updated monitoring and evaluation plan (Hillman et al. 2013).

2.1 Broodstock Collection and Sampling

Methods for collecting broodstock are described in the Annual Broodstock Collection Protocols (WDFW 2016). Generally, broodstock were collected over the migration period (to the extent allowed in ESA-permit provisions) in proportion to their temporal occurrence at collection sites, with in-season adjustments dictated by 2016 run timing and trapping success relative to achieving weekly and annual collection objectives. Pre-season weekly collection objectives are shown in Table 2.1 and assumptions associated with broodstock trapping are provided in Table 2.2.

Table 2.1. Weekly collection objectives for steelhead and Chinook in 2016.

Collection week beginning day	Chiwawa/Nason Spring Chinook[a]		Hatchery Chelan Falls Summer Chinook	Wild Wenatchee Summer Chinook	Wild Methow Summer Chinook	Wenatchee Steelhead	
	Hatchery	Wild				Hatchery	Wild
30 May	6	4					
6 June	10	8					
13 June	16	12					
20 June	24	18					
27 June	24	20		70	12		
4 Jul	20	12	90	46	20	1	1
11 Jul	8	4	80	26	22	1	2
18 Jul			70	36	18	2	3
25 Jul			50	28	10	3	3
1 Aug			40	26	6	3	3
8 Aug			20	20	4	4	4
15 Aug				18	4	4	5
22 Aug					4	4	5
29 Aug					2	6	4
5 Sep					2	7	6
12 Sep					2	7	8
19 Sep						8	8
26 Sep						8	6
3 Oct						8	4
10 Oct						2	2
17 Oct						1	2
24 Oct						1	2
Total	**108**	**150**	**350**	**270**	**106**	**70**	68

[a] Chiwawa NOR spring Chinook (n = up to 80) were collected from the Chiwawa Weir with no specific weekly objectives generated, which is consistent with the Broodstock Collection Protocols. Previously PIT-tagged Chiwawa NOR spring Chinook were also targeted at Tumwater Dam. All Nason Creek spring Chinook were collected at Tumwater Dam from the week of 30 May

through the week of 11 July proportionate to run timing. For 2016, HOR Chiwawa spring Chinook were collected for the Nason spring Chinook safety net program.

Table 2.2. Biological and trapping assumptions associated with collecting broodstock for the Chelan and Grant PUD Hatchery Programs, 2016.[1]

Assumptions	Wenatchee Steelhead	Chiwawa Spring Chinook	Nason Spring Chinook		Wenatchee Summer Chinook	Chelan Falls Summer Chinook	Methow Summer Chinook
			Conservation Program	Safety Net Program			
Production level	247,300 yearling smolts	144,026 yearling smolts	125,000 yearling smolts	98,670 yearling smolts	500,001 yearling smolts	576,000 yearling smolts	200,000 yearling smolts
Broodstock required	138 adults (not to exceed 33% of population)	80 adults (not to exceed 33% of NOR population)	70 adults (not to exceed 33% of population)	72 adults	270 adults (not to exceed 33% of the population)	350 adults	106 adults (not to exceed 33% of the population)
Trapping period	1 July-14 Nov	1 June – 15 July (Tumwater) 13 June-31 July (Chiwawa Weir)	1 June – 15 July	1 June – 15 July	27 June – 15 Sept (Dryden) 15 July- 15 Sept (Tumwater)	1 July – 15 Sep	1 July – 15 Sept
# days/week	5	7 (Tumwater) Not to exceed 15 cumulative trapping days (Chiwawa Weir)	7	7	5 (Dryden) 2 (Tumwater)	7	3
# hours/day	24	24 (Tumwater) 24 up/24 down (Chiwawa Weir)	24	24	24	24	16
Broodstock composition	50% WxW; 50% HxH	100% WxW	100% WxW	100% HxH	100% WxW	100% HxH	100% WxW
Trapping site	Dryden Dam for HxH; Tumwater for WxW. (Tumwater will be used if weekly quota not achieved for WxW (hatchery) at Dryden Dam)	Tumwater Dam and Chiwawa Weir	Tumwater Dam	Tumwater Dam	Dryden Dam (Tumwater will be used if weekly quota not achieved at Dryden Dam)	Chelan River Water Conveyance Canal Trap	Wells Dam east or west ladder

Several biological parameters were measured during broodstock collection at adult collection sites. Those parameters included the date and start and stop time of trapping; number of each species

[1] Throughout this document, "HxH" refers to hatchery-origin by hatchery-origin crosses and "WxW" refers to natural-origin by natural-origin crosses.

collected for broodstock; origin, size, and sex of trapped fish; age from scale analysis; and pre-spawn mortality. For each species, trap efficiency, extraction rate, and trap operation effectiveness were estimated following procedures in Hillman et al. (2013). In addition, a representative sample of most species trapped but not taken for broodstock were sampled for origin, sex, age, and size (stock assessment).

2.2 Within Hatchery Monitoring

Methods for monitoring hatchery activities are described in Hillman et al. (2013). Biological information collected from all spawned adult fish included age at maturity, length at maturity, spawn time, and fecundity of females. In addition, all fish were checked for tags and females were sampled for pathogens.

Throughout the rearing period in the hatchery, fish were sampled for growth, health, and survival. Each month, lengths and weights were collected from a sample of fish and rearing density indices were calculated. In addition, fish were examined monthly for health problems following standard fish health monitoring practices for hatcheries. Various life-stage survivals were estimated for each hatchery stock. These estimates were then compared to the "standard" survival rates identified in Table 2.3 to provide insight as to how well the hatchery operations were performing. Failure to achieve a survival standard could indicate a problem with some part of the hatchery program. However, failure to meet a standard may not be indicative of the overall success of the program to meet the goals identified in Section 1.

Table 2.3. Standard life-stage survival rates for fish reared within the Chelan PUD hatchery programs (from Hillman et al. 2013).

Life stage	Standard survival rate (%)
Collection-to-spawning (females)	90
Collection-to-spawning (males)	85
Unfertilized egg-to-eyed	92
Unfertilized egg-to-ponding	98
30 d after ponding	97
100 d after ponding	93
Ponding-to-release	90
Transport-to-release	95
Unfertilized egg-to-release	81

Nearly all hatchery fish from each stock were marked (adipose fin clip) or tagged (coded-wire tag) in 2016. Different combinations of marks and tags were used depending on the stock. In addition, Chelan PUD personnel PIT tagged 10,207 juvenile WxW Chiwawa spring Chinook and 10,104 juvenile Nason Creek spring Chinook (5,052 WxW and 5,050 HxH); 5,050 Wenatchee WxW steelhead (Circular Ponds), 12,626 Wenatchee WxW and HxH steelhead (Raceway), and 2,525 Wenatchee steelhead (Blackbird Pond); and 10,103 Chelan River summer Chinook, 5,064 Methow (Carlton) summer Chinook, and 20,994 Wenatchee summer Chinook (10,565 Raceway and 10,429 Circular Ponds). PIT tags will be used to estimate migration timing and survival rates (e.g., smolt-to-adult) outside the hatchery.

Lastly, the size and number of fish released were assessed and compared to programmed production levels. The goal of the program is that numbers released and their sizes should fall within 10% of the programmed targets identified in Table 2.4. However, because of constraints due to run size and proportions of wild and hatchery adults, production levels may not be met every year.

Table 2.4. Targets for fish released from the PUD hatchery programs; CV = coefficient of variation.

Hatchery stock	Release targets	Size targets		
		Fork length (CV)	Weight (g)	Fish/pound
Wenatchee Summer Chinook	500,001	163 (9.0)	45.4	18[a]
Methow Summer Chinook	200,000	163 (9.0)	45.4	13-17
Chelan Falls Summer Chinook (yearlings)	576,000	161 (9.0)	45.4	13[b]
Chiwawa Spring Chinook	144,026	155 (9.0)	37.8	18
Nason Spring Chinook	223,670	155 (9.0)	37.8	18
Wenatchee Steelhead	247,300	191 (9.0)	75.6	6

[a]An experimental release size of 30-45 grams (10-15 FPP) was in place for brood years 2012-2014.
[b]An experimental release size of 20-45 grams (10-22 FPP) was in place for brood years 2012-2014.

2.3 Juvenile Sampling

Juvenile sampling within streams included operation of rotary screw traps, snorkel observations, and PIT tagging. Methods for sampling juvenile fish are described in Hillman et al. (2013).

A smolt trap was located on the Wenatchee River near the town of Cashmere at RM 8.3 (Lower Wenatchee Trap), in Nason Creek about 0.6 miles upstream from the mouth, in the White River about 5.8 miles upstream from the mouth, and in the Chiwawa River about 0.4 miles upstream from the mouth (Chiwawa Trap). All traps operated throughout the smolt migration period. The Chiwawa Trap operated between 2 March and 21 November 2016. The Nason Creek Trap operated from 1 March to 30 November in 2016. The White River trap operated from 1 March through 30 November 2016. The Lower Wenatchee Trap operated between 29 January and 26 June 2016. Throughout the trapping period, the traps were briefly inoperable during periods when flows were too high or low, during high water temperatures, during large hatchery releases, and because of heavy debris loads, ice, and mechanical malfunctions.

The following data were collected at each trap site: water temperature, discharge, number and identification of all species captured, degree of smoltification for anadromous fish, presence of marks and tags, size (fork lengths and weights), and scales from smolts. Trap efficiencies at each trap site were estimated by using mark-recapture trials conducted over a wide range of discharges. Linear regression models relating discharge and trap efficiencies were developed to estimate daily trap efficiencies during periods when no mark-recapture trials were conducted. The total number of fish migrating past the trap each day was estimated as the quotient of the daily number of fish captured and the estimated daily trap efficiency. Summing the daily totals resulted in the total emigration estimate.

Snorkel observations were used to estimate the number of juvenile spring Chinook salmon, juvenile rainbow/steelhead, and bull trout within the Chiwawa River basin. The focus of the study was on juvenile spring Chinook salmon. Sampling followed a stratified random design with proportional allocation of sites among strata. Strata were identified based on unique combinations of geology, land type, valley bottom type, stream state condition, and habitat types. A total of 187 randomly selected sites were surveyed during August (Table 2.5). Counts of fish within each sampling site were adjusted based on detection efficiencies, which were related to water temperature. That is, non-linear models that described relationships between water temperatures and detection efficiencies (Hillman et al. 1992) were used to estimate total numbers of fish within sampling sites. These numbers were then converted to densities by dividing total fish numbers by the wetted surface area and water volume of sample sites. Total numbers within a stratum were estimated as the product of fish densities times the total wetted surface or water volume for the stratum. The sum of fish numbers across strata resulted in the total number of fish within the basin. The calculation of total numbers, densities, and degrees of certainty are explained fully in Hillman and Miller (2004).

Table 2.5. Location of strata and numbers of randomly sampled snorkel sites within each stratum that were sampled in the Chiwawa River Basin in 2016.

Reach/stratum	River miles (RM)	Number of randomly selected sites
Chiwawa River		
1	0.0-3.8	11
2	3.8-5.5	5
3	5.5-7.9	8
4	7.9-8.9	6
5	8.9-10.8	5
6	10.8-11.8	6
7	11.8-20.0	29
8	20.0-25.4	24
9	25.4-28.8	11
10	28.8-31.1	21
Phelps Creek		
1	0.0-0.4	1
Chikamin Creek (includes Minnow Creek)		
1	0.0-1.5	12
Rock Creek		
1	0.0-0.7	9
Unnamed stream on USGS map		
1	0.0-0.1	1
Big Meadow Creek		
1	0.0-1.0	13
Alder Creek		
1	0.0-0.1	4
Brush Creek		
1	0.0-0.1	2
Clear Creek		

Reach/stratum	River miles (RM)	Number of randomly selected sites
1	0.0-0.1	2

Working in collaboration with the Comparative Survival Study (CSS) funded by BPA, crews PIT tagged juvenile wild Chinook, wild steelhead, wild sockeye, and in some instances wild coho salmon collected at the smolt traps and collected within the Chiwawa River and Nason Creek using electrofishing techniques. The proposed number of wild spring Chinook and steelhead to be tagged at each location is provided in Table 2.6. The goal of this tagging program is to estimate freshwater juvenile productivity, better understand life-history characteristics, overwinter movement, and survival of salmonids, and to calculate SARs for spring Chinook salmon in the Wenatchee River basin. The PIT tagging effort funded by the PUDs in the Chiwawa River and Nason Creek is specifically directed at addressing uncertainties of estimating abundance using screw traps (e.g., fish passage during times when trapping is not possible).

Table 2.6. Number of wild spring Chinook, steelhead (≥65 mm), and sockeye proposed for PIT tagging at different locations within the Wenatchee River basin, 2016. NT = no sample size target.

Sampling location	Target sample size		
	Wild spring Chinook	Wild steelhead	Wild Sockeye
Chiwawa Trap	2,500-8,000	500-2,000	NT
Nason Creek Trap	2,500-8,000	500-2,000	NT
White River Trap	200-500	NT	NT
Lower Wenatchee Trap	1,000-2,500	50-250	3,000-5,000
Chiwawa Remote Sampling	3,000	NT	NT
Nason Remote Sampling	3,000	NT	NT

Survival rates for various juvenile life-stages were calculated based on estimates of seeding levels (total egg deposition), parr abundance, numbers of emigrants, and smolt abundance. Total egg deposition was estimated as the product of the number of redds counted in the basin times the mean fecundity of female spawners. Fecundity was estimated from females collected for broodstock using an electronic egg counter. Numbers of emigrants and smolts were estimated at trapping sites and numbers of parr were estimated using snorkel observations only in the Chiwawa River basin. Survival estimates could not be calculated for some stocks (e.g., summer Chinook) because specific life-stage abundance estimates were lacking.

2.4 Spawning/Carcass Surveys

Methods for conducting carcass and spawning ground surveys are detailed in Hillman et al. (2013). Information collected during spawning surveys included spawn time, redd distribution, and redd abundance. Data collected during carcass surveys included sex, size (fork length and postorbital-to-hypural length), scales for aging[2], degree of egg voidance, DNA samples, and identification of marks or tags. The sampling goal for carcasses was 20% of the spawning population.

[2] In this report, we use two methods of describing age. One is termed the "European Method." This method has two digits, separated by a period. The first digit represents the number of winters the fish spent in freshwater before migrating to the sea. The second digit indicates the number of winters the fish spent in the ocean. For example, a fish designated as 1.2 spent one winter in freshwater and two in the ocean. A fish designated as 0.3 migrated to the ocean

Steelhead surveys were conducted throughout the mainstem Wenatchee River and downstream from PIT-tag interrogation systems on the Chiwawa River, Nason Creek, and Peshastin Creek. These surveys were conducted during March through June in reaches and index areas described in Table 2.7. Total redd counts in these reaches were estimated by expanding counts within non-index areas by expansion factors developed within index areas.

Table 2.7. Description of reaches and index areas surveyed for steelhead redds in the Wenatchee River basin.

Stream	Code	Reach*	Index/reference area
Wenatchee River	W1	Mouth to Sleepy Hollow Br	River Bend to Sleepy Hollow Br
	W2	Sleepy Hollow Br to L. Cashmere Br	Sleepy Hollow Br to Cashmere Boat Rmp
	W3	L. Cashmere Br to Dryden Dam	Williams Canyon to Dryden Dam
	W5	Peshastin Br to Leavenworth Br	Irrigation Flume to Leavenworth Br
	W6	Leavenworth Br to Icicle Rd Br	Leavenworth Boat Ramp to Icicle Ck
	W7	Icicle Rd Br to Tumwater Dam	Icicle Br to Penstock Br
	W8	Tumwater Dam to Tumwater Br	Island below Swiftwater to Swiftwater CG
	W9	Tumwater Br to Chiwawa R	Tumwater Br to Plain
	W10	Chiwawa R to Lk Wenatchee	Chiwawa Pump St. to Lk Wenatchee
Peshastin Creek	P1	Mouth to PIT Detection Site	Mouth to PIT Detection Site
Chiwawa River	C1	Mouth to Rd 62 Br RM 6.4	Mouth to PIT Detection Site
Nason Creek	N1	Mouth to PIT Detection Site	Mouth to PIT Detection Site

* Reaches 2, 6, 8, 9, and 10 (major spawning areas) are surveyed weekly, while Reaches 1, 3, 5, and 7 (minor survey areas) are surveyed during peak spawning.

Beginning in 2014, adult steelhead escapement estimates in the majority of tributaries in the Wenatchee River basin were generated using mark-recapture techniques based on steelhead PIT tagged at Priest Rapids Dam. Mark-recapture estimates in the tributaries were then added to the estimates based on redd surveys to generate a total spawning escapement to the Wenatchee River basin.

Spring Chinook redd and carcass surveys were conducted during August through September in the Chiwawa River (including Rock and Chikamin creeks), Nason Creek, Icicle Creek, Peshastin Creek (including Ingalls Creek), upper Wenatchee River, Little Wenatchee River, and the White River (including the Napeequa River and Panther Creek). Survey reaches for spring Chinook are described in Table 2.8.

Table 2.8. Description of reaches surveyed for spring Chinook redds and carcasses in the Wenatchee River basin.

Stream	Code	Reach	River mile (RM)
Chiwawa River	C1	Mouth to Grouse Creek	0.0-11.7
	C2	Grouse Creek to Rock Creek	11.7-19.3
	C3	Rock Creek to Schaefer Creek	19.3-22.4

in its first year and spent three winters in the ocean. The other method describes the total age of the fish (egg-to-spawning adult, i.e., gravel-to-gravel), so fish demarcated as 0.3 or 1.2 are considered 4-year-olds, from the same brood.

Stream	Code	Reach	River mile (RM)
	C4	Schaefer Creek to Atkinson Flats	22.4-25.6
	C5	Atkinson Flats to Maple Creek	25.6-27.0
	C6	Maple Creek to Phelps Creek	27.0-30.3
	C7	Phelps Creek to Buck Creek	30.3-31.4
Rock Creek	R1	Mouth to Chiwawa River Road Bridge	0.0-0.5
Chikamin Creek	K1	Mouth to Chiwawa River Road Bridge	0.0-0.5
Nason Creek	N1	Mouth to Kahler Creek Bridge	0.0-3.9
	N2	Kahler Creek Bridge to Hwy 2 Bridge	3.9-8.3
	N3	Hwy 2 Bridge to Lower RR Bridge	8.3-13.2
	N4	Lower RR Bridge to Whitepine Creek	13.2-15.4
Little Wenatchee River	L1	Mouth to Old Fish Weir	0.0-2.7
	L2	Old Fish Weir to Lost Creek	2.7-5.2
	L3	Lost Creek to Rainy Creek	5.2-9.2
	L4	Rainy Creek to Falls	9.2-Falls
White River	H1	Mouth to Sears Creek Bridge	0.0-6.4
	H2	Sears Creek Bridge to Napeequa River	6.4-11.0
	H3	Napeequa River to Grasshopper Meadows	11.0-12.9
	H4	Grasshopper Meadows to Falls	12.9-16.1
Napeequa River	Q1	Mouth to Take Out	0.0-1.0
Panther Creek	T1	Mouth to Boulder Field	0.0-1.0
Wenatchee River	W8	Tumwater Dam to Tumwater Bridge	30.9-35.6
	W9	Tumwater Bridge to Chiwawa River	35.6-48.4
	W10	Chiwawa River to Lake Wenatchee	48.4-54.2
Chiwaukum Creek	U1	Mouth to Metal Bridge	0.0-1.0
Icicle Creek	I1	Mouth to Hatchery	0.0-2.8
	I2	Hatchery to Sleeping Lady	2.8-3.3
	I3	Sleeping Lady to Snow Creek	3.3-3.8
Peshastin Creek	P1	Mouth to Camas Creek	0.0-5.9
	P2	Camas Creek to Mouth of Scotty Creek	5.9-16.3
Ingalls Creek	D1	Mouth to Trailhead	0.0-1.0

The sockeye salmon hatchery program ended after the 2011 brood year. As a result, monitoring activities that focused on evaluating the effects of the supplementation program on the natural population switched to monitoring the abundance and productivity of the natural population (McElhaney et al. 2000). Thus, estimation of spawn time and carcass surveys were discontinued in 2014. Nevertheless, this report retains the results of carcass sampling during the period 1993-2013. Survey reaches in which carcasses and live fish (for area-under-the-curve estimates) were conducted are identified in Table 2.9.

From 2009-2013, mark-recapture methods were used to estimate sockeye spawning escapement within the White River, while area-under-the-curve (AUC) methods were used to estimate spawning escapement within the Little Wenatchee River. Beginning in 2014, mark-recapture methods were used to estimate the spawning escapement of sockeye in both the White River and Little Wenatchee watersheds.

Table 2.9. Description of reaches surveyed for sockeye salmon carcasses and live fish in the Wenatchee River basin during survey years 1993-2013.

Stream	Code	Reach	River mile (RM)
Little Wenatchee River	L1	Mouth to Old Fish Weir	0.0-2.7
	L2	Old Fish Weir to Lost Creek	2.7-5.2
	L3	Lost Creek to Rainy Creek	5.2-9.2
White River	H1	Mouth to Sears Creek Bridge	0.0-6.4
	H2	Sears Creek Bridge to Napeequa River	6.4-11.0
	H3	Napeequa River to Grasshopper Meadows	11.0-12.9
Napeequa River	Q1	Mouth to End	0.0-1.0

Wenatchee summer Chinook redd and carcass surveys were conducted from September through November throughout the entire mainstem Wenatchee River, which was divided into ten reaches (Table 2.10). Surveys were conducted weekly in all reaches. All redds were enumerated during weekly census counts.

Table 2.10. Description of reaches surveyed for summer Chinook redds in the Wenatchee River basin.

Code	Reach	River mile
W1	Mouth to Sleepy Hollow Br	0.0-3.3
W2	Sleepy Hollow Br to L. Cashmere Br	3.3-9.5
W3	L. Cashmere Br to Dryden Dam	9.5-17.8
W4	Dryden Dam to Peshastin Br	17.8-20.0
W5	Peshastin Br to Leavenworth Br	20.0-23.9
W6	Leavenworth Br to Icicle Rd Br	23.9-26.4
W7	Icicle Rd Br to Tumwater Dam	26.4-30.9
W8	Tumwater Dam to Tumwater Br	30.9-35.6
W9	Tumwater Br to Chiwawa River	35.6-47.9
W10	Chiwawa River to Lake Wenatchee	47.9-54.2

Summer Chinook redd and carcass surveys were also conducted in the Methow and Chelan rivers from September through November. Total (map) redd counts were conducted in these rivers. Table 2.11 describes the survey reaches on the Methow River. The Colville Tribes conducted summer Chinook redd and carcass surveys in the Okanogan River basin. Those results are reported in a separate report (annual report to BPA).

Table 2.11. Description of reaches surveyed for summer Chinook redds and carcasses on the Methow, Okanogan, and Similkameen rivers.

Stream	Code	Reach	River mile (RM)
Methow River	M1	Mouth to Methow Bridge	0.0-14.8
	M2	Methow Bridge to Carlton Bridge	14.8-27.2
	M3	Carlton Bridge to Twisp Bridge	27.2-39.6
	M4	Twisp Bridge to MVID	39.6-44.9
	M5	MVID to Winthrop Bridge	44.9-49.8
	M6	Winthrop Bridge to Hatchery Dam	49.8-51.6
Okanogan River	O1	Mouth to Mallot Bridge	0.0-16.9
	O2	Mallot Bridge to Okanogan Bridge	16.9-26.1
	O3	Okanogan Bridge to Omak Bridge	26.1-30.7
	O4	Omak Bridge to Riverside Bridge	30.7-40.7
	O5	Riverside Bridge to Tonasket Bridge	40.7-56.8
	O6	Tonasket Bridge to Zosel Dam	56.8-77.4
Similkameen River	S1	Driscoll Channel to Oroville Bridge	0.0-1.8
	S2	Oroville Bridge to Enloe Dam	1.8-5.7

For summer and spring Chinook, total spawning escapements for each population were estimated as the product of total number of redds times the ratio of fish per redd for a specific stock.[3] Fish per redd ratios were estimated as the ratio of males to females sampled at broodstock collection sites and monitoring sites (e.g., Leavenworth National Fish Hatchery, Dryden Dam, Tumwater Dam, Chiwawa Weir, etc.). For steelhead, spawning escapement was estimated with a combination of PIT-tag-based tributary and redd-based mainstem Wenatchee River estimates. Total spawning escapement for sockeye salmon in the Little Wenatchee and White River watersheds was estimated using mark-recapture methods. Adult sockeye were PIT tagged at Tumwater Dam and Bonneville Dam[4] and detected in the Little Wenatchee and White rivers with stationary PIT-tag interrogation systems.

Derived metrics calculated from carcass surveys, broodstock sampling, stock assessments, and harvest records included proportion of hatchery spawners, stray rates, age-at-maturity, length-at-age, smolt-to-adult survival (SAR), hatchery replacement rates (HRR), harvest rates, and natural replacement rates (NRR). The target HRRs (from Hillman et al. 2013) for different stocks raised in the PUD hatchery programs are provided in Table 2.12. Methods for calculating derived variables are described in Hillman et al. (2013) and in "White Papers" developed by the Hatchery Evaluation Technical Team (HETT) (see Appendices in Hillman et al. 2012). The abundance of hatchery and natural-origin Chinook salmon spawners was based upon the proportion of carcasses by origin that were collected on the spawning grounds.

[3] Expansion factor = (1 + (number of males/number of females)).

[4] Adult sockeye that were tagged at Bonneville Dam and detected at Tumwater Dam were included in the mark-recapture analyses.

Table 2.12. Hatchery replacement rate (HRR) targets for stocks raised in the PUD Hatchery Programs.

Program	Number of broodstock	Smolts released	HRR targets
Chiwawa Spring Chinook	74	144,026	6.7
Nason Creek Spring Chinook	66	125,000	6.7
Wenatchee Summer Chinook	278	500,001	5.7
Methow Summer Chinook	100	200,000	3.0
Wenatchee Steelhead	130	247,300	6.9

Derived data that rely on CWTs (e.g., HRR, SAR, stray rates, etc.) are five or more years behind release information because of the lag time for returning adult fish to enter the fishery and spawning grounds, and the processing of tags. Consequently, complete information on rates and ratios based on CWTs is generally only available for brood years before 2010.

SECTION 3: WENATCHEE STEELHEAD

The goal of summer steelhead supplementation in the Wenatchee Basin is to use artificial production to replace adult production lost because of mortality at Rock Island and Rocky Reach dams, as well as inundation compensation for Rocky Reach Dam, while not reducing the natural production or long-term fitness of steelhead in the basin. The Rock Island Fish Hatchery Complex began operation in 1989 under funding from Chelan PUD. The Complex operated originally through the Rock Island Settlement Agreement, but since 2004 has operated under the Rock Island and Rocky Reach Anadromous Fish Agreement and Habitat Conservation Plans.

Prior to 1998, steelhead eggs were received from Wells Hatchery (adult broodstock were collected at Wells Dam); fish were reared at Eastbank Fish Hatchery and then released into the Wenatchee River. Beginning in 1998, the program changed to collecting broodstock within the Wenatchee Basin. Currently, adult hatchery steelhead are collected from the run-at-large at the right and left-bank traps at Dryden Dam, and at Tumwater Dam if the weekly quotas cannot be achieved at Dryden Dam. Natural-origin (WxW) adult steelhead are collected from the run-at-large at Tumwater and Dryden dams if the weekly quotas cannot be achieved at Dryden Dam.

Before 2012, the goal was to collect up to 208 adult steelhead (50% natural-origin fish and 50% hatchery-origin fish) for the Wenatchee steelhead program. In 2011, the Hatchery Committees reevaluated the amount of hatchery compensation needed to achieve NNI. Based on that evaluation, the goal of the program was revised. The current goal (which began in 2012) is to collect 130 adult steelhead (64 natural-origin and 66 hatchery-origin fish) for a 247,300 smolt program, but the number of broodstock collected cannot exceed 33% of the natural Wenatchee steelhead population. Broodstock collection occurs from about 1 July through 15 November at Dryden and Tumwater dams, with trapping occurring up to 24 hours per day, five days a week. The intent of the current program is to target adults necessary to meet a 50% natural-origin, conservation-oriented program and a 50% hatchery-origin safety-net program.

Before the 2012 brood year, adult steelhead were held and spawned at Wells Fish Hatchery because of unsuitable adult holding temperatures at Eastbank Fish Hatchery. Beginning with the 2012 brood year, adult steelhead holding and spawning have occurred at Eastbank Fish Hatchery with the installation of a water chiller system. Before 2012, juvenile steelhead were reared at a combination of facilities including Eastbank, Chelan, Turtle Rock, Rocky Reach Annex, and Chiwawa facilities. Juvenile steelhead reared in these facilities were trucked to release locations on the Wenatchee River, Chiwawa River, and Nason Creek. A percentage of the fish have also been released volitionally from Blackbird Pond and Rolfing Pond. Beginning in the fall of 2012, the entire Wenatchee steelhead program overwinters at the Chiwawa Acclimation Facility. Some of these fish are transferred to short-term remote acclimation sites (e.g., Blackbird Pond and Rolfing Pond), while others are planted from trucks throughout the Wenatchee, Nason, and Chiwawa basins.

Before 2012, the production goal for the Wenatchee steelhead supplementation program was to release 400,000 yearling smolts into the Wenatchee Basin at six fish per pound. Since 2012, the revised production goal is to release 247,300 smolts (123,650 for conservation and 123,650 for safety net). Targets for fork length and weight are 191 mm (CV = 9.0) and 75.6 g, respectively; the target size at release is six fish per pound. Over 96% of these fish receive CWTs. In addition, since 2006, juvenile steelhead from different parental-cross groups (e.g., WxW, HxW, and HxH) have been PIT tagged annually. No HxW crosses have occurred since brood year 2009.

Beginning in 2010 and consistent with ESA Section 10(a)(1)(A) permit 1395, adult management activities have been conducted to remove excess hatchery-origin steelhead before they spawn in the natural environment. This is accomplished through removal at Tumwater Dam and/or through conservation fisheries. The objective of these activities is to achieve proportion of hatchery-origin spawners (pHOS) and Proportionate Natural Influence (PNI) goals for the Wenatchee steelhead program. Results of adult management activities are submitted to NOAA Fisheries in a separate annual report by 31 August of the year the adult management was concluded.

3.1 Broodstock Sampling

This section focuses on results from sampling 2015 and 2016 brood years of Wenatchee steelhead, which were collected at Dryden and Tumwater dams. The 2015 brood begins the tracking of the life cycle of steelhead released in 2016. The 2016 brood is included because juveniles from this brood are still maintained within the hatchery.

Origin of Broodstock

A total of 136 Wenatchee steelhead from the 2014 return (2015 brood) were collected at Dryden and Tumwater dams (Table 3.1). About 56% of these were natural-origin (adipose fin present and no CWT) fish and the remaining 44% were hatchery-origin (CWT and adipose fin present) adults. Origin was determined by analyzing scales and/or otoliths. The total number of steelhead spawned from the 2015 brood was 110 adults (52.7% natural-origin and 47.3% hatchery-origin).

A total of 132 steelhead were collected from the 2015 return (2016 brood) at Dryden and Tumwater dams; 67 (50.8%) natural-origin (adipose fin present and no CWT) and 66 (45.5%) hatchery-origin (CWT and adipose fin present) adults. A total of 132 steelhead were spawned; 50% were natural-origin fish and 50% were hatchery fish (Table 3.1). Origin was confirmed by sampling scales and/or otoliths.

Table 3.1. Numbers of wild and hatchery steelhead collected for broodstock, numbers that died before spawning, and numbers of steelhead spawned, 1998-2016. Unknown origin fish (i.e., undetermined by scale analysis, no elastomer, no CWT, no fin clips, and no additional hatchery marks) were considered naturally produced. Mortality includes fish killed at spawning and surplus broodstock.

Brood year	Wild steelhead					Hatchery steelhead					Total number spawned
	Number collected	Prespawn loss[a]	Mortality	Number spawned	Number released	Number collected	Prespawn loss[a]	Mortality	Number spawned	Number released	
1998	35	0	0	35	0	43	4	2	37	0	72
1999	58	5	1	52	0	67	1	2	64	0	116
2000	39	2	1	36	0	101	9	12	60	20	96
2001	64	5	8	51	0	114	5	6	103	0	154
2002	99	0	1	96	2	113	1	0	64	48	160
2003	63	10	4	49	0	92	2	0	90	0	139
2004	85	3	0	75	7	132	1	0	61	70	136
2005	95	8	0	87	0	114	7	1	104	2	191
2006	101	5	0	93	3	98	0	0	69	29	162
2007	79	0	2	76	1	97	0	14	58	25	134
2008	104	0	3	77	22	107	0	28	54	25	131

Brood year	Wild steelhead					Hatchery steelhead					Total number spawned
	Number collected	Prespawn loss[a]	Mortality	Number spawned	Number released	Number collected	Prespawn loss[a]	Mortality	Number spawned	Number released	
2009	101	2	0	86	13	107	1	4	73	29	159
2010	106	1	1	96	8	105	2	23	75	5	171
2011	104	8	1	91	4	104	13	2	70	0	161
Average[b]	***81***	***4***	***2***	***71***	***4***	***100***	***3***	***7***	***70***	***18***	***142***
Median	***95***	***3***	***1***	***77***	***2***	***105***	***2***	***2***	***67***	***13***	***147***
2012	63	3	0	59	1	66	0	1	65	0	124
2013	63	8	1	49	5	84	9	7	68	0	117
2014	65	0	1	64	0	70	0	2	68	0	132
2015	76	5	0	58	13	60	0	8	52	0	110
2016	67	0	1	66	0	66	0	0	66	0	132
Average[c]	***67***	***3***	***1***	***59***	***4***	***69***	***2***	***4***	***64***	***0***	***123***
Median	***65***	***3***	***1***	***59***	***1***	***66***	***0***	***2***	***66***	***0***	***124***

[a] Pre-spawn loss represents the number of fish that died during the holding period before spawning. Mortality is the number of fish that were surplused following spawning.
[b] This average and median represent the program before recalculation in 2011.
[c] This average and median represent the current program, which began in 2012.

Age/Length Data

Broodstock ages were determined from examination of scales and/or otoliths. For the 2015 brood year, natural-origin steelhead consisted primarily of 2-salt adults, while hatchery steelhead consisted almost equally of 1 and 2-salt adults (Table 3.2). For the 2016 brood year, natural and hatchery-origin steelhead consisted primarily of 2-salt adults (Table 3.2).

Table 3.2. Percent of hatchery and wild steelhead of different ages (saltwater ages) collected from broodstock, 1998-2016.

Brood year	Origin	Saltwater age		
		1	2	3
1998	Wild	39.4	60.6	0.0
	Hatchery	20.9	79.1	0.0
1999	Wild	50.0	48.3	1.7
	Hatchery	81.8	18.2	0.0
2000	Wild	56.4	43.6	0.0
	Hatchery	67.9	32.1	0.0
2001	Wild	51.7	48.3	0.0
	Hatchery	14.9	85.1	0.0
2002	Wild	55.6	44.4	0.0
	Hatchery	94.6	5.4	0.0
2003	Wild	13.1	85.3	1.6
	Hatchery	29.4	70.6	0.0
2004	Wild	94.8	5.2	0.0
	Hatchery	95.2	4.8	0.0
2005	Wild	22.1	77.9	0.0

Brood year	Origin	Saltwater age		
		1	2	3
	Hatchery	20.5	79.5	0.0
2006	Wild	28.7	71.3	0.0
	Hatchery	60.3	39.7	0.0
2007	Wild	40.3	59.3	0.0
	Hatchery	62.1	37.9	0.0
2008	Wild	65.4	33.7	0.9
	Hatchery	88.8	11.2	0.0
2009	Wild	39.8	57.8	2.4
	Hatchery	23.4	76.6	0.0
2010	Wild	65.2	33.7	1.1
	Hatchery	76.5	23.5	0.0
2011	Wild	27.5	72.5	0.0
	Hatchery	36.0	64.0	0.0
2012	Wild	42.4	52.5	5.1
	Hatchery	40.9	59.1	0.0
2013	Wild	40.7	57.4	1.9
	Hatchery	45.5	54.5	0.0
2014	Wild	47.5	50.8	1.6
	Hatchery	29.4	70.6	0.0
2015	Wild	15.9	82.5	1.6
	Hatchery	47.2	52.7	0.0
2016	Wild	33.8	66.2	0.0
	Hatchery	42.4	57.6	0.0
Average	***Wild***	***43.7***	***55.3***	***0.9***
	Hatchery	***51.5***	***48.5***	***0.0***
Median	***Wild***	***40.7***	***57.4***	***0.0***
	Hatchery	***45.5***	***54.5***	***0.0***

There was little difference between mean lengths of hatchery and natural-origin steelhead in the 2015 and 2016 brood years (Table 3.3). Natural-origin fish were on average 1 to 3 cm larger than hatchery-origin fish of the same age.

Table 3.3. Mean fork length (cm) at age (saltwater ages) of hatchery and wild steelhead collected from broodstock, 1998-2016; N = sample size and SD = 1 standard deviation.

Brood year	Origin	Steelhead fork length (cm)								
		1-Salt			2-Salt			3-Salt		
		Mean	N	SD	Mean	N	SD	Mean	N	SD
1998	Wild	63	15	4	79	20	5	-	0	-
	Hatchery	61	9	4	73	34	4	-	0	-

Brood year	Origin	Steelhead fork length (cm)								
		1-Salt			2-Salt			3-Salt		
		Mean	N	SD	Mean	N	SD	Mean	N	SD
1999	Wild	65	29	5	74	28	5	77	1	-
	Hatchery	62	54	4	73	12	4	-	0	-
2000	Wild	64	22	3	74	17	5	-	0	-
	Hatchery	60	57	3	71	27	4	-	0	-
2001	Wild	61	33	6	77	31	5	-	0	-
	Hatchery	62	17	4	72	97	4	-	0	-
2002	Wild	64	55	4	77	44	4	-	0	-
	Hatchery	63	106	4	73	6	4	-	0	-
2003	Wild	69	8	6	77	52	5	91	1	-
	Hatchery	66	27	4	75	65	4	-	0	-
2004	Wild	63	73	6	78	4	2	-	0	-
	Hatchery	61	59	3	73	3	1	-	0	-
2005	Wild	59	21	4	74	74	5	-	0	-
	Hatchery	59	23	4	72	89	4	-	0	-
2006	Wild	63	27	5	75	67	6	-	0	-
	Hatchery	61	41	4	72	27	5	-	0	-
2007	Wild	64	31	6	76	46	5	-	0	-
	Hatchery	60	60	4	71	36	5	-	0	-
2008	Wild	64	68	4	77	35	4	80	1	-
	Hatchery	60	95	4	72	12	2	-	0	-
2009	Wild	65	33	5	76	48	6	81	2	0
	Hatchery	63	18	4	75	59	5	-	-	-
2010	Wild	64	60	5	74	31	5	76	1	-
	Hatchery	61	53	5	73	23	5	-	-	-
2011	Wild	62	28	5	76	74	5	-	0	-
	Hatchery	60	36	4	74	64	4	-	0	-
2012	Wild	63	25	3	74	31	5	74	3	2
	Hatchery	59	27	3	74	39	4	-	0	-
2013	Wild	61	22	5	77	31	5	74	1	-
	Hatchery	60	35	3	74	42	4	-	0	-
2014	Wild	61	29	4	75	31	4	61	1	-
	Hatchery	60	20	3	72	48	4	-	0	-
2015	Wild	61	10	3	77	52	4	85	1	-
	Hatchery	59	26	3	76	29	5	-	0	-
2016	Wild	62	22	4	74	43	4	-	0	-
	Hatchery	61	28	4	71	38	5	-	0	-
Average	***Wild***	***63***	***32***	***5***	***76***	***40***	***5***	***78***	***1***	***1***

Brood year	Origin	Steelhead fork length (cm)								
		1-Salt			2-Salt			3-Salt		
		Mean	N	SD	Mean	N	SD	Mean	N	SD
	Hatchery	*61*	*42*	*4*	*73*	*39*	*4*	*-*	*0*	*-*

Sex Ratios

Male steelhead in the 2015 brood year made up about 50% of the adults collected, resulting in an overall male to female ratio of 1.00:1.00 (Table 3.4). For the 2016 brood year, males made up about 50.4% of the adults collected, resulting in an overall male to female ratio of 1.02:1.00. On average (1998-2016), the sex ratio is slightly less than the 1:1 ratio assumed in the broodstock protocol (Table 3.4).

Table 3.4. Numbers of male and female wild and hatchery steelhead collected for broodstock, 1998-2016. Ratios of males to females are also provided.

Brood year	Number of wild steelhead			Number of hatchery steelhead			Total M/F ratio
	Males (M)	Females (F)	M/F	Males (M)	Females (F)	M/F	
1998	13	22	0.59:1.00	15	28	0.54:1.00	0.56:1.00
1999	22	36	0.61:1.00	35	32	1.09:1.00	0.84:1.00
2000	18	21	0.86:1.00	60	41	1.46:1.00	1.26:1.00
2001	38	26	1.46:1.00	40	74	0.54:1.00	0.78:1.00
2002	32	67	0.48:1.00	81	32	2.53:1.00	1.14:1.00
2003	19	44	0.43:1.00	44	48	0.92:1.00	0.68:1.0
2004	43	42	1.02:1.00	90	42	2.14:1.00	1.58:1.00
2005	36	59	0.61:1.00	46	68	0.68:1.00	0.65:1.00
2006	38	63	0.60:1.00	47	51	0.92:1.00	0.75:1.00
2007	36	43	0.84:1.00	49	48	1.02:1.00	0.93:1.00
2008	61	43	1.42:1.00	68	39	1.74:1.00	1.57:1.00
2009	44	57	0.77:1.00	54	53	1.02:1.00	0.89:1.00
2010	49	57	0.86:1.00	62	43	1.44:1.00	1.11:1.00
2011	44	60	0.73:1.00	50	54	0.93:1.00	0.82:1.00
2012	30	33	0.91:1.00	31	35	0.89:1.00	0.90:1.00
2013	33	30	1.10:1.00	38	46	0.83:1.00	0.93:1.00
2014	30	33	0.91:1:00	36	36	1.00:1.00	0.96:1.00
2015	34	42	0.81:1.00	34	26	1.31:1.00	1.00:1.00
2016	34	33	1.03:1.00	33	33	1.00:1.00	1.02:1.00
Total	***654***	***811***	***0.81:1.00***	***913***	***829***	***1.10:1.00***	***0.96:1.00***

Fecundity

Fecundities for Wenatchee steelhead in brood years 2015 and 2016 averaged 5,895 and 5,174 eggs per female, respectively (Table 3.5). Mean fecundity for the 2015 brood year was greater while the 2016 brood year was less than the 5,678 eggs per female assumed in the broodstock protocol.

Table 3.5. Mean fecundity of wild, hatchery, and all female steelhead collected for broodstock, 1998-2016.

Brood year	Mean fecundity		
	Wild	Hatchery	Total
1998	6,202	5,558	5,924
1999	5,691	5,186	5,424
2000	5,858	5,729	5,781
2001	5,951	6,359	6,270
2002	5,776	5,262	5,626
2003	6,561	6,666	6,621
2004	5,118	5,353	5,238
2005	5,545	6,061	5,832
2006	5,688	5,251	5,492
2007	5,840	5,485	5,660
2008	5,693	5,153	5,433
2009	6,199	6,586	6,408
2010	5,458	5,423	5,442
2011	6,276	6,100	6,203
2012	5,309	6,388	5,891
2013	5,749	5,770	5,762
2014	5,831	5,847	5,839
2015	6,220	5,532	5,895
2016	5,392	4,956	5,174
Average	***5,808***	***5,719***	***5,785***
Median	***5,776***	***5,558***	***5,781***

3.2 Hatchery Rearing

Rearing History

Number of eggs taken

From 1998-2011, a total of 493,827 eggs were required to meet the program release goal of 400,000 smolts. This was based on the unfertilized egg-to-release survival standard of 81%. In 2012, the egg take target was reduced to 305,309, which is needed to meet the revised release target of 247,300 smolts. Between 1998 and 2011, the egg take goal was reached 57% of the time (Table 3.6). Since 2011, the target has been reached or exceeded 100% of the time (Table 3.6).

Table 3.6. Numbers of eggs taken from steelhead broodstock, 1998-2016.

Brood year	Number of eggs taken
1998	224,315
1999	303,083
2000	280,872
2001	549,464

Brood year	Number of eggs taken
2002	503,030
2003	532,708
2004	408,538
2005	672,667
2006	546,382
2007	462,662
2008	439,980
2009	633,229
2010	499,499
2011	522,049
Average (1998-2011)	***488,782***
Median (1998-2001)	***501,265***
2012	371,151
2013	339,949
2014	395,453
2015	324,212
2016	341,511
Average (2012-present)	***354,455***
Median (2012-present)	***341,511***

Number of acclimation days

Juvenile WxW steelhead from the Chelan Fish Hatchery and HxH steelhead from the Eastbank Fish Hatchery were transferred to Chiwawa Acclimation Facility in November 2015. In March 2016, about 25,000 HxH steelhead were transferred from the Chiwawa Acclimation Facility to Blackbird Pond near Leavenworth for final acclimation on Wenatchee River water. Fish were acclimated for 23 d at Blackbird Pond before a volitional release was initiated on 20 April. The remainder stayed at the Chiwawa Acclimation Facility until they were volitionally and forced released from the facility during late April to early-May.

Juvenile Wenatchee steelhead at the Chiwawa Acclimation Facility were acclimated and reared on Wenatchee and Chiwawa River water. Before 2012, Wenatchee steelhead were reared on Columbia River water from January through May before being trucked and released into the Wenatchee River basin (Table 3.7).

Table 3.7. Water source and mean acclimation period for Wenatchee steelhead, brood years 1998-2016.

Brood year	Release year	Parental origin	Water source	Number of Days
1998	1999	H x H	Wenatchee/Chiwawa	36
		H x W	Wenatchee/Chiwawa	36
		W x W	Wenatchee/Chiwawa	36
1999	2000	H x H	Wenatchee/Chiwawa	138
		H x W	Wenatchee/Chiwawa	138

Brood year	Release year	Parental origin	Water source	Number of Days
		W x W	Wenatchee/Chiwawa	138
		H x W	Eastbank	0
		W x W	Eastbank	0
2000	2001	H x H	Wenatchee/Chiwawa	122
		H x W	Wenatchee/Chiwawa	122
		H x W	Wenatchee/Chiwawa	122
		W x W	Wenatchee/Chiwawa	122
2001	2002	H x H	Columbia	92
		H x H	Wenatchee/Chiwawa	63
		H x W	Columbia	92
		H x W	Wenatchee/Chiwawa	63
		W x W	Columbia	153
2002	2003	H x H	Columbia	98
		H x W	Columbia	98
		W x W	Columbia	117
2003	2004	H x H	Columbia	88
		H x W	Wenatchee/Chiwawa	84
		W x W	Columbia	148
2004	2005	H x H	Columbia	160
		H x W	Columbia	160
		W x W	Columbia	160
2005	2006	H x H	Columbia	116
		H x W	Columbia	113
		W x W	Columbia	141
2006	2007	Early H x W	Columbia	111
		Late H x W	Columbia	112
		W x W	Columbia	148
2007	2008	Early H x W	Columbia	94-95
		Late H x W	Columbia	91-93
		W x W	Columbia	138
2008	2009	Early H x W	Columbia	120-121
		Early H x W	Columbia/Wenatchee	120-121/28-95
		Late H x W	Columbia	114-115
		W x W	Columbia	152-153
2009	2010	Early H x W	Columbia	93-94
		Early H x W	Columbia/Wenatchee	99-111
		Early H x W	Wenatchee	31-129

Brood year	Release year	Parental origin	Water source	Number of Days
		Late H x W	Columbia	84-87
		W x W	Columbia/Nason	118-120/28
2010	2011	H x H	Wenatchee	188-192
		H x H	Wenatchee	37-87
		H x H	Columbia	181
		W x W	Columbia	148-149
		W x W	Columbia/Nason	113-114/42-101
		W x W	Columbia	148-149
2011	2012	W x W	Wenatchee	160-201
		W x W	Wenatchee	179-188
		W x W	Wenatchee	21-72
		W x W	Nason	56-107
2012	2013	H x H	Wenatchee	168-189
		H x H	Wenatchee	168-225
		W x W	Wenatchee	168-225
		W x W	Wenatchee	168-189
		W x W	Chiwawa	187
2013	2014	H x H	Wenatchee[a]	7-67
		H x H	Wenatchee	168-169
		W x W	Wenatchee	176-197
		W x W	Wenatchee	179-204
2014	2015	H x H	Wenatchee[a]	41-110
		H x H	Wenatchee	161-179
		W x W	Wenatchee	157-172
		W x W	Wenatchee	168-171
2015	2016	H x H	Wenatchee[a]	23-81
		H x H	Wenatchee	156-172
		W x W	Wenatchee	162-178
		W x W	Wenatchee	160-176

[a] Steelhead overwintered in Pond 3 at the Chiwawa Acclimation Facility on Chiwawa River water before they were transferred to Blackbird Pond.

Release Information

Numbers released

In 2011, the HCP Hatchery Committee agreed to reduce the Wenatchee summer steelhead program from 400,000 smolts to 247,300 smolts. Based on this new goal and the number of WxW steelhead present, all HxH steelhead were transferred to the Ringold Fish Hatchery to be included in their production program for the 2012 release.

The release of 2015 brood Wenatchee steelhead achieved 79% of the 247,300 target with about 195,344 smolts released into the Wenatchee and Chiwawa rivers and Nason Creek (Table 3.8). Distribution of juvenile steelhead released in each of the three streams was determined by the mean proportion of steelhead redds in each basin. About 28.2% and 19.3% of the steelhead were released in Nason Creek and the Chiwawa River, respectively. The balance of the program was split between the Wenatchee River downstream from Tumwater Dam (10.9%) and the Wenatchee River upstream from the dam (41.5%).

Table 3.8. Numbers of steelhead smolts released from the hatchery, brood years 1998-2015. Before brood year 2011, the release target for steelhead was 400,000 smolts. Beginning with brood year 2011, the release target is 247,300 smolts.

Brood year	Release year	Number of smolts
1998	1999	172,078
1999	2000	175,701
2000	2001	184,639
2001	2002	335,933
2002	2003	302,060
2003	2004	374,867
2004	2005	294,114
2005	2006	452,184
2006	2007	299,937
2007	2008	306,690
2008	2009	327,143
2009	2010	484,772
2010	2011	354,314
Average (1998-2010)		***312,649***
Median (1998-2010)		***306,690***
2011	2012	206,397
2012	2013	249,004
2013	2014	229,836
2014	2015	264,758
2015	2016	195,344
Average (2011-present)		***229,068***
Median (2011-present)		***229,836***

Numbers marked

Wenatchee hatchery steelhead from the 2015 brood were marked with coded wire tags (CWT) in the snout. About 44.9% of the juveniles released were also adipose fin clipped (Table 9).

Table 3.9. Release location and marking scheme for the 1998-2015 brood Wenatchee steelhead.

Brood year	Release location	Parental origin	Proportion Ad-clip	CWT or VIE color/side	Tag rate	Number released
1998	Chiwawa River	H x H	0.000	Red Left	0.994	52,765
	Chiwawa River	H x W	0.000	Green Left	0.990	37,013
	Chiwawa River	W x W	0.000	Orange Left	0.827	82,300
1999	Wenatchee River	H x H	0.000	Green Left	0.911	45,347
	Wenatchee River	H x W	0.000	Orange Left	0.927	30,713
	Chiwawa River	H x H	0.000	Red Right	0.936	25,622
	Chiwawa River	H x W	0.000	Green Right	0.936	43,379
	Chiwawa River	W x W	0.000	Orange Right	0.936	30,600
2000	Chiwawa River	H x H	0.000	Red Left	0.963	33,417
	Chiwawa River	H x W	0.000	Green Left	0.963	57,716
	Chiwawa River	H x W	0.000	Green Right	0.949	48,029
	Chiwawa River	W x W	0.000	Orange Right	0.949	45,477
2001	Nason Creek	H x W	0.000	Green Right	0.934	75,276
	Nason Creek	W x W	0.000	Orange Right	0.934	48,115
	Chiwawa River	H x W	0.000	Green Left	0.895	92,487
	Chiwawa River	H x H	0.000	Red Left	0.895	120,055
2002	Chiwawa River	H x H	0.000	Red Left	0.920	156,145
	Chiwawa River	H x W	0.000	Green Left	0.928	33,528
	Nason Creek	W x W	0.000	Orange Right	0.928	112,387
2003	Wenatchee River	H x H	0.000	Red Left	0.968	117,663
	Chiwawa River	H x W	0.000	Green Left	0.927	191,796
	Nason Creek	W x W	0.000	Orange Right	0.962	65,408
2004	Wenatchee River	H x H	0.500	Red Left	0.804	39,636
	Chiwawa River	H x W	0.000	Green Left	0.977	153,959
	Nason Creek	W x W	0.000	Pink Right	0.940	100,519
2005	Wenatchee River	H x H	1.000	Red Left	0.983	104,552
	Wenatchee River	H x W	0.616	Green Left	0.979	190,319
	Chiwawa River	H x W	0.616	Green Left	0.979	18,634
	Chiwawa River	W x W	0.000	Pink Right	0.969	14,124
	Nason Creek	W x W	0.000	Pink Right	0.969	124,555
2006	Wenatchee River	H x W (early)	1.000	Green Right	0.918	66,022

Brood year	Release location	Parental origin	Proportion Ad-clip	CWT or VIE color/side	Tag rate	Number released
	Wenatchee River	H x W (late)	0.671	Green Left	0.935	92,176
	Chiwawa River	H x W (late)	0.671	Green Left	0.935	41,240
	Chiwawa River	W x W	0.000	Pink Right	0.945	7,500
	Nason Creek	W x W	0.000	Pink Right	0.945	92,999
2007	Wenatchee River	H x W (early)	0.967	Green Right	0.950	64,310
	Wenatchee River	H x W (late)	0.586	Green Left	0.951	97,549
	Chiwawa River	H x W (late)	0.586	Green Left	0.951	43,011
	Chiwawa River	W x W	0.000	Pink Right	0.952	7,026
	Nason Creek	W x W	0.000	Pink Right	0.952	94,794
2008	Blackbird Pond	HxW (early)	0.917	Green Right	0.910	49,878
	Wenatchee River	H x W (early)	0.917	Green Right	0.910	48,624
	Wenatchee River	H x W (late)	0.595	Green Left	0.908	74,848
	Chiwawa River	H x W (late)	0.595	Green Left	0.908	25,835
	Chiwawa River	W x W	0.000	Pink Right	0.904	25,778
	Nason Creek	W x W	0.000	Pink Right	0.904	102,170
2009	Blackbird Pond	H x W (early)	0.969	Green Right	0.934	50,248
	Wenatchee River	H x W (early)	0.969	Green Right	0.934	105,239
	Wenatchee River	H x W (late)	0.973	Green Left	0.975	27,612
	Wenatchee River	H x W (late)	0.000	Green Left	0.975	45,435
	Chiwawa River	H x W (early)	0.969	Green Right	0.934	23,835
	Chiwawa River	H x W (late)	0.973	Green Left	0.975	33,047
	Chiwawa River	H x W (late)	0.000	Green Left	0.975	54,381
	Nason Creek	W x W	0.000	Pink Right	0.979	145,029
2010	Wenatchee River	H x H	0.994	-	0.984	24,838
	Wenatchee River	H x H	0.994	-	0.984	45,000
	Wenatchee River	H x H	0.994	-	0.984	92,113
	Chiwawa River	W x W	0.000	Pink Right	0.917	81,174
	Nason Creek	W x W	0.000	Pink R/Pink L	0.884	20,000
	Nason Creek	W x W	0.000	Pink Right	0.917	91,189
2011	Wenatchee River	W x W	0.985	CWT	0.953	70,885
	Wenatchee River	W x W	0.985	CWT	0.953	24,992
	Wenatchee River	W x W	0.000	CWT	0.987	25,569

Brood year	Release location	Parental origin	Proportion Ad-clip	CWT or VIE color/side	Tag rate	Number released
	Chiwawa River	W x W	0.985	CWT	0.953	31,050
	Nason Creek	W x W	0.000	CWT	0.989	18,254
	Nason Creek	W x W	0.985	CWT	0.953	36,225
2012	Wenatchee River	W x W	0.000	CWT	0.965	14,824
	Wenatchee River	H x H	1.000	AD/CWT	0.920	9,841
	Wenatchee River	W x W	0.000	CWT	0.965	28,362
	Wenatchee River	H x H	1.000	AD/CWT	0.920	76,695
	Chiwawa River	W x W	0.000	CWT	0.965	12,760
	Chiwawa River	H x H	1.000	AD/CWT	0.920	34,503
	Nason Creek	W x W	0.000	CWT	0.965	43,854
	Nason Creek	W x W	0.000	CWT	0.965	28,165
2013	Wenatchee River	W x W	0.000	CWT	0.963	36,736
	Wenatchee River	H x H	0.998	AD/CWT	0.990	55,055
	Wenatchee River	H x H	0.998	AD/CWT	0.990	25,316
	Chiwawa River	W x W	0.000	CWT	0.963	9,360
	Chiwawa River	H x H	0.998	AD/CWT	0.990	14,040
	Nason Creek	W x W	0.000	CWT	0.963	50,503
	Nason Creek	H x H	0.998	AD/CWT	0.990	38,826
2014	Wenatchee River	W x W	0.000	CWT	0.968	72,345
	Wenatchee River	H x H	0.996	AD/CWT	0.996	58,130
	Wenatchee River	H x H	0.996	AD/CWT	0.996	28,122
	Chiwawa River	W x W	0.000	CWT	0.968	20,443
	Chiwawa River	H x H	0.996	AD/CWT	0.996	14,599
	Nason Creek	W x W	0.000	CWT	0.968	41,188
	Nason Creek	H x H	0.996	AD/CWT	0.996	29,931
2015	Wenatchee River	W x W	0.000	CWT	0.972	52,446
	Wenatchee River	H x H	0.993	AD/CWT	0.980	28,633
	Wenatchee River	H x H	0.993	AD/CWT	0.980	21,386
	Chiwawa River	W x W	0.000	CWT	0.972	20,022
	Chiwawa River	H x H	0.993	AD/CWT	0.980	17,752
	Nason Creek	W x W	0.000	CWT	0.972	35,148
	Nason Creek	H x H	0.993	AD/CWT	0.980	19,957

Numbers PIT tagged

Table 3.10 summarizes the number of hatchery steelhead of different parental origins that have been PIT-tagged and released into the Wenatchee River basin.

Table 3.10. Summary of PIT-tagging activities for Wenatchee hatchery steelhead, brood years 2006-2015.

Brood year	Release location	Parental origin	Number of fish tagged	Number of tagged fish that died	Number of tags shed	Number of tagged fish released
2006	Wenatchee River	H x W (early)	10,036	479	24	9,533
	Wenatchee/Chiwawa rivers	H x W (late)	10,031	922	20	9,089
	Chiwawa River/Nason	W x W	10,019	152	352	9,515
2007	Wenatchee River	H x W (early)	9,852	22	10	9,820
	Wenatchee/Chiwawa rivers	H x W (late)	10,063	73	78	9,912
	Chiwawa River/Nason	W x W	10,038	55	1	9,982
2008	Wenatchee River	H x W (early)	10,101	59	15	10,027
	Wenatchee/Chiwawa rivers	H x W (late)	10,104	106	17	9,981
	Chiwawa River/Nason	W x W	10,101	159	80	9,862
2009	Wenatchee/Chiwawa rivers	H x W (early)	10,114	574	11	9,529
	Wenatchee (Blackbird)	H x W (early)	8,100	0	0	8,100
	Wenatchee/Chiwawa rivers	H x W (late)	10,115	271	11	9,833
	Chiwawa pilot	H x W (early)	10,107	532	103	9,472
	Chiwawa River/Nason	W x W	10,101	38	3	10,060
2010	Wenatchee River	HxH	10,100	624	21	9,455
	Chiwawa River/Nason	WxW	10,100	206	0	9,894
	Wenatchee (Blackbird)	HxH	10,101	235	8	9,858
	Wenatchee River	HxH	10,100	46	28	10,026
2011	Wenatchee/Chiwawa/Nason	WxW (circular)	10,101	139	30	9,932
	Wenatchee/Chiwawa/Nason	WxW (raceway)	20,220	121	35	20,064
2012	Wenatchee/Chiwawa/Nason	WxW (circular)	15,244	176	4	15,064
	Wenatchee/Chiwawa/Nason	HxH (raceway)	10,223	140	13	10,070
2013	Wenatchee/Chiwawa/Nason	WxW	5,100	95	1	5,004
	Wenatchee/Chiwawa/Nason	HxH	10,201	84	12	10,105
2014	Wenatchee/Chiwawa/Nason	WxW	9,051	53	0	8,998
	Wenatchee/Chiwawa/Nason	HxH	10,129	243	76	9,810
2015	Wenatchee/Chiwawa/Nason	WxW	12,101	60	0	12,041
	Wenatchee/Chiwawa/Nason	HxH	11,115	55	0	11,060

2016 Brood Wenatchee WxW Summer Steelhead (Circular Ponds)—A total of 5,050 Wenatchee WxW summer steelhead were PIT tagged at the Chiwawa Acclimation Facility on 23-24 February 2017. These fish were tagged in circular ponds #1 and #3. Fish were not fed during tagging or for two days before and after tagging. Fish averaged 141-149 mm in length and 29-38 g at time of tagging.

2016 Brood Wenatchee HxH and WxW Summer Steelhead (Raceway)—A total of 12,626 Wenatchee HxH and WxW summer steelhead were PIT tagged at the Chiwawa Acclimation Facility on 27 February to 3 March 2017. These fish were tagged in raceway #2. Fish were not fed during tagging or for two days before and after tagging. Fish averaged 129-130 mm in length and 22-26 g at time of tagging.

2016 Brood Wenatchee Summer Steelhead (Blackbird Pond)—A total of 2,525 Wenatchee summer steelhead destined for Blackbird Pond were PIT tagged at the Chiwawa Acclimation Facility on 21-22 February 2017. These fish were tagged in raceway #3. Fish were not fed during tagging or for two days before and after tagging. Fish averaged 133 mm in length and 25 g at time of tagging.

Fish size and condition at release

Except for the Blackbird Pond release, all 2015 brood steelhead were trucked and released as yearling smolts in April and May 2016. The Blackbird Pond group was released volitionally beginning on 20 April. Both WxW and HxH fish did not meet the targets for length, weight, or coefficient of variation (CV) for fork length (Table 3.11). The HxH group was combined with the WxW group in Pond 2 once they were transferred to Chiwawa Acclimation Facility. The HxH fish were larger than the WxW fish at the time of transfer but smaller at the time of release.

Table 3.11. Mean lengths (FL, mm), weight (g and fish/pound), and coefficient of variation (CV) of steelhead smolts released from the hatchery, brood years 1998-2015. Size targets are provided in the last row of the table.

Brood year	Release year	Parental origin	Fork length (mm)		Mean weight	
			Mean	CV	Grams (g)	Fish/pound
1998	1999	H x H	201	11.1	92.3	5
		H x W	190	12.8	76.9	6
		W x W	173	12.0	55.3	8
1999	2000	H x H	181	8.9	70.6	6
		H x W	187	7.2	75.3	6
		W x W	184	11.3	71.5	6
2000	2001	H x H	218	15.2	122.4	4
		H x W	209	10.6	107.5	4
		W x W	205	10.7	100.9	5
2001	2002	H x H	179	17.4	67.0	7
		H x W	192	15.6	82.8	6
		W x W	206	11.6	102.6	4

Brood year	Release year	Parental origin	Fork length (mm)		Mean weight	
			Mean	CV	Grams (g)	Fish/pound
2002	2003	H x H	194	13.1	83.0	6
		H x W	191	13.0	77.4	6
		W x W	180	19.1	70.3	7
2003	2004	H x H	191	14.4	73.1	6
		H x W	199	12.9	83.9	5
		W x W	200	11.1	90.1	5
2004	2005	H x H	204	11.3	87.2	6
		H x W	202	13.5	71.9	5
		W x W	198	12.4	76.6	6
2005	2006	H x H	215	12.6	116.6	4
		H x W	198	11.8	86.3	5
		W x W	189	15.4	55.3	6
2006	2007	H x H (early)	213	12.1	109.6	4
		H x W (late)	186	11.8	68.3	7
		W x W	178	11.1	58.6	8
2007	2008	H x W (early)	192	17.4	77.1	6
		H x W (late)	179	19.3	63.8	7
		W x W	183	12.3	62.8	7
2008	2009	H x W (early)	184	11.6	68.0	7
		H x W (late)	186	11.6	73.5	6
		W x W	181	13.0	59.7	8
2009	2010	H x W (early)	197	11.3	84.2	5
		H x W (late)	192	11.1	72.7	6
		W x W	190	9.6	70.5	6
2010	2011	H x H	183	14.1	68.9	4
		W x W	188	10.5	68.1	7
2011	2012	H x H	NA	NA	NA	NA
		W x W	156	17.1	45.2	10
2012	2013	H x H / W x W	150	16.1	40.8	11
		H x H / W x W	157	16.4	45.0	10
		W x W	156	18.7	49.0	9
2013	2014	H x H / W x W	157	14.5	49.4	9
		H x H	127	16.2	26.8	17
		W x W	162	20.4	55.8	8
2014	2015	H x H / W x W	152	15.4	40.9	11

Brood year	Release year	Parental origin	Fork length (mm)		Mean weight	
			Mean	CV	Grams (g)	Fish/pound
		H x H	145	13.5	36.6	12
		W x W	162	15.3	50.6	9
2015	2016	H x H / W x W	163	16.1	53.1	9
		H x H	162	9.4	46.1	10
		W x W	180	13.8	70.6	6
Targets			***191***	***9.0***	***75.6***	***6***

Survival Estimates

Overall survival of Wenatchee steelhead (WxW and HxH) from green (unfertilized) egg to release was below the standard set for the program. This is largely because of lower unfertilized egg to eyed egg survival (Table 3.12).

The Wenatchee steelhead program, from its inception, has experienced highly variable fertilization rates. It is unknown at this time what mechanisms may be influencing stock performance at these stages.

Table 3.12. Hatchery life-stage survival rates (%) for steelhead, brood years 1998-2015. Survival standards or targets are provided in the last row of the table.

Brood year	Collection to spawning		Unfertilized egg-eyed	Eyed egg-ponding	30 d after ponding	100 d after ponding	Ponding to release	Transport to release	Unfertilized egg-release
	Female	Male							
1998	92.0	100.0	85.5	91.7	99.2	98.8	97.8	99.9	76.7
1999	91.2	100.0	66.9	93.0	95.9	94.9	93.1	99.7	58.0
2000	83.9	96.2	77.6	86.7	99.3	98.9	97.7	99.5	65.7
2001	90.0	100.0	73.0	91.8	99.1	97.8	91.3	99.7	61.1
2002	99.0	100.0	69.2	93.1	95.9	94.4	89.6	89.6	60.0
2003	87.0	96.8	86.3	83.8	97.2	94.8	97.6	85.3	70.4
2004	97.6	98.5	83.4	93.7	97.8	94.1	92.2	99.9	72.0
2005	91.3	95.1	81.3	92.1	95.6	91.8	89.7	99.6	67.2
2006	99.1	95.3	73.2	85.4	95.4	94.6	87.8	98.5	54.9
2007	100.0	100.0	80.3	92.0	95.7	92.7	89.8	99.1	66.3
2008	100.0	100.0	87.1	88.4	99.0	97.4	96.6	99.5	74.4
2009	97.3	100.0	89.0	97.2	96.0	95.2	88.6	96.6	76.6
2010	96.7	100.0	93.8	93.9	91.0	86.2	80.6	96.0	70.9
2011[a]	96.3	94.4	74.2	97.7	96.6	89.5	86.4	98.4	62.7
2012	95.2	98.4	74.7	99.7	97.8	94.0	90.1	98.9	67.1
2013	80.8	97.0	75.0	96.5	97.8	96.6	93.4	99.2	67.6
2014	100.0	100.0	83.3	96.7	95.8	89.9	87.9	98.7	70.8
2015	93.3	98.6	68.5	94.9	96.6	95.8	92.7	97.8	60.3

Brood year	Collection to spawning		Unfertilized egg-eyed	Eyed egg-ponding	30 d after ponding	100 d after ponding	Ponding to release	Transport to release	Unfertilized egg-release
	Female	Male							
Average	*93.9*	*98.4*	*79.0*	*92.7*	*96.8*	*94.3*	*91.3*	*97.6*	*66.8*
Median	*95.8*	*99.3*	*79.0*	*93.1*	*96.6*	*94.7*	*90.7*	*99.0*	*67.2*
Standard	*90.0*	*85.0*	*92.0*	*98.0*	*97.0*	*93.0*	*90.0*	*95.0*	*81.0*

[a] Survival estimates are only for WxW steelhead.

3.3 Disease Monitoring

Rearing of the 2015 brood Wenatchee summer steelhead was similar to previous years with fish being held on Chelan spring water, Eastbank well water, and Chelan well water before being transferred for overwinter acclimation at the Chiwawa Acclimation Facility. Volitional and force-released fish were released into Nason Creek, Chiwawa River, and the Wenatchee River. The 2015 WxW Wenatchee steelhead had no significant health issues during the rearing period.

3.4 Natural Juvenile Productivity

During 2016, juvenile steelhead were sampled at the Lower Wenatchee, Chiwawa, and Nason Creek traps and counted during snorkel surveys within the Chiwawa River basin. Because the snorkel surveys targeted juvenile Chinook salmon, the entire distribution of juvenile steelhead in the Chiwawa River basin was not surveyed. Therefore, the parr numbers presented below represent a minimum estimate.

Parr Estimates

A total of 16,244 (±14%) age-0 (<100 mm) and 4,031 (±15%) age-1+ (100-200 mm)[5] steelhead/rainbow were estimated in the Chiwawa River basin in August 2016 (Table 3.13 and 3.14). During the survey period 1992-2016, numbers of age-0 and 1+ steelhead/rainbow have ranged from 1,410 to 45,727 and 754 to 22,130, respectively, in the Chiwawa River basin (Table 3.13 and 3.14; Figure 3.1). Numbers of all fish counted in the Chiwawa River basin are reported in Appendix A.

Juvenile steelhead/rainbow were distributed primarily throughout the lower seven reaches of the Chiwawa River (downstream from Rock Creek). Their densities were highest in the lower portions of the river and in tributaries. Age-0 steelhead/rainbow most often used riffle and multiple channel habitats in the Chiwawa River, although they also associated with woody debris in pool and glide habitat. In tributaries, they were generally most abundant in small pools. Those that were observed in riffles selected stations in quiet water behind small and large boulders, or occupied stations in quiet water along the stream margin. In pool and multiple-channel habitats, age-0 steelhead/rainbow used the same kinds of habitat as age-0 Chinook salmon.

Age-1+ steelhead/rainbow most often used pool, riffle, and multiple-channel habitats. Those that used pools were usually in deeper water than subyearling steelhead/rainbow and Chinook salmon. Like age-0 steelhead/rainbow, age-1+ steelhead/rainbow generally selected stations in quiet water behind boulders in riffles, but the two age groups rarely occurred together. Age-1+ steelhead/rainbow used deeper and faster water than did subyearling steelhead/rainbow.

[5] A steelhead/rainbow trout larger than 200 mm (8 in) was considered a resident trout.

Table 3.13. Total numbers of age-0 steelhead/rainbow trout estimated in different steams in the Chiwawa River basin during snorkel surveys in August 1992-2016; NS = not sampled.

Sample Year	Chiwawa River	Phelps Creek	Chikamin Creek	Rock Creek	Unnamed Creek	Big Meadow Creek	Alder Creek	Brush Creek	Clear Creek	Total
1992	4,927	NS	NS	NS	NS	NS	NS	NS	NS	**4,927**
1993	3,463	0	356	185	NS	NS	NS	NS	NS	**4,004**
1994	953	0	256	24	0	177	0	0	0	**1,410**
1995	6,005	0	744	90	0	371	40	107	0	**7,357**
1996	3,244	0	71	40	0	763	127	0	0	**4,245**
1997	6,959	224	84	324	0	1,124	58	50	0	**8,823**
1998	2,972	22	280	96	113	397	18	22	0	**3,921**
1999	5,060	20	253	189	0	255	34	27	0	**5,838**
2000	NS	NS	NS	NS	NS	NS	NS	NS	NS	**NS**
2001	35,759	192	1,449	1,826	0	6,345	156	0	0	**45,727**
2002	12,137	0	2,252	889	0	4,948	277	18	0	**20,521**
2003	9,911	296	996	1,166	96	5,366	73	116	0	**18,020**
2004	8,464	110	583	113	40	957	35	78	0	**10,380**
2005	4,852	120	2,931	477	45	2,973	65	0	0	**11,463**
2006	10,669	21	858	872	34	3,647	73	71	0	**16,245**
2007	8,442	53	2,137	348	11	2,955	65	28	34	**14,073**
2008	9,863	0	2,260	859	0	1,987	57	168	36	**15,230**
2009	13,231	0	1,183	449	0	2,062	170	67	17	**17,179**
2010	17,572	0	2,870	1,478	5	2,843	182	35	33	**25,018**
2011	35,825	0	1,503	804	0	1,066	56	152	40	**39,446**
2012	21,537	0	1,817	1,501	0	2,164	42	54	19	**27,134**
2013	17,889	0	602	816	0	2,189	44	99	43	**21,682**
2014	12,256	21	1,617	1,039	0	1,005	32	56	57	**16,083**
2015	4,532	0	1,989	1,675	0	1,761	170	62	19	**10,208**
2016	10,971	0	1,419	996	0	2,721	50	62	25	**16,244**
Average	***11,146***	***47***	***1,240***	***707***	***16***	***2,185***	***83***	***58***	***15***	***15,216***
Median	***9,164***	***0***	***1,183***	***804***	***0***	***2,025***	***58***	***55***	***0***	***14,652***

Table 3.14. Total numbers of age-1+ steelhead/rainbow trout estimated in different steams in the Chiwawa River basin during snorkel surveys in August 1992-2016; NS = not sampled.

Sample Year	Chiwawa River	Phelps Creek	Chikamin Creek	Rock Creek	Unnamed Creek	Big Meadow Creek	Alder Creek	Brush Creek	Clear Creek	Total
1992	2,533	NS	NS	NS	NS	NS	NS	NS	NS	**2,533**
1993	2,530	0	228	102	NS	NS	NS	NS	NS	**2,860**
1994	4,972	0	476	296	5	107	0	0	0	**5,856**
1995	8,769	0	494	71	0	183	0	0	0	**9,517**
1996	11,381	0	6	27	0	435	0	0	0	**11,849**
1997	6,574	160	0	105	0	66	0	0	0	**6,905**
1998	10,403	0	133	49	0	0	0	0	0	**10,585**

Sample Year	Chiwawa River	Phelps Creek	Chikamin Creek	Rock Creek	Unnamed Creek	Big Meadow Creek	Alder Creek	Brush Creek	Clear Creek	Total
1999	21,779	0	68	201	0	82	0	0	0	**22,130**
2000	NS	NS	NS	NS	NS	NS	NS	NS	NS	**NS**
2001	9,368	16	186	407	0	646	0	0	0	**10,623**
2002	7,200	0	199	165	0	1,526	0	0	0	**9,090**
2003	4,745	362	426	599	0	47	0	0	0	**6,179**
2004	7,700	107	209	0	0	174	0	0	0	**8,190**
2005	4,624	63	957	257	0	287	0	0	0	**6,188**
2006	7,538	76	748	1,186	0	985	0	0	0	**10,533**
2007	6,976	0	945	96	0	431	0	0	0	**8,448**
2008	8,317	0	1,168	298	0	793	0	0	0	**10,576**
2009	4,998	16	320	102	0	167	21	0	5	**5,629**
2010	8,324	32	366	393	0	780	21	0	0	**9,916**
2011	13,329	0	415	470	0	689	0	0	0	**14,903**
2012	7,671	0	285	410	0	210	0	0	0	**8,576**
2013	6,439	0	0	48	0	766	0	0	0	**7,253**
2014	4,568	13	96	211	0	165	0	0	31	**5,084**
2015	614	0	40	100	0	0	0	0	0	**754**
2016	3,418	0	256	40	0	309	0	8	0	**4,031**
Average	***7,282***	***37***	***349***	***245***	***0***	***402***	***2***	***0***	***2***	***8,259***
Median	***7,088***	***0***	***256***	***165***	***0***	***249***	***0***	***0***	***0***	***8,319***

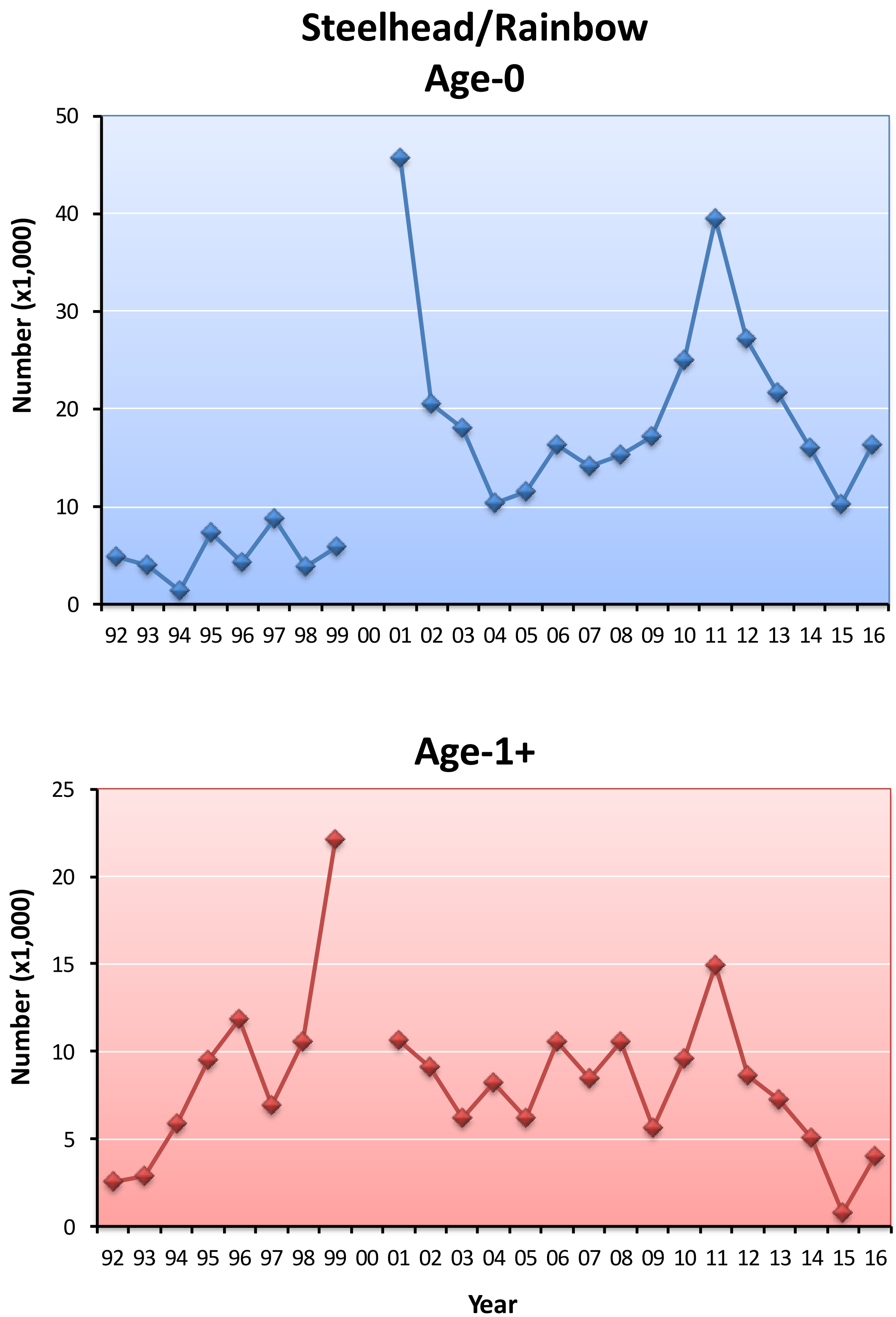

Figure 3.1. Numbers of subyearling and yearling steelhead/rainbow trout within the Chiwawa River basin in August 1992-2016; ND = no data.

Emigrant and Smolt Estimates

Numbers of steelhead smolts and emigrants were estimated at the Chiwawa, Nason, and Lower Wenatchee traps in 2016.

Chiwawa Trap

The Chiwawa Trap operated between 2 March and 21 November 2016. During the trapping period, the trap was inoperable for 72 days due to high or low river discharge, debris, major hatchery releases, and mechanical issues. The trap operated in a single position throughout the sampling season. Monthly captures of all fish collected at the Chiwawa Trap are reported in Appendix B.

A total of 195 wild steelhead/rainbow smolts, 1,518 hatchery smolts, and 1,522 wild parr and fry were captured at the Chiwawa Trap. Most (99%) of the hatchery steelhead were collected in May, while most (75%) of the wild steelhead smolts were captured in April through June (Figure 3.2). Although steelhead/rainbow parr and fry emigrated throughout the sampling period, peaks in emigration were observed in April through June and in October (Figure 3.2). Of the total number of wild steelhead captured, 87% were classified as parr and fry. Three mark-recapture efficiency trials were conducted with a pooled trap efficiency of 8.1%.

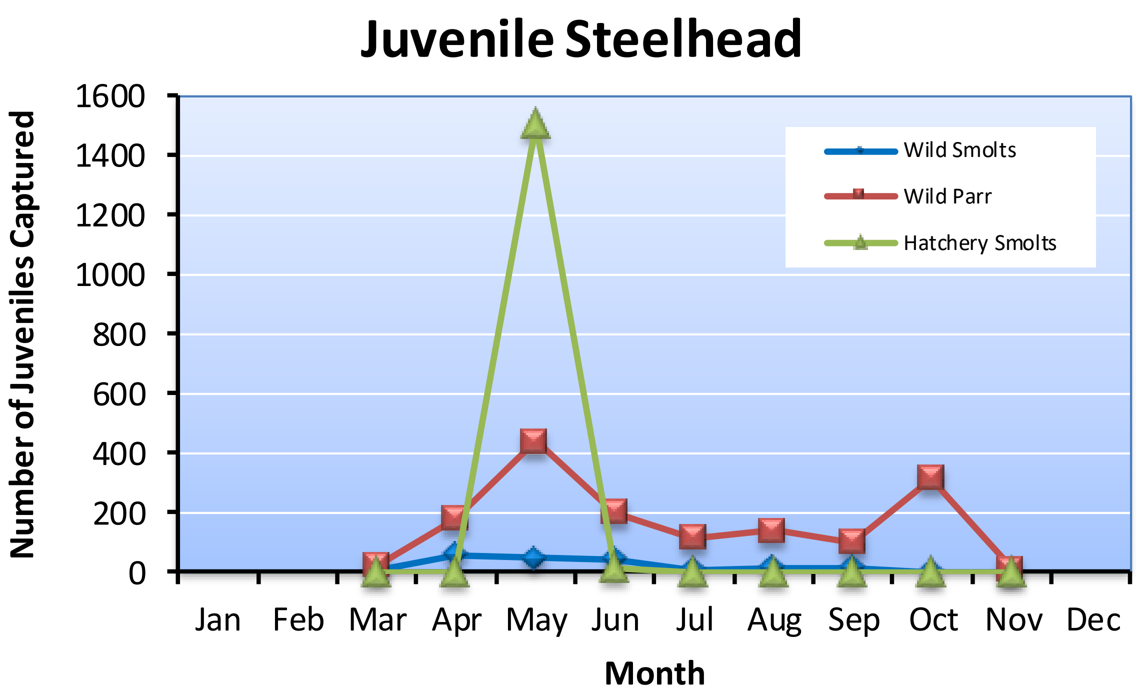

Figure 3.2. Monthly captures of wild smolts, wild parr, and hatchery smolt steelhead/rainbow at the Chiwawa Trap, 2016.

Nason Creek Trap

The Nason Creek Trap operated between 1 March and 30 November 2016. During the nine-month sampling period the trap was inoperable for 62 days because of low discharge and flooding. The trap captured a total of 9 wild steelhead smolts, 98 hatchery steelhead smolts, 663 wild steelhead parr, and 335 wild steelhead fry. The estimated wild steelhead emigration for brood year 2013 was

13,417 (± 9,133). Egg-to-emigrant survival rate for brood year 2012 steelhead was 1.7% and the egg-to-emigrant survival rate for brood year 2012 was 3.0%. Productivity, measured as emigrants-per-redd, was 99.

Lower Wenatchee Trap

The Lower Wenatchee Trap operated between 29 January and 26 June 2016. During that time, the trap was inoperable for 23 days because of too high and low river discharge, debris, elevated river temperatures, large hatchery releases, and mechanical issues. During the sampling period, a total of 329 wild steelhead parr and fry, 88 wild steelhead smolts, and 259 hatchery steelhead were captured at the trap. Because of the low numbers of steelhead encountered at the trap, it was not possible to carry out mark-recapture trials using steelhead. In addition, because there was a poor relationship between trap efficiency and river flow, a pooled estimate was used to derive the number of steelhead emigrants. Using this pooled method, it was estimated that 10,135 (±102,145) steelhead >50 mm FL emigrated out of the Wenatchee during the trapping season. Figure 3.3 shows the monthly captures of all steelhead collected at the Lower Wenatchee Trap. All fish captured in the trap are reported in Appendix B.

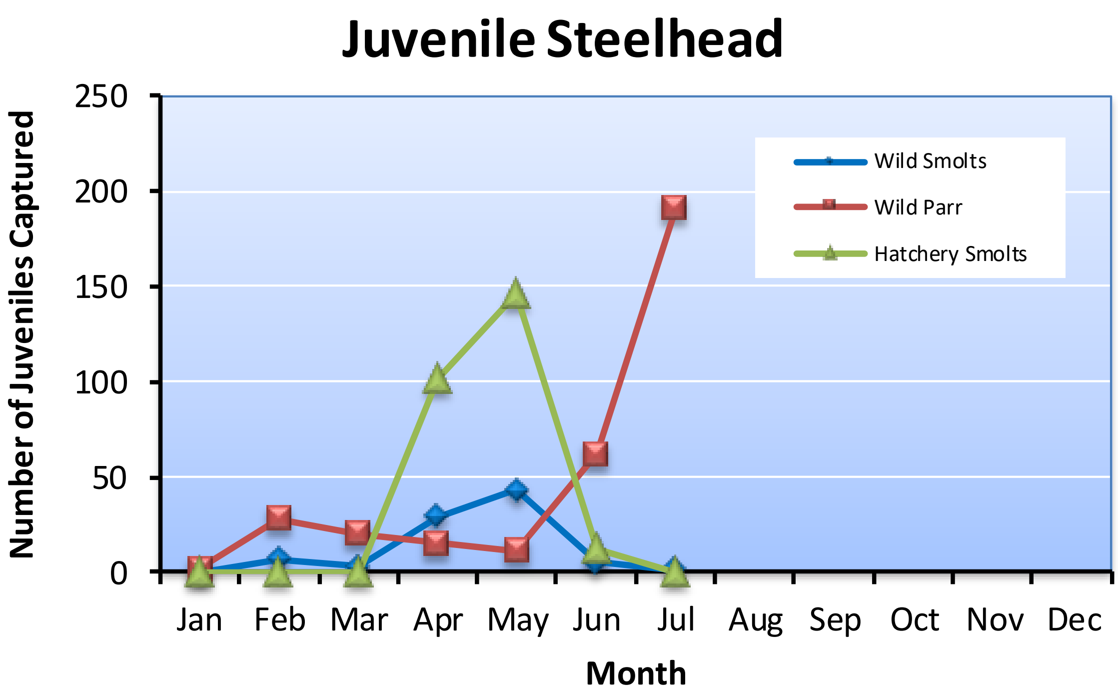

Figure 3.3. Monthly captures of wild smolts, wild parr, and hatchery smolt steelhead/rainbow at the Lower Wenatchee Trap, 2016.

PIT Tagging Activities

As part of the Comparative Survival Study (CSS) and PUD studies, a total of 1,980 juvenile steelhead/rainbow trout (1,979 wild and one hatchery) were PIT tagged and released in 2016 in the Wenatchee River basin (Table 3.15a). Most of these were tagged at the Chiwawa Trap. See Appendix C for a complete list of all fish captured, tagged, lost, and released.

Table 3.15a. Numbers of wild and hatchery steelhead/rainbow trout that were captured, tagged, and released at different locations within the Wenatchee River basin, 2016. Numbers of fish that died or shed tags are also given.

Sampling Location	Species and Life Stage	Number captured	Number of recaptures	Number tagged	Number died	Shed tags	Total tags released	Percent mortality
Chiwawa Trap	Wild Steelhead	1,717	18	1,323	10	10	1,313	0.58
	Hatchery Steelhead	1,518	0	1	0	0	1	0.00
	Total	**3,235**	**18**	**1,324**	**10**	**10**	**1/314**	**0.00**
Nason Creek Trap	Wild Steelhead	1,007	6	531	1	1	530	0.10
	Hatchery Steelhead	98	7	0	0	0	0	0.00
	Total	**1,105**	**13**	**531**	**1**	**1**	**530**	**0.00**
White River Trap	Wild Steelhead	5	0	5	0	0	5	0.00
	Hatchery Steelhead	0	0	0	0	0	0	0.00
	Total	**5**	**0**	**5**	**0**	**0**	**5**	**0.00**
Lower Wenatchee Trap	Wild Steelhead	417	0	131	6	0	131	1.44
	Hatchery Steelhead	259	0	0	1	0	0	0.37
	Total	**676**	**0**	**131**	**7**	**0**	**131**	**0.01**
Total:	**Wild Steelhead**	**3,146**	**24**	**1,990**	**17**	**11**	**1,979**	**0.01**
	Hatchery Steelhead	**1,875**	**7**	**1**	**1**	**0**	**1**	**0.00**
Grand Total:		**5,021**	**31**	**1,991**	**18**	**11**	**1,980**	**0.00**

Numbers of steelhead/rainbow PIT-tagged and released as part of CSS and PUD studies during the period 2006-2016 are shown in Table 3.15b.

Table 3.15b. Summary of the numbers of wild and hatchery steelhead/rainbow trout that were tagged and released at different locations within the Wenatchee River basin, 2006-2016.

Sampling Location	Species and Life Stage	Numbers of PIT-tagged steelhead/rainbow released										
		2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Chiwawa Trap	Wild Steelhead	1,366	832	1,431	1,127	930	1,012	1,011	1,228	1,186	1,795	1,313
	Hatchery Steelhead	0	3	2	1	2	1	2	0	3	1	1
	Total	**1,366**	**835**	**1,433**	**1,128**	**932**	**1,013**	**1,013**	**1,228**	**1,189**	**1,796**	**1,314**
Chiwawa River (Angling or Electrofish)	Wild Steelhead	33	167	94	35	99	0	0	0	23	0	0
	Hatchery Steelhead	1	47	35	43	64	0	0	0	0	0	0
	Total	**34**	**214**	**129**	**78**	**163**	**0**	**0**	**0**	**23**	**0**	**0**
Upper Wenatchee Trap[1]	Wild Steelhead	21	37	24	46	69	82	70	43	--	--	--
	Hatchery Steelhead	0	0	0	0	0	0	0	0	--	--	--
	Total	**21**	**37**	**24**	**46**	**69**	**82**	**70**	**43**	**--**	**--**	**--**
Nason Creek Trap	Wild Steelhead	1,167	1,335	2,154	753	1,557	805	1,087	1,998	838	383	**530**
	Hatchery Steelhead	0	0	0	0	0	0	538	0	0	0	**0**
	Total	**1,167**	**1,335**	**2,154**	**753**	**1,557**	**805**	**1,625**	**1,998**	**838**	**383**	**530**

Sampling Location	Species and Life Stage	Numbers of PIT-tagged steelhead/rainbow released										
		2006	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**
Nason Creek (Angling or Electrofish)	Wild Steelhead	174	452	255	459	318	0	0	0	0	0	0
	Hatchery Steelhead	26	75	87	197	32	0	0	0	0	0	0
	Total	**200**	**527**	**342**	**656**	**350**	**0**	**0**	**0**	**0**	**0**	**0**
White River Trap	Wild Steelhead	0	0	0	12	10	5	5	6	5	6	**5**
	Hatchery Steelhead	0	0	0	0	0	0	0	0	0	0	**0**
	Total	**0**	**0**	**0**	**12**	**10**	**5**	**5**	**6**	**5**	**6**	**5**
Upper Wenatchee (Angling or Electrofish)	Wild Steelhead	413	1,001	21	7	30	--	--	--	--	--	--
	Hatchery Steelhead	2	64	26	23	9	--	--	--	--	--	--
	Total	**415**	**1,065**	**47**	**30**	**39**	**--**	**--**	**--**	**--**	**--**	**--**
Middle Wenatchee (Angling or Electrofish)	Wild Steelhead	0	0	981	867	1,517	0	0	850	--	--	--
	Hatchery Steelhead	0	0	11	5	57	0	0	2	--	--	--
	Total	**0**	**0**	**992**	**872**	**1,574**	**0**	**0**	**852**	**--**	**--**	**--**
Lower Wenatchee (Angling or Electrofish)	Wild Steelhead	0	0	102	69	--	--	--	--	--	--	--
	Hatchery Steelhead	0	0	10	9	--	--	--	--	--	--	--
	Total	**0**	**0**	**112**	**78**	**--**	**--**	**--**	**--**	**--**	**--**	**--**
Peshastin Creek (Angling or Electrofish)	Wild Steelhead	0	0	0	92	307	--	--	--	--	--	--
	Hatchery Steelhead	0	0	0	0	0	--	--	--	--	--	--
	Total	**0**	**0**	**0**	**92**	**307**	**--**	**--**	**--**	**--**	**--**	**--**
Lower Wenatchee Trap	Wild Steelhead	131	461	285	227	465	0	0	613	133	290	131
	Hatchery Steelhead	0	0	0	1	0	0	0	0	4	1	0
	Total	**131**	**461**	**285**	**228**	**465**	**0**	**0**	**613**	**137**	**291**	**131**
Total:	**Wild Steelhead**	**3,305**	**4,285**	**5,347**	**3,694**	**5,302**	**1,904**	**2,173**	**4,738**	**2,185**	**2,474**	**1,979**
	Hatchery Steelhead	**29**	**189**	**171**	**279**	**164**	**1**	**540**	**2**	**7**	**2**	**1**
Grand Total:		**3,334**	**4,474**	**5,518**	**3,973**	**5,466**	**1,905**	**2,713**	**4,740**	**2,192**	**2,476**	**1,980**

[1] 2013 was the last year that the Upper Wenatchee Trap operated.

3.5 Spawning Surveys

Surveys for steelhead redds were conducted during March through early June 2016, in the mainstem Wenatchee River and portions of select tributaries (Chiwawa River, Nason Creek, and Peshastin Creek). Beginning in 2014, adult steelhead escapement estimates in the majority of tributaries in the Wenatchee River basin were generated using mark-recapture techniques based on steelhead PIT tagged at Priest Rapids Dam (BPA funded; see Appendix D and Truscott et al. 2016 for details).

Redd Counts

A total estimate of 126 steelhead redds were counted in the Wenatchee River and the lower portions of select tributaries in 2016 (Table 3.16). Because steelhead escapement estimates in tributaries are based on mark-recapture techniques, there are no or limited redd counts in tributaries beginning in 2014. Additionally, mainstem redd counts since 2014 were expanded based on estimates of observer efficiency (see Appendix D). Thus, evaluation of trends in redd counts is appropriate only before 2014.

Table 3.16. Numbers of steelhead redds estimated within different streams/watersheds within the Wenatchee River basin, 2001-2016; NS = not surveyed. Redd counts from 2004-2013 have been conducted within the same areas and with the same methods. Beginning in 2014, complete redd counts were conducted only within the mainstem Wenatchee River. Therefore, trends in redd counts are only appropriate for the mainstem Wenatchee River from 2004 through 2013.

Survey year	Number of steelhead redds							
	Chiwawa	Nason	Little Wenatchee	White	Wenatchee River[a]	Icicle	Peshastin	Total
2001	25	27	NS	NS	116	19	NS	**187**
2002	80	80	1	0	315	27	NS	**503**
2003	64	121	5	3	248	16	15	**472**
2004	62	127	0	0	151	23	34	**397**
2005	162	412	0	2	459	8	97	**1,140**
2006	19	77	NS	0	191	41	67	**395**
2007	11	78	0	1	46	6	17	**159**
2008	11	88	NS	1	100	37	49	**286**
2009	75	126	0	0	327	102	32	**662**
2010	74	270	4	3	380	120	118	**969**
2011	77	235	2	0	323	180	115	**932**
2012	8	158	0	0	137	47	65	**415**
2013	27	135	NS	NS	200	48	62	**472**
2014	5	0	NS	NS	195[b]	NS	5	**205**
2015	1	1	NS	NS	258[b]	NS	1	**262**
2016	0	0	NS	NS	126[b]	NS	0	**126**

[a] Includes redds in Beaver and Chiwaukum creeks.
[b] Steelhead redd counts in the mainstem Wenatchee River were expanded based on estimated observer efficiency (see Appendix D).

Redd Distribution

Steelhead redds were not evenly distributed among survey reaches on the Wenatchee River in 2016 (Table 3.17). About 91.3% of the spawning in the Wenatchee River occurred upstream from Tumwater Dam (Table 3.17).

Table 3.17. Numbers and percentages of steelhead redds counted within different reaches on the Wenatchee River during March through early June, 2016; CV = coefficient of variation, NA = not available, NS = not surveyed.

Reach	Reach type	Number of redds counted	Expanded redd counts		Percent of redds within stream/watershed
			Estimated	CV	
Wenatchee 1 (W1)	Non-index	0	0	NA	0.0
Wenatchee 2 (W2)	Index	0	0	NA	0.0

Reach	Reach type	Number of redds counted	Expanded redd counts		Percent of redds within stream/watershed
			Estimated	CV	
Wenatchee 3 (W3)	Non-index	0	0	NA	0.0
Wenatchee 4 (W4)	Non-index	0	0	NA	0.0
Wenatchee 5 (W5)	Non-index	0	0	NA	0.0
Wenatchee 6 (W6)	Index	11	11	1.42	8.7
Wenatchee 6 (W6)	Non-index	0	0	NA	0.0
Wenatchee 7 (W7)	NS	NA	NA	NA	NA
Wenatchee 8 (W8)	Index	1	1	0.59	0.8
Wenatchee 9 (W9)	Index	23	26	1.48	20.6
Wenatchee 9 (W9)	Non-index	3	3	0.42	2.4
Wenatchee 10 (W10)	Index	72	82	1.39	65.1
Wenatchee 10 (W10)	Non-index	2	3	0.34	2.4
Total		**112**	**126**	**1.04**	**100.0**

Spawn Timing

Steelhead began spawning during the second week of March in the Wenatchee River. Spawning activity appeared to begin once the mean daily stream temperature reached about 5.5ºC and was observed in water temperatures ranging from 3.7-8.8ºC. Steelhead spawning peaked during the third week of April in the Wenatchee River (Figure 3.4).

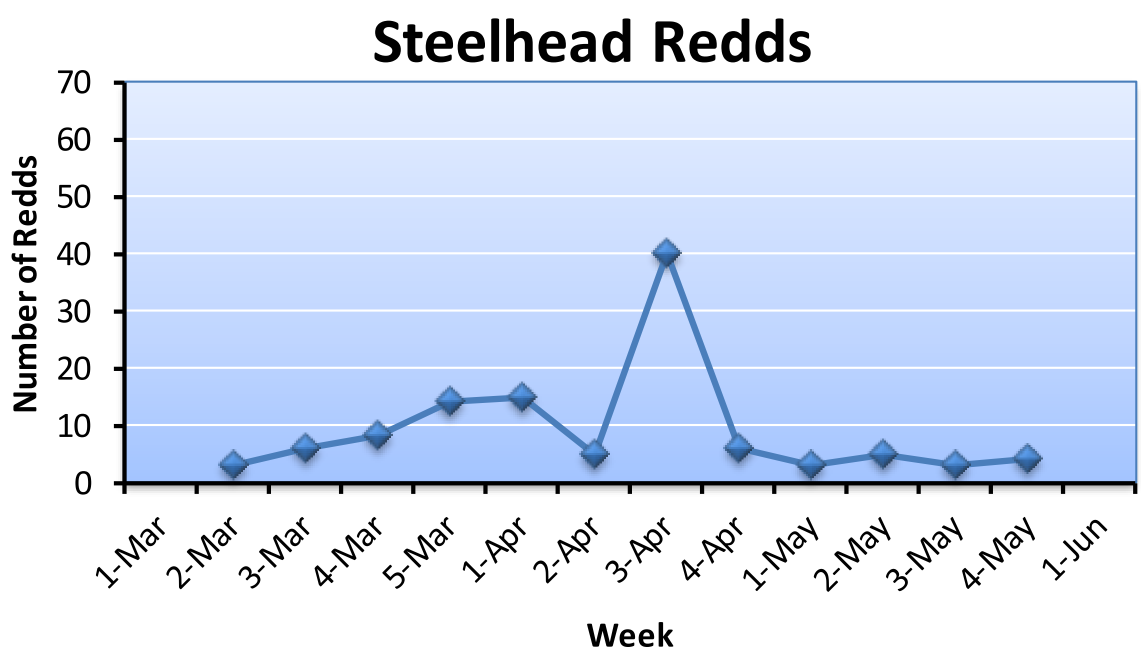

Figure 3.4. Numbers of steelhead redds counted during different weeks on the Wenatchee River, March through early June 2016.

Spawning Escapement

Before 2014, steelhead spawning escapement upstream from Tumwater Dam was calculated as the number of redds (in the Wenatchee River and tributaries upstream from the dam) times the fish per redd ratio (based on sex ratios estimated at Tumwater Dam using video surveillance).[6] Beginning in 2014, escapement in tributaries was estimated using PIT-tag mark-recapture techniques (Truscott et al. 2016; Table 3.18), while observer efficiency expanded redd counts were used to estimate escapement in the mainstem Wenatchee River (Appendix D). Total redd counts were also used to estimate escapement in the lower portions of the main tributaries (downstream from the PIT interrogation sites).

Table 3.18. Spawning escapement estimates for natural-origin and hatchery-origin steelhead within tributaries of the Wenatchee River, brood year 2016. Escapement estimates were based on PIT-tag mark-recapture techniques (Truscott et al. 2016). CV = coefficient of variation and NA = not available.

Tributary	Natural-origin steelhead		Hatchery-origin steelhead	
	Estimate	CV	Estimate	CV
Mission Creek	33	0.38	13	0.69
Peshastin Creek	151	0.19	0	NA
Chumstick Creek	74	0.27	39	0.37
Icicle Creek	72	0.25	18	0.53
Chiwaukum Creek	64	0.36	11	1.00
Chiwawa River	45	0.44	134	0.35
Nason Creek	57	0.39	94	0.32

The estimated fish per redd ratio for steelhead in 2016 was 1.65 (Table 3.19). Multiplying this ratio by the total number of redds estimated in the Wenatchee River upstream from Tumwater Dam resulted in a spawning escapement of 167 steelhead (Table 3.19). Adding this estimate to the mark-recapture estimates of tributary escapement (239 hatchery + 166 wild = 405) indicates that 572 (CV = 0.167) escaped to spawning areas upstream from Tumwater Dam in 2016 (see Appendix D).

Table 3.19. Numbers of steelhead counted at Tumwater Dam, fish/redd estimates (based on male-to-female ratios estimated at Tumwater Dam), numbers of steelhead redds counted upstream from Tumwater Dam, total spawning escapement upstream from Tumwater Dam (estimated as the total number of redds times the fish/redd ratio), and the proportion of the Tumwater Dam count that made up the spawning escapement. Beginning in 2014, escapements include estimates from redd counts in the Wenatchee River and mark-recapture techniques in tributaries.

Survey year	Total count at Tumwater Dam	Fish/redd	Number of redds			Spawning escapement[a]	Proportion of Tumwater count that spawned
			Index area	Non-index area	Total redds		
2001	820	2.08	118	19	137	285	0.35
2002	1,720	2.68	296	179	475	1,273	0.74
2003	1,810	1.60	353	88	441	706	0.39

[6] Expansion factor = (1 + (number of males/number of females)).

Survey year	Total count at Tumwater Dam	Fish/redd	Number of redds			Spawning escapement[a]	Proportion of Tumwater count that spawned
			Index area	Non-index area	Total redds		
2004	1,869	2.21	277	92	369	815	0.44
2005	2,650	1.61	828	136	964	1,552	0.59
2006	1,053	2.05	192	34	226	463	0.44
2007	657	1.94	105	29	134	260	0.40
2008	1,328	2.81	124	35	159	447	0.34
2009	1,781	1.83	284	107	391	716	0.40
2010	2,270	2.33	546	95	641	1,494	0.66
2011	1,130	1.79	427	33	460	823	0.73
2012	1,055	2.00	273	22	295	590	0.56
2013	1,087	1.65	276	9	285	470	0.43
Average[b]	***1,488***	***2.02***	***333***	***59***	***392***	***763***	***0.50***
Median	***1,328***	***2.00***	***277***	***35***	***369***	***706***	***0.44***
2014	865	1.70	124	0	124	839	0.97
2015	1,009	1.78	232	11	243	1,123	1.11
2016	1,017	1.65	120	6	126	572	0.56
Average[c]	***964***	***1.71***	***159***	***6***	***164***	***845***	***0.88***
Median	***1,009***	***1.70***	***124***	***6***	***126***	***839***	***0.97***

[a] Escapement estimates before 2014 were based on expanded redd counts in the Wenatchee River and tributaries; escapement estimates beginning in 2014 were based on expanded redd counts within the Wenatchee River and mark-recapture techniques in tributaries.
[b] The average and median are based on estimates from 2004 to 2013.
[c] The average and median are based on estimates from 2014 to present.

3.6 Life History Monitoring

Life history characteristics of steelhead were assessed by examining fish collected at broodstock collection sites, examining videotape at Tumwater Dam, and by reviewing tagging data and fisheries statistics. Before brood year 2011, some statistics could not be calculated because few steelhead were tagged with CWTs. Since brood year 2011, all steelhead released from the hatchery program have been tagged with CWTs. In addition, about 23,101 of the 2015 brood were PIT tagged. With the placement of remote PIT tag detectors in spawning streams in 2007 and 2008, statistics such as origin on spawning grounds, stray rates, and SARs can be estimated more accurately.

Migration Timing

Sampling at Tumwater Dam indicates that steelhead migrate throughout the year; however, the migration distribution is bimodal, indicating that steelhead migrate past Tumwater Dam in two pulses: one pulse during summer-autumn the year before spawning and another during winter-spring the year of spawning (Figure 3.5). Most steelhead passed Tumwater Dam during July through October and April. The highest proportion of both wild and hatchery fish migrated during October.

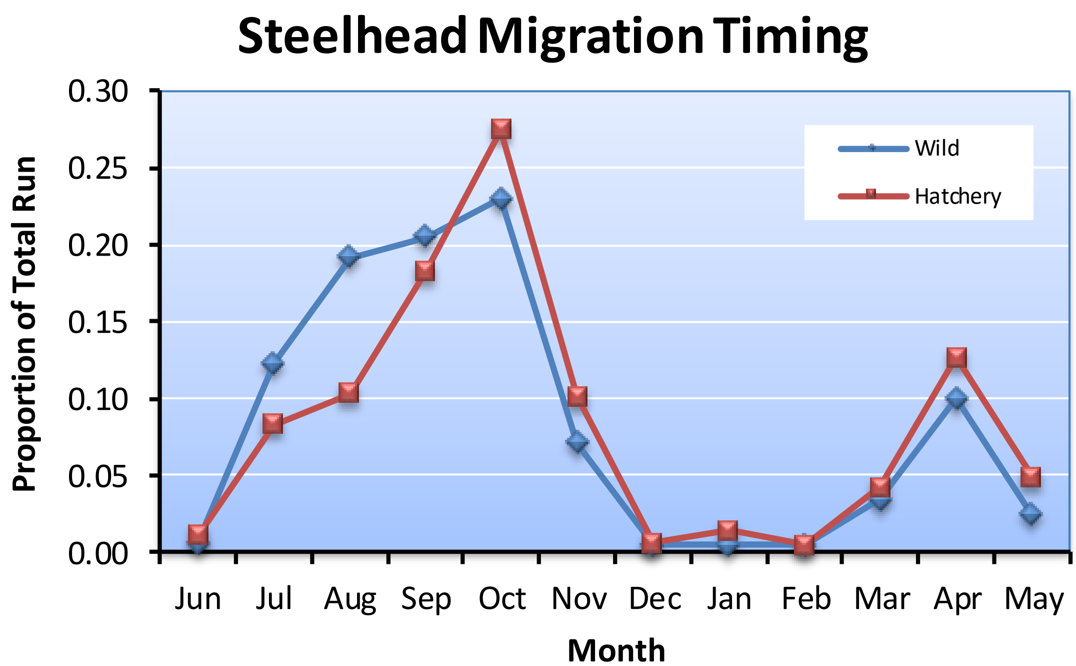

Figure 3.5. Proportion of wild and hatchery steelhead sampled at Tumwater Dam for the combined brood years of 1999-2016.

Because the migration of steelhead is bimodal, we estimated migration statistics separately for each migration pulse (i.e., summer-autumn migration and winter-spring migration). That is, we compared migration statistics for wild and hatchery steelhead passing Tumwater Dam during the summer-autumn period independent of those for the winter-spring migration period. We estimated the week and month that 10%, 50% (median), and 90% of the wild and hatchery steelhead passed Tumwater Dam during the two migration periods. We also estimated the mean weekly and monthly migration timing for wild and hatchery steelhead.

Migration timing of wild and hatchery fish at Tumwater Dam varied depending on the migration season (Table 3.20a and b; Figure 3.5). For the summer-autumn migration period, wild steelhead arrived at the dam about one week earlier than hatchery steelhead. In contrast, there was little difference in migration timing of wild and hatchery steelhead during the winter-spring migration period.

Table 3.20a. The week that 10%, 50% (median), and 90% of the wild and hatchery steelhead passed Tumwater Dam during their summer-autumn migration (June through December) and during their winter-spring migration (January through May), 1999-2016. The average week is also provided for both migration periods. Migration timing is based on video sampling at Tumwater. The presence of eroded fins and/or missing adipose fins was used to distinguish hatchery fish from wild fish during video monitoring at Tumwater Dam. Estimates also include steelhead collected for broodstock.

Spawn year	Origin	Steelhead Migration Time (week)									
		Summer-Autumn Migration (Jun-Dec)					Winter-Spring Migration (Jan-May)				
		10%	50%	90%	Mean	Sample size	10%	50%	90%	Mean	Sample size
1999	Wild	27	32	47	35	81	12	16	17	15	29
	Hatchery	25	31	47	34	47	12	16	18	15	27
2000	Wild	31	36	41	36	238	11	14	18	14	40
	Hatchery	31	34	41	36	194	12	14	16	14	69
2001	Wild	29	34	41	35	391	13	15	17	15	84
	Hatchery	30	38	41	36	227	12	16	17	15	156
2002	Wild	29	39	46	38	810	13	14	17	14	181
	Hatchery	35	42	46	41	610	12	15	18	15	124
2003	Wild	30	33	40	35	731	3	9	16	9	193
	Hatchery	30	35	51	37	372	3	9	15	9	538
2004	Wild	30	40	45	39	644	13	16	18	16	222
	Hatchery	29	40	44	38	677	11	17	19	16	361
2005	Wild	30	39	43	38	986	10	15	17	15	206
	Hatchery	27	38	42	36	1,112	12	16	18	15	377
2006	Wild	29	40	43	39	428	12	15	17	15	191
	Hatchery	29	41	43	39	334	4	13	16	12	181
2007	Wild	30	36	41	35	277	11	17	17	15	108
	Hatchery	29	38	43	36	90	11	17	18	16	214
2008	Wild	30	38	43	38	397	13	15	18	16	123
	Hatchery	33	41	45	40	554	14	18	19	17	311
2009	Wild	30	37	46	37	338	13	15	19	15	87
	Hatchery	29	35	46	36	1,133	13	16	19	16	229
2010	Wild	31	37	45	38	648	11	15	18	15	171
	Hatchery	31	40	45	40	1,207	12	16	19	16	309
2011	Wild	29	36	44	36	797	13	17	19	17	118
	Hatchery	31	39	45	39	991	15	18	19	18	240
2012	Wild	31	34	41	35	642	15	20	20	17	83
	Hatchery	32	39	43	38	715	15	19	19	17	223
2013	Wild	31	36	43	37	755	13	16	18	15	55
	Hatchery	31	42	45	40	1,431	16	17	18	16	210
2014	Wild	29	35	41	35	549	14	18	19	17	57

Spawn year	Origin	Steelhead Migration Time (week)									
		Summer-Autumn Migration (Jun-Dec)					Winter-Spring Migration (Jan-May)				
		10%	50%	90%	Mean	Sample size	10%	50%	90%	Mean	Sample size
	Hatchery	32	40	42	38	511	15	17	19	17	78
2015	Wild	29	38	43	37	714	11	14	17	14	48
	Hatchery	32	39	43	39	928	12	16	17	15	57
2016	Wild	34	41	45	39	610	13	16	19	16	58
	Hatchery	36	41	44	40	692	12	16	19	15	56
Average	***Wild***	***30***	***37***	***43***	***37***	***558***	***12***	***15***	***18***	***15***	***114***
	Hatchery	***31***	***39***	***44***	***38***	***657***	***12***	***16***	***18***	***15***	***209***
Median	***Wild***	***30***	***37***	***43***	***37***	***626***	***13***	***15***	***18***	***15***	***98***
	Hatchery	***31***	***39***	***44***	***38***	***610***	***12***	***16***	***18***	***16***	***214***

Table 3.20b. The month that 10%, 50% (median), and 90% of the wild and hatchery steelhead passed Tumwater Dam during their summer-autumn migration (June through December) and during their winter-spring migration (January through May), 1999-2016. The average month is also provided for both migration periods. Migration timing is based on video sampling at Tumwater. The presence of eroded fins and/or missing adipose fins was used to distinguish hatchery fish from wild fish during video monitoring at Tumwater Dam. Estimates also include steelhead collected for broodstock.

Spawn year	Origin	Steelhead Migration Time (month)									
		Summer-Autumn Migration (Jun-Dec)					Winter-Spring Migration (Jan-May)				
		10%	50%	90%	Mean	Sample size	10%	50%	90%	Mean	Sample size
1999	Wild	7	8	11	8	81	3	4	4	4	29
	Hatchery	6	8	11	8	47	3	4	4	4	27
2000	Wild	8	9	10	9	238	3	4	5	4	40
	Hatchery	8	8	10	9	194	3	4	4	4	69
2001	Wild	7	8	10	8	391	3	4	4	4	84
	Hatchery	7	9	10	9	227	3	4	4	4	156
2002	Wild	7	9	11	9	810	3	4	4	4	181
	Hatchery	9	10	11	10	610	3	4	5	4	124
2003	Wild	7	8	10	8	731	1	3	4	3	193
	Hatchery	7	8	12	9	372	1	3	4	2	538
2004	Wild	7	10	11	9	644	3	4	4	4	222
	Hatchery	7	10	10	9	677	3	4	5	4	361
2005	Wild	7	9	10	9	986	3	4	4	4	206
	Hatchery	7	9	10	9	1,112	3	4	5	4	377
2006	Wild	7	10	10	10	428	3	4	4	4	191
	Hatchery	7	10	10	9	334	1	3	4	3	181
2007	Wild	7	9	10	9	277	3	4	4	4	108
	Hatchery	7	9	10	9	90	3	4	5	4	214

Spawn year	Origin	Steelhead Migration Time (month)									
		Summer-Autumn Migration (Jun-Dec)					Winter-Spring Migration (Jan-May)				
		10%	50%	90%	Mean	Sample size	10%	50%	90%	Mean	Sample size
2008	Wild	7	9	10	9	397	3	4	5	4	123
	Hatchery	8	10	11	10	554	4	4	5	4	311
2009	Wild	7	9	11	9	338	3	4	5	4	87
	Hatchery	7	8	11	9	1,133	3	4	5	4	229
2010	Wild	8	9	11	9	648	3	4	5	4	171
	Hatchery	8	10	11	10	1,207	3	4	5	4	309
2011	Wild	7	9	11	9	797	4	4	5	4	118
	Hatchery	8	9	11	9	991	4	5	5	5	240
2012	Wild	8	8	10	9	642	4	4	5	4	83
	Hatchery	8	9	10	9	715	4	4	5	4	223
2013	Wild	8	9	10	9	755	4	4	5	4	55
	Hatchery	8	10	11	10	1,431	4	4	5	4	210
2014	Wild	7	9	10	9	549	4	4	5	4	57
	Hatchery	8	10	10	9	511	4	4	5	4	78
2015	Wild	7	9	10	9	714	3	4	4	4	48
	Hatchery	8	9	10	9	928	3	4	4	4	57
2016	Wild	8	10	11	9	610	3	4	5	4	58
	Hatchery	9	10	10	10	692	3	4	5	4	56
Average	***Wild***	***7***	***9***	***10***	***9***	***558***	***3***	***4***	***5***	***4***	***114***
	Hatchery	***8***	***9***	***11***	***9***	***657***	***3***	***4***	***5***	***4***	***209***
Median	***Wild***	***7***	***9***	***10***	***9***	***626***	***3***	***4***	***5***	***4***	***98***
	Hatchery	***8***	***9***	***10***	***9***	***644***	***3***	***4***	***5***	***4***	***212***

Age at Maturity

Nearly all steelhead broodstock collected at Tumwater and Dryden dams lived in saltwater 1 to 2 years (saltwater age) (Table 3.21). Very few saltwater age-3 fish returned and those that did were wild fish. On average, there was a difference between the saltwater age at return of wild and hatchery fish. A greater proportion of hatchery fish returned as saltwater age-1 fish than did wild fish. In contrast, a greater number of wild fish returned as saltwater-2 fish than did hatchery fish (Figure 3.6).

Table 3.21. Proportions of wild and hatchery steelhead broodstock of different ages collected at Tumwater and Dryden dams, brood years 1998-2016. Age represents the number of years the fish lived in salt water.

Brood year	Origin	Saltwater age			Sample size
		1	2	3	
1998	Wild	0.39	0.61	0.00	35
	Hatchery	0.21	0.79	0.00	43

Brood year	Origin	Saltwater age			Sample size
		1	2	3	
1999	Wild	0.50	0.48	0.02	58
	Hatchery	0.82	0.18	0.00	67
2000	Wild	0.56	0.44	0.00	39
	Hatchery	0.68	0.32	0.00	101
2001	Wild	0.52	0.48	0.00	64
	Hatchery	0.15	0.85	0.00	114
2002	Wild	0.56	0.44	0.00	99
	Hatchery	0.95	0.05	0.00	113
2003	Wild	0.13	0.85	0.02	63
	Hatchery	0.29	0.71	0.00	92
2004	Wild	0.95	0.05	0.00	85
	Hatchery	0.95	0.05	0.00	132
2005	Wild	0.22	0.78	0.00	95
	Hatchery	0.21	0.79	0.00	114
2006	Wild	0.29	0.71	0.00	101
	Hatchery	0.60	0.40	0.00	98
2007	Wild	0.40	0.59	0.00	79
	Hatchery	0.62	0.38	0.00	97
2008	Wild	0.65	0.34	0.01	104
	Hatchery	0.89	0.11	0.00	107
2009	Wild	0.40	0.58	0.20	83
	Hatchery	0.23	0.77	0.0	77
2010	Wild	0.65	0.34	0.01	92
	Hatchery	0.77	0.23	0.00	98
2011	Wild	0.28	0.73	0.00	102
	Hatchery	0.36	0.64	0.00	100
2012	Wild	0.42	0.53	0.05	59
	Hatchery	0.41	0.59	0.00	66
2013	Wild	0.41	0.57	0.02	54
	Hatchery	0.46	0.55	0.00	77
2014	Wild	0.48	0.51	0.02	61
	Hatchery	0.29	0.71	0.00	68
2015	Wild	0.16	0.83	0.02	63
	Hatchery	0.47	0.53	0.00	55
2016	Wild	0.34	0.66	0.00	65
	Hatchery	0.42	0.58	0.00	66
Average	***Wild***	***0.44***	***0.54***	***0.02***	***75***
	Hatchery	***0.54***	***0.46***	***0.00***	***89***

Brood year	Origin	Saltwater age			Sample size
		1	2	3	
Median	***Wild***	***0.45***	***0.55***	***0.00***	***65***
	Hatchery	***0.48***	***0.52***	***0.00***	***97***

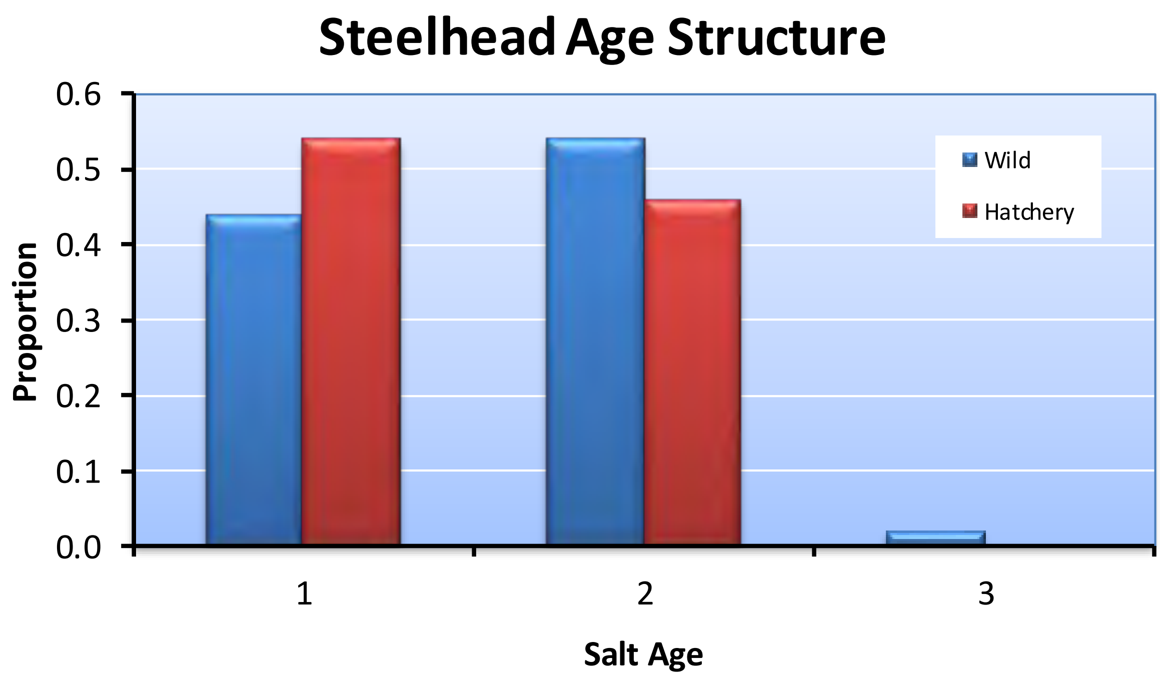

Figure 3.6. Proportions of wild and hatchery steelhead of different saltwater ages sampled at Tumwater Dam for the combined years 1998-2016.

Size at Maturity

On average, hatchery steelhead collected at Tumwater and Dryden dams were about 2 to 3 cm smaller than wild steelhead (Table 3.22).

Table 3.22. Mean fork length (cm) at age (saltwater ages) of hatchery and wild steelhead collected from broodstock, brood years 1998-2016; N = sample size and SD = 1 standard deviation.

Brood year	Origin	Steelhead fork length (cm)								
		1-Salt			2-Salt			3-Salt		
		Mean	N	SD	Mean	N	SD	Mean	N	SD
1998	Wild	63	15	4	79	20	5	-	0	-
	Hatchery	61	9	4	73	34	4	-	0	-
1999	Wild	65	29	5	74	28	5	77	1	-
	Hatchery	62	54	4	73	12	4	-	0	-
2000	Wild	64	22	3	74	17	5	-	0	-

Brood year	Origin	Steelhead fork length (cm)								
		1-Salt			2-Salt			3-Salt		
		Mean	N	SD	Mean	N	SD	Mean	N	SD
	Hatchery	60	57	3	71	27	4	-	0	-
2001	Wild	61	33	6	77	31	5	-	0	-
	Hatchery	62	17	4	72	97	4	-	0	-
2002	Wild	64	55	4	77	44	4	-	0	-
	Hatchery	63	106	4	73	6	4	-	0	-
2003	Wild	69	8	6	77	52	5	91	1	-
	Hatchery	66	27	4	75	65	4	-	0	-
2004	Wild	63	73	6	78	4	2	-	0	-
	Hatchery	61	59	3	73	3	1	-	0	-
2005	Wild	59	21	4	74	74	5	-	0	-
	Hatchery	59	23	4	72	89	4	-	0	-
2006	Wild	63	27	5	75	67	6	-	0	-
	Hatchery	61	41	4	72	27	5	-	0	-
2007	Wild	64	31	6	76	46	5	-	0	-
	Hatchery	60	60	4	71	36	5	-	0	-
2008	Wild	64	68	4	77	35	4	80	2	-
	Hatchery	60	95	4	72	12	2	-	0	-
2009	Wild	65	33	5	76	48	6	81	2	0
	Hatchery	63	18	4	75	59	5	-	0	-
2010	Wild	64	60	5	74	31	5	76	1	-
	Hatchery	61	53	5	73	23	5	-	0	-
2011	Wild	62	28	5	76	74	5	-	0	-
	Hatchery	60	36	4	74	64	4	-	0	-
2012	Wild	63	25	3	74	31	5	74	3	2
	Hatchery	59	27	3	74	39	4	-	0	-
2013	Wild	61	22	5	77	31	5	74	1	-
	Hatchery	60	35	3	74	42	4	-	0	-
2014	Wild	61	29	4	75	31	4	61	1	-
	Hatchery	60	20	3	72	48	4	-	0	-
2015	Wild	61	10	3	77	52	4	85	1	-
	Hatchery	59	26	3	76	29	5	-	0	-
2016	Wild	62	22	4	74	43	4	-	0	-
	Hatchery	61	28	4	71	38	5	-	0	-
Average	***Wild***	***63***	***32***	***5***	***76***	***40***	***5***	***78***	***1***	***1***
	Hatchery	***61***	***42***	***4***	***73***	***39***	***4***	***-***	***0***	***-***
Median	***Wild***	***63***	***28***	***5***	***76***	***35***	***5***	***77***	***0***	***1***
	Hatchery	***61***	***35***	***4***	***73***	***36***	***4***	***-***	***0***	***-***

Contribution to Fisheries

Nearly all harvest on Wenatchee steelhead occurs within the Columbia basin. Harvest rates on steelhead in the Lower Columbia River fisheries (both tribal and non-tribal) are generally less than 5-10% (NMFS 2004). A sport fishery may be opened on Upper Columbia River steelhead when the natural-origin steelhead run is predicted to exceed 1,300 fish at Priest Rapids Dam and the total Upper Columbia River steelhead run is predicted to exceed 9,550 steelhead. To minimize effects on natural-origin steelhead in the tributary fisheries, a three-tiered system as outlined in Permit 1395 is used to determine maximum allowable natural-origin steelhead take during the fishery (Table 3.23a).

Table 3.23a. Three-tiered system for determining natural-origin effects during the recreational fishery on steelhead in tributaries upstream from Rock Island Dam.

Tier	Wenatchee		Methow		Okanogan	
	NOR[1]	Effect[2]	NOR[1]	Effect[2]	NOR[1]	Effect[2]
No Fishery	≤ 599	0%	≤ 499	0%	≤ 119	0%
Tier 1	600	2%	500	2%	120	5%
Tier 2	1700	4%	1600	4%	120	7%
Tier 3	2500	6%	2500	6%	600	10%

1. Estimated natural-origin escapement to tributaries.
2. Maximum allowable take on natural-origin fish.

WDFW implemented a selective recreational steelhead fishery in the upper Columbia River during fall 2015 through winter 2016 (Table 3.23b). The fishery was conducted as a conservation measure to reduce the proportion of hatchery-origin steelhead on the spawning grounds. There were 56 hatchery steelhead harvested and an additional eight wild steelhead hook-and-release mortalities estimated for the Wenatchee River basin. Over the eight years that the Wenatchee River had a recreational fishery, average harvest has been about 183 hatchery steelhead and 16 wild steelhead hook-and-release mortalities. In the mixed population fishery within the mainstem Columbia from Priest Rapids Dam to Chief Joseph Dam, the average harvest of hatchery steelhead has been 861steelhead with 17 wild hook-and-release mortalities.

Table 3.23b. Harvest and mortality estimates for Upper Columbia steelhead in the Wenatchee and mainstem Columbia River (Priest Rapids Dam to Chief Joseph Dam). Estimated steelhead sport harvest on Wenatchee hatchery steelhead and hook-and-release mortality on wild steelhead (WDFW 2016). The wild steelhead mortality estimate is based on a hook-and-release mortality rate of 5%. Mainstem harvest from Priest Rapids Dam to Chief Joseph Dam is a mixed-population steelhead fishery that may contain fish from the Wenatchee, Entiat, Methow, and Okanogan rivers.

Year	Priest Rapids Escapement			Wenatchee			Mainstem Columbia		
	H	W	Total	H	W	Total	H	W	Total
2006-2007	--	--	--	--	--	--	694	3	697
2007-2008	--	--	--	444	15	459	1,137	13	1,150
2008-2009	14,147	3,232	17,379	--	--	--	921	10	931
2009-2010	29,206	5,682	34,888	251	17	268	1,448	29	1,477
2010-2011	18,710	7,642	26,352	106	12	118	1,412	40	1,452
2011-2012	13,230	4,092	17,322	250	19	269	855	22	877

2012-2013	--	--	--	125	26	151	722	20	744
2013-2014	8,417	4,211	12,628	135	17	152	506	9	515
2014-2015	15,791	5,218	21,009	99	14	113	99	14	113
2015-2016	8,696	2,829	11,525	56	8	64	678	13	690
Average	***15,457***	***4,701***	***20,158***	***183***	***16***	***199***	***861***	***17***	***865***
Median	***14,147***	***4,211***	***17,379***	***130***	***16***	***152***	***855***	***13***	***811***

Origin on Spawning Grounds

With the implementation of PIT-tag mark-recapture techniques in 2014, we can estimate the contribution of natural-origin and hatchery-origin fish on the spawning grounds (Table 3.24). Based on mark-recapture estimates, naturally produced steelhead made up about 60.6% of the escapement in 2016. Importantly, the abundance of hatchery fish in the upper Wenatchee Basin was regulated through surplusing (removal) at Tumwater Dam. A total of 290 hatchery steelhead were surplused at the dam resulting in the passage of 1,025 steelhead over the dam in 2016. Natural-origin steelhead comprised 59.4% (N = 609) of the steelhead that passed the dam.

Table 3.24. Spawning escapement estimates for natural-origin and hatchery-origin steelhead within the Wenatchee River, brood years 2014-2016. Escapement estimates were based on PIT-tag mark-recapture techniques (see Appendix D).

Tributary	Natural-origin steelhead			Hatchery-origin steelhead		
	2014	2015	2016	2014	2015	2016
Mission Creek	94	71	33	31	23	13
Peshastin Creek	226	206	151	6	40	0
Chumstick Creek	78	38	74	7	0	39
Icicle Creek	76	83	72	45	52	18
Chiwaukum Creek	37	48	64	9	12	11
Chiwawa River	142	168	45	103	168	134
Nason Creek	190	237	57	148	68	94
Wenatchee River	340	252	118	251	298	91
Total	***978***	***1,103***	***614***	***545***	***661***	***400***

Straying

Stray rates of Wenatchee steelhead can be estimated by examining the locations where PIT-tagged hatchery steelhead were last detected. PIT tagging of steelhead began with brood year 2005, which allows estimation of stray rates by brood return. These data only provide estimates for brood years 2005 through 2012, because later brood years are still rearing in the ocean. The most recent completed brood year is 2012.

Based on PIT-tag analyses, about 5.1% of brood year 2012 was last detected in streams outside of the Wenatchee River basin. Beginning with brood year 2011, steelhead have been overwinter-acclimated at the Chiwawa Acclimation Facility. This may be the reason for the observed reduction in stray rates since 2011. On average, for brood years 2011 through 2012, about 4% of the hatchery steelhead returns were last detected in streams outside the Wenatchee River basin (Table 3.25).

Steelhead have been detected in the Entiat and Methow rivers as well as in the Deschutes and Tucannon rivers. Several were last detected at Wells Dam. The numbers in Table 3.25 should be considered rough estimates because they are not based on confirmed spawning (only last detections).

Table 3.25. Number and percent of hatchery-origin Wenatchee steelhead that homed to target spawning areas and the target hatchery program, and number and percent that strayed to non-target spawning areas and hatchery programs for brood years 2005-2012. Estimates were based on last detections of PIT-tagged hatchery steelhead. Percent strays should be less than 5%.

Brood Year	Homing				Straying			
	Target streams		Target hatchery*		Non-target stream		Non-target hatchery	
	Number	%	Number	%	Number	%	Number	%
2005	76	73.1	1	1.0	27	26.0	0	0.0
2006	72	61.0	3	2.5	43	36.4	0	0.0
2007	171	60.4	2	0.7	110	38.9	0	0.0
2008	79	86.8	2	2.2	10	11.0	0	0.0
2009	185	83.3	2	0.9	35	15.8	0	0.0
2010	79	80.6	1	1.0	18	18.4	0	0.0
2011	120	87.6	13	9.5	4	2.9	0	0.0
2012	139	89.1	9	5.8	8	5.1	0	0.0
Average	***115***	***76.2***	***4***	***2.7***	***32***	***21.1***	***0***	***0.0***
Median	***100***	***82.0***	***2***	***1.6***	***23***	***17.1***	***0***	***0.0***

* Homing to the target hatchery includes Wenatchee hatchery steelhead that are captured and included as broodstock in the Wenatchee Hatchery program. These hatchery fish are typically collected at Dryden and Tumwater dams.

Genetics

Genetic studies were conducted in 2012 to determine the potential effects of the Wenatchee Supplementation Program on natural-origin summer steelhead in the Wenatchee River basin (Seamons et al. 2012; the entire report is appended as Appendix E). Temporal collections were obtained from hatchery and natural-origin adult summer steelhead captured at Dryden and Tumwater dams during summer and fall of 1997 through 2009 (excepting 2004 and 2005). Natural-origin steelhead consisted of a mixed collection representing all the spawning subpopulations located upstream. Therefore, to determine population substructure within the basin, samples were also taken from juvenile steelhead collected at smolt traps located within the Chiwawa River, Nason Creek, and Peshastin Creek, and from the Entiat River. Samples were also taken from juvenile steelhead collected at the smolt trap in the lower Wenatchee River. These, like natural-origin adult collections, consisted of a mixed collection representing all subpopulations located upstream. A total of 1,468 hatchery-origin and natural-origin adults were processed and 1,542 juvenile steelhead from the Wenatchee and Entiat Rivers were processed for genetic variation with 132 genetic (single nucleotide polymorphism loci; SNPs) markers. Peshastin Creek and the Entiat River served as no-hatchery-outplant controls. Genetic data were interrogated for the presence or absence of spatial and temporal trends in allele frequencies, genetic distances, and effective population size.

Allele Frequencies—Changes to the summer steelhead hatchery supplementation program had no detectable effect on genetic diversity of wild populations. On average, hatchery-origin adults had higher minor allele frequencies (MAF) than natural-origin adults, which may simply reflect the mixed ancestry of hatchery adults. Both hatchery and natural-origin adults had MAF similar to juveniles collected in spawning tributaries and in the Entiat River. There was no temporal trend in allele frequencies or observed heterozygosity in adult or juvenile collections and allele frequencies in control populations were no different than those still receiving hatchery outplants. This suggests that the hatchery program has had little effect on allele frequencies since broodstock sources changed in 1998 from mixed-ancestry broodstock collected in the Columbia River to using broodstock collected in the Wenatchee River.

Genetic Distances—As intended, interbreeding of Wenatchee River hatchery and natural-origin adults reduced the genetic differences between Wells Hatchery adults and Wenatchee River natural-origin adults observed in the first few years after changing the broodstock collection protocol. Although there were detectable genetic differences between hatchery and natural-origin adults, the magnitude of that difference declined over time. Hatchery adults were genetically different from natural-origin adults and juveniles based on pair-wise F_{ST} and principal components analysis, most likely because of the smaller effective population size (N_b) in the hatchery population (see below). Pair-wise F_{ST} estimates and genetic distances between hatchery and natural-origin adults collected the same year declined over time suggesting that the interbreeding of hatchery and natural-origin adults in the hatchery (and presumably in the wild) is slowly homogenizing Wenatchee River summer steelhead. Analyses using brood year were inconclusive because of limitations in the data.

Effective Population Size—Although the effective population size of the Wenatchee River hatchery steelhead program was consistently small, it does not appear to have caused a reduction in the effective population size of wild populations. On average, estimates of N_b were much lower and varied less for hatchery adults than for natural-origin adults and juveniles. Estimates of N_b for hatchery adults declined from the earliest brood years to a stable new low value after broodstock practices were changed in 1998. There was no indication that this had any effect on N_b in natural-origin adults and juveniles; N_b estimates for natural-origin adults and juveniles were, on average, higher and varied considerably over the 1998-2010 period and showed no temporal trend.

It is important to note that no new information will be reported on genetics until the next five-year report (2018).

Proportionate Natural Influence

Another method for assessing the genetic risk of a supplementation program is to determine the influence of the hatchery and natural environments on the adaptation of the composite population. This is estimated by the proportion of natural-origin fish in the hatchery broodstock (pNOB) and the proportion of hatchery-origin fish in the natural spawning escapement (pHOS). We calculated Proportionate Natural Influence (PNI) by iterating Ford's (2002) equations 5 and 6 to equilibrium, using a heritability of 0.3 and a selection strength of three standard deviations.[7] The larger the PNI value, the greater the strength of selection in the natural environment relative to that of the hatchery

[7] According to authorized annual take permits, PNI is calculated using the PNI approximate equation 11 (HSRG 2009; Appendix A). However, in this report, we used Ford's (2002) equations 5 and 6 with a heritability of 0.3 and a selection strength of three standard deviations to calculate PNI (C. Busack, NOAA Fisheries, 21 March 2016, provided the model for calculating PNI). This approach is more accurate than using the PNI approximate equation.

environment. For the natural environment to dominate selection, PNI should be greater than 0.50, and important integrated populations should have a PNI of at least 0.67 (HSRG/WDFW/NWIFC 2004). For the Wenatchee steelhead program, PNI is managed with the goal of achieving a five-year running average of PNI ≥ 0.67 basin-wide. In years when the natural-origin escapement is low (i.e., < 433 fish), the Wenatchee steelhead population will be managed to meet escapement goals rather than PNI.

For brood years 2001-2016, PNI values were less than 0.67 (Table 3.26), suggesting that the hatchery environment has a greater influence on adaptation of Wenatchee steelhead than does the natural environment.

Table 3.26. Proportionate Natural Influence (PNI) values for the Wenatchee steelhead supplementation program for brood years 2001-2016. NOS = number of natural-origin steelhead on the spawning grounds; HOS = number of hatchery-origin steelhead on the spawning grounds; NOB = number of natural-origin steelhead collected for broodstock; and HOB = number of hatchery-origin steelhead included in hatchery broodstock.

Brood year	Spawners[a]			Broodstock			PNI[b]	PNI (5-yr mean)
	NOS	HOS	pHOS	NOB	HOB	pNOB		
2001	158	127	0.45	51	103	0.33	0.45	--
2002	731	542	0.43	96	64	0.60	0.59	--
2003	355	350	0.50	49	90	0.35	0.43	--
2004	371	445	0.55	75	61	0.55	0.51	--
2005	690	862	0.56	87	104	0.46	0.47	0.49
2006	253	210	0.45	93	69	0.57	0.57	0.51
2007	145	115	0.44	76	58	0.57	0.58	0.51
2008	168	279	0.62	77	54	0.59	0.50	0.53
2009	171	545	0.76	86	73	0.54	0.43	0.51
2010	524	970	0.65	96	75	0.56	0.48	0.51
2011	351	472	0.57	91	70	0.57	0.51	0.50
2012	381	209	0.35	59	65	0.48	0.59	0.50
2013	322	148	0.31	49	68	0.42	0.59	0.52
2014	476	363	0.46	64	68	0.48	0.54	0.54
2015	639	484	0.43	58	52	0.53	0.57	0.56
2016	280	324	0.54	66	66	0.50	0.50	0.56
Average	***376***	***403***	***0.52***	***73***	***71***	***0.51***	***0.52***	***0.52***
Median	***353***	***357***	***0.46***	***76***	***68***	***0.54***	***0.51***	***0.51***

[a] The presence of eroded fins or missing adipose fins was used to distinguish hatchery fish from wild fish during video monitoring at Tumwater The PNI estimates are appropriate for steelhead spawning upstream from Tumwater Dam but may not represent PNI for steelhead spawning downstream from Tumwater Dam. Dam. Because not all hatchery fish have eroded fins or missing adipose fins, it is likely we are underestimating WxW hatchery steelhead returns based on video monitoring.
[b] PNI was calculated previously using PNI approximate equation 11 (HSRG 2009; their Appendix A). All PNI values presented here were recalculated by iterating Ford's (2002) equations 5 and 6 to equilibrium using a heritability of 0.3 and a selection strength of three standard deviations. C. Busack, NOAA Fisheries, 21 March 2016, provided the model for calculating PNI.

Post-Release Survival and Travel Time

We used PIT-tagged fish to estimate survival rates and travel time (arithmetic mean days) of hatchery steelhead from release sites (e.g., Chiwawa River, Nason Creek, and Wenatchee River) to McNary Dam, and smolt to adult ratios (SARs) from release to detection at Bonneville Dam (Table 3.27).[8] Over the 12 brood years for which PIT-tagged hatchery fish are available, survival rates from the release sites to McNary Dam ranged from 0.055 to 0.785 (note that survival rates of 0.000 were associated with very small sample sizes); SARs from release to detection at Bonneville Dam ranged from 0.000 to 0.038. Average travel time from the release sites to McNary Dam ranged from 13 to 100 days.

Some of the variation in survival rates and travel time was related to release location, type of release, and rearing scenario. For example, on average, steelhead released in the Chiwawa River appeared to have higher survival rates to McNary Dam than did steelhead released in the lower and upper Wenatchee River or Nason Creek. Within the Chiwawa River, steelhead identified as "movers" had the highest survival rates to McNary Dam, while those identified as "non-screened" had the lowest survival. For steelhead released into Nason Creek and the Wenatchee River, fish released from circulars had higher survival rates than those released from raceways. On average, steelhead released from Blackbird Pond had lower survival rates to McNary Dam than those released from circulars. Based on the available data, SARs varied little among the release locations or rearing scenarios.

Travel time from release to McNary Dam varied among release locations and rearing scenario. In general, steelhead released into the Chiwawa River and Nason Creek appeared to travel more quickly to McNary Dam than did steelhead released into the Wenatchee River. Of those released into the Chiwawa River, steelhead released volitionally from raceways appeared to travel to McNary Dam more quickly than those forced released; although there are few replicates and differences in travel times are small. On average, there appeared to be little differences in travel times for steelhead reared in raceways or circulars that were released into Nason Creek.

Table 3.27. Total number of Wenatchee hatchery summer steelhead released with PIT tags, their survival and travel times (mean days) to McNary Dam, and smolt-to-adult (SAR) ratios for brood years 2005-2015. SARs were estimated to Bonneville Dam. Standard errors are shown in parentheses. NA = not available (i.e., for SARs, not all the adults from the release groups have returned to the Columbia River).

Brood year	Release location[a]	Crosses[b]	Type of release	Rearing scenario[c]	Number of tagged fish released	Survival to McNary Dam	Travel time to McNary Dam (d)	SAR to Bonneville Dam
2003	Chiwawa	HxW	NA	Turtle Rock	29,801	0.755 (0.029)	18.2 (16.7)	0.003 (0.000)
	Nason	WxW	NA	Turtle Rock	34,823	0.648 (0.026)	19.3 (19.6)	0.004 (0.000)
	Wenatchee	HxH	NA	Turtle Rock	30,018	0.767 (0.030)	18.1 (20.6)	0.003 (0.000)
2004	Chiwawa	HxW	NA	Turtle Rock	2,439	0.480 (0.037)	26.9 (59.5)	0.011 (0.002)
	Chiwawa	WxW	NA	Turtle Rock	853	0.485 (0.054)	21.1 (8.8)	0.008 (0.003)
	Nason	WxW	NA	Turtle Rock	8,826	0.412 (0.017)	26.7 (56.1)	0.010 (0.001)
	Wenatchee	HxH	NA	Turtle Rock	9,705	0.621 (0.022)	15.8 (6.3)	0.033 (0.002)

[8] It is important to point out that because of fish size differences among rearing tanks or raceways, fish PIT tagged in one tank or raceway may not represent untagged fish rearing in other tanks or raceways.

Brood year	Release location[a]	Crosses[b]	Type of release	Rearing scenario[c]	Number of tagged fish released	Survival to McNary Dam	Travel time to McNary Dam (d)	SAR to Bonneville Dam
	Wenatchee	HxW	NA	Turtle Rock	7,379	0.606 (0.029)	19.3 (7.4)	0.013 (0.001)
2005	Chiwawa	HxW	NA	Turtle Rock	3,448	0.540 (0.065)	22.6 (27.2)	0.017 (0.002)
	Chiwawa	WxW	NA	Turtle Rock	717	0.521 (0.128)	22.2 (8.0)	0.013 (0.004)
	Nason	WxW	NA	Turtle Rock	7,306	0.416 (0.031)	21.3 (9.2)	0.009 (0.001)
	Wenatchee	HxH	NA	Turtle Rock	8,610	0.656 (0.057)	20.1 (35.8)	0.017 (0.001)
	Wenatchee	HxW	NA	Turtle Rock	5,021	0.649 (0.074)	20.2 (9.0)	0.014 (0.002)
2006	NA	NA	NA	NA	NA	NA	NA	NA
2007	Chiwawa	HxW	NA	Turtle Rock	2,882	0.520 (0.057)	22.3 (7.9)	0.020 (0.003)
	Chiwawa	WxW	NA	Turtle Rock	785	0.467 (0.069)	18.7 (9.0)	0.038 (0.007)
	Nason	WxW	NA	Turtle Rock	8,060	0.505 (0.030)	22.3 (24.1)	0.030 (0.002)
	Wenatchee	HxW	NA	Turtle Rock	9,047	0.631 (0.041)	18.2 (17.2)	0.038 (0.002)
2008	Chiwawa	HxW L	NA	Turtle Rock	2,008	0.574 (0.080)	20.3 (7.0)	0.006 (0.002)
	Chiwawa	WxW	NA	Turtle Rock	1,457	0.546 (0.090)	31.6 (108.5)	0.010 (0.003)
	Nason	WxW	NA	Turtle Rock	7,951	0.500 (0.037)	21.4 (17.5)	0.014 (0.001)
	Wenatchee	HxW E	NA	Turtle Rock	4,517	0.511 (0.044)	19.5 (7.7)	0.008 (0.001)
	Wenatchee	HxW L	NA	Turtle Rock	6,710	0.545 (0.038)	19.3 (6.8)	0.010 (0.001)
2009	Chiwawa	HxW E	Forced	Turtle Rock	4,874	0.576 (0.076)	24.3 (8.3)	0.012 (0.002)
	Chiwawa	HxW E	Volitional	Chiw. Circ	8,653	0.785 (0.100)	19.4 (26.0)	0.007 (0.001)
	Nason	WxW	Forced	Turtle Rock	8,918	0.504 (0.042)	27.2 (26.6)	0.017 (0.001)
	Wenatchee	HxW E	Forced	Turtle Rock	11,300	0.543 (0.041)	25.8 (54.8)	0.014 (0.001)
	Wenatchee	HxW E	Forced	Turtle Rock	6,681	0.597 (0.063)	28.9 (72.2)	0.013 (0.001)
	Wenatchee	HxW L	Forced	Turtle Rock	4,619	0.478 (0.052)	21.7 (7.6)	0.015 (0.002)
	Wenatchee	HxW E	Volitional	Blackbird	2,184	0.317 (0.054)	NA	0.010 (0.002)
	Wenatchee	WxW	Volitional	Rohlfing	566	0.443 (0.187)	NA	0.014 (0.005)
2010	Chiwawa	WxW	Forced	Turtle Rock	4,226	0.586 (0.057)	24.4 (60.1)	0.009 (0.001)
	Nason	WxW	Forced	Turtle Rock	5,256	0.548 (0.044)	23.5 (53.3)	0.010 (0.001)
	Wenatchee	HxH	Forced	Turtle Rock	8,506	0.583 (0.053)	30.2 (50.1)	0.004 (0.001)
	Wenatchee	HxH	Volitional	Blackbird	9,858	0.629 (0.046)	NA	0.006 (0.001)
	Wenatchee	HxH	Volitional	Chiw. Circ	10,031	0.413 (0.043)	21.6 (66.1)	0.001 (0.000)
2011	Chiwawa	WxW	Volitional	RCY	3,603	0.407 (0.056)	15.1 (8.3)	0.005 (0.001)
	Nason	WxW	Volitional	RCY	4,065	0.334 (0.042)	20.9 (60.9)	0.005 (0.001)
	Wenatchee	WxW	Non-movers	Circular	1,122	0.354 (0.228)	40.6 (89.1)	0.000 (--)

Brood year	Release location[a]	Crosses[b]	Type of release	Rearing scenario[c]	Number of tagged fish released	Survival to McNary Dam	Travel time to McNary Dam (d)	SAR to Bonneville Dam
	Wenatchee	WxW	Non-movers	RCY	2,395	0.368 (0.084)	22.7 (57.0)	0.004 (0.001)
	Wenatchee	WxW	Volitional	Blackbird	2,099	0.660 (0.016)	NA	0.010 (0.002)
	Wenatchee	WxW	Volitional	Circular	7,206	0.278 (0.043)	31.6 (74.3)	0.006 (0.001)
	Wenatchee	WxW	Volitional	RCY	4,422	0.327 (0.032)	15.2 (25.6)	0.008 (0.001)
	All	WxW	NA	Circular	1,628	0.055 (0.016)	100.4 (151.7)	0.002 (0.001)
	All	WxW	NA	RCY	3,479	0.289 (0.034)	13.6 (8.4)	0.004 (0.001)
2012	Chiwawa	HxH	Volitional	RCY	2,891	0.407 (0.057)	15.2 (7.2)	NA
	Nason	WxW	Forced	Circular	4,271	0.378 (0.065)	25.0 (33.1)	NA
	Nason	WxW	Volitional	Circular	5,404	0.364 (0.048)	24.9 (31.6)	NA
	L Wenatchee	HxH	Forced	RCY	587	0.164 (0.074)	52.2 (114.7)	NA
	U Wenatchee	HxH	Volitional	RCY	2,224	0.573 (0.138)	18.7 (8.4)	NA
	U Wenatchee	HxH	Forced	RCY	1,969	0.603 (0.140)	24.7 (42.5)	NA
	Wenatchee	HxH	Volitional	Blackbird	1,658	0.428 (0.092)	NA	NA
	All	HxH	NA	RCY	769	0.325 (0.163)	97.3 (286.2)	NA
	All	WxW	NA	Circular	5,397	0.327 (0.049)	25.4 (45.0)	NA
2013	Chiwawa	Mixed	Volitional	RCY	1,567	0.354 (0.064)	15.2 (7.0)	NA
	Nason	Mixed	Volitional	RCY	3,796	0.448 (0.115)	20.2 (9.4)	NA
	Nason	Mixed	Volitional	Circ or RCY	308	0.146 (0.053)	17.4 (2.9)	NA
	Nason	WxW	Non-movers	Circular	74	0.000 (-)	0.0 (-)	NA
	Nason	WxW	Volitional	Circular	1,286	0.192 (0.063)	18.4 (6.4)	NA
	L Wenatchee	Mixed	Non-movers	RCY	3,275	0.317 (0.131)	35.3 (69.5)	NA
	U Wenatchee	Mixed	Volitional	RCY	2,862	0.458 (0.081)	16.3 (9.7)	NA
	Wenatchee	HxH	Volitional	Blackbird	819	0.337 (0.128)	NA	NA
	All	HxH	NA	RCY	907	0.000 (--)	36.7 (17.6)	NA
	All	WxW	NA	Circ or RCY	232	0.000 (--)	38.0 (--)	NA
2014	Chiwawa	Mixed	Movers	RCY	793	0.754 (0.497)	27.7 (7.6)	NA
	Chiwawa	Mixed	Non-screen	RCY	915	0.367 (0.236)	25.0 (8.1)	NA
	Nason	Mixed	Movers	RCY	1,553	0.216 (0.084)	28.4 (29.4)	NA
	Nason	Mixed	Non-screen	RCY	1,653	0.076 (0.018)	24.2 (7.1)	NA
	Nason	WxW	Movers	Circular	949	0.244 (0.104)	47.4 (91.0)	NA
	Nason	WxW	Non-screen	Circular	873	0.369 (0.190)	20.8 (6.9)	NA
	L Wenatchee	Mixed	Non-movers	RCY	2,596	0.139 (0.026)	26.4 (59.5)	NA
	U Wenatchee	Mixed	Movers	RCY	2,042	0.278 (0.051)	21.9 (8.2)	NA

Brood year	Release location[a]	Crosses[b]	Type of release	Rearing scenario[c]	Number of tagged fish released	Survival to McNary Dam	Travel time to McNary Dam (d)	SAR to Bonneville Dam
	U Wenatchee	Mixed	Non-screen	RCY	1,563	0.126 (0.026)	28.7 (8.2)	NA
	U Wenatchee	WxW	Movers	Circular	356	0.278 (0.165)	17.0 (6.5)	NA
	U Wenatchee	WxW	Non-movers	Circular	596	0.381 (0.192)	15.8 (6.8)	NA
	U Wenatchee	WxW	Non-screen	Circular	1,230	0.349 (0.104)	25.8 (57.4)	NA
	Wenatchee	HxH	Volitional	Blackbird	1,814	0.225 (0.055)	NA	NA
	All	Mixed	NA	Circ or RCY	1,884	0.113 (0.030)	41.7 (61.8)	NA
2015	Chiwawa	Mixed	Movers	RCY	4,365	0.423 (0.040)	13.6 (5.7)	NA
	Nason	Mixed	Mixed	RCY	675	0.164 (0.035)	19.8 (8.9)	NA
	Nason	Mixed	Movers	RCY	2,427	0.332 (0.053)	18.6 (6.7)	NA
	Nason	Mixed	Non-screen	RCY	2,123	0.275 (0.056)	20.0 (7.6)	NA
	Nason	WxW	Movers	Circular	1,105	0.412 (0.082)	15.5 (5.3)	NA
	Nason	WxW	Non-screen	Circular	916	0.402 (0.111)	14.9 (5.1)	NA
	L Wenatchee	Mixed	Non-movers	RCY	1,658	0.244 (0.073)	13.0 (6.5)	NA
	U Wenatchee	Mixed	Movers	RCY	2,773	0.341 (0.032)	16.3 (7.9)	NA
	U Wenatchee	Mixed	Non-screen	RCY	1,435	0.469 (0.094)	19.7 (8.9)	NA
	U Wenatchee	WxW	Movers	Circular	1,061	0.555 (0.079)	13.9 (7.3)	NA
	U Wenatchee	WxW	Non-screen	Circular	849	0.355 (0.064)	12.7 (5.5)	NA
	Wenatchee	HxH	Non-screen	Blackbird	2,337	0.364 (0.039)	NA	NA
	All	Mixed	NA	Circ or RCY	1,381	0.167 (0.105)	19.4 (10.8)	NA

[a] All = Chiwawa River, Nason Creek, and the Wenatchee River.
[b] HxH = hatchery by hatchery cross; WxW = wild by wild cross; Mixed = both HxH and WxW crosses; E = early; and L = late.
[c] Circ = circulars; RCY = raceway.

Natural and Hatchery Replacement Rates

Natural replacement rates (NRR) were calculated as the ratio of natural-origin recruits (NOR) to the parent spawning population (spawning escapement). Natural-origin recruits are naturally produced (wild) fish that survive to contribute to harvest (directly or indirectly), to broodstock, and to spawning grounds. We do not account for fish that died in route to the spawning grounds (migration mortality) or died just before spawning (pre-spawn mortality) (see Appendix B in Hillman et al. 2012). For brood years 1998-2012, NRR for summer steelhead in the Wenatchee River basin averaged 0.66 (range, 0.13-3.10) if harvested fish were included in the estimate (Table 3.28).

Hatchery replacement rates (HRR) are the hatchery adult-to-adult returns and were calculated as the ratio of hatchery-origin recruits (HOR) to the parent broodstock collected. These rates should be greater than the NRRs and greater than or equal to 6.9 (the calculated target value in Hillman et al. 2013). The target value of 6.9 includes harvest. In nearly all years, HRRs were greater than NRRs (Table 3.28). HRRs exceeded the estimated target value of 6.9 in 11 of the 15 years.

Table 3.28. Broodstock collected, spawning escapements, natural and hatchery-origin recruits (NOR and HOR), and natural and hatchery replacement rates (NRR and HRR with harvest) for summer steelhead in the Wenatchee River basin, brood years 1998-2012.

Brood year	Broodstock Collected	Spawning Escapement	Harvest included			
			HOR	NOR	HRR	NRR
1998	78	602	148	1,867	1.89	3.10
1999	125	343	1,944	334	15.55	0.97
2000	120	1,030	312	878	2.60	0.85
2001	178	1,655	10,335	1,050	58.06	0.66
2002	162	5,000	1,905	515	11.76	0.13
2003	155	2,598	956	504	6.17	0.27
2004	217	2,949	2,538	728	11.70	0.25
2005	209	3,609	3,106	904	14.86	0.25
2006	199	2,219	1,454	1,007	7.31	0.45
2007	176	880	535	430	3.04	0.49
2008	107	1,835	1,121	714	10.48	0.39
2009	107	1,733	1,024	709	9.57	0.41
2010	105	6,236	3,999	2,237	38.09	0.36
2011	104	3,049	859	2,189	8.26	0.72
2012	129	2,514	1,094	1,420	8.48	0.56
Average	***145***	***2,417***	***2,089***	***1,032***	***13.85***	***0.66***
Median	***129***	***2,219***	***1,121***	***878***	***9.57***	***0.45***

Smolt-to-Adult Survivals

Smolt-to-adult ratios (SARs) are calculated as the number of returning hatchery adults divided by the number of tagged hatchery smolts released. SARs are generally based on CWT returns. However, prior to brood year 2011, Wenatchee steelhead were not extensively tagged with CWTs. Therefore, elastomer-tagged fish were used to estimate SARs from release to capture at Priest Rapids Dam. With the return of brood year 2011, SARs will be based on PIT-tag detections at Bonneville Dam.

SARs (not adjusted for tag loss) for Wenatchee steelhead ranged from 0.0009 to 0.0315 (mean = 0.0093) for brood years 1996-2010 (Table 3.29). For brood years 2011 to present, SARs (to Bonneville Dam) averaged 0.0056 (Table 3.29).

Table 3.29. Smolt-to-adult ratios (SARs) for Wenatchee hatchery steelhead. Estimates for brood years 1996-2010 were based on elastomer tags recaptured at Priest Rapids Dam. SARs were not adjusted for tag loss after release. For brood years 2011 to present, SARs are based on PIT-tag detections to Bonneville Dam.

Brood year	Number of tagged smolts released	SAR
1996	348,693	0.0034
1997	429,422	0.0041

Brood year	Number of tagged smolts released	SAR
1998	172,078	0.0009
1999	175,661	0.0111
2000	184,639	0.0017
2001	335,933	0.0308
2002	302,060	0.0063
2003	374,867	0.0025
2004	294,114	0.0038
2005	452,184	0.0107
2006	258,697	0.0100
2007	306,690	0.0315
2008	327,133	0.0090
2009	484,826	0.0080
2010[a]	192,363	0.0054
Average	***309,291***	***0.0093***
Median	***306,690***	***0.0063***
2011	30,019	0.0057
2012	25,134	0.0055
Average	***27,577***	***0.0056***
Median	***27,577***	***0.0056***

[a] Only 192,363 WxW progeny from brood year 2010 were elastomer tagged; 161,951 HxH steelhead were released.

3.7 ESA/HCP Compliance

Broodstock Collection

Collection of brood year 2015 broodstock for Wenatchee summer steelhead at Dryden and Tumwater dams began on 1 July and ended on 15 October 2014 at Dryden Dam and 10 November 2014 at Tumwater Dam consistent with the collection period identified in the 2014 broodstock collection protocol. The broodstock collection achieved a total collection of 142 steelhead, including 76 natural-origin steelhead (of the 76 fish collected, 58 were spawned and 13 were released back to the river.

About 1,278 steelhead were handled and released (or surplused) at Tumwater and Dryden dams during brood year 2015 Wenatchee steelhead broodstock collection. Most were hatchery-origin fish handled at Tumwater Dam and ultimately surplused to meet the pHOS objective upstream from Tumwater Dam. Fish released at Dryden Dam were released because the weekly quota for hatchery or wild steelhead had been attained, but not for both hatchery and wild fish, or because they were non-target fish (adipose clipped), or they were unidentifiable hatchery-origin steelhead. All steelhead released were allowed to fully recover from the anesthesia and released immediately upstream from the trap sites.

In addition to steelhead encountered at Dryden Dam during steelhead broodstock collection, an estimated 48 spring Chinook salmon were captured and released unharmed immediately upstream from the trap facility. Consistent with ESA Section 10 Permit 1395 impact minimization measures, all ESA species handled were subject of water-to-water transfers.

Hatchery Rearing and Release

The 2015 brood Wenatchee steelhead reared throughout all life stages without significant mortality (defined as >10% population mortality associated with a single event). However, the 2015 brood had poor fertilization to eyed-egg survival (60.3%) combined with somewhat low eyed-egg to ponding survival resulting in an unfertilized-to-release survival of 68.5%, which was considerably less than the program target of 81% (see Section 3.2).

Juvenile rearing occurred at three separate facilities including Eastbank Fish Hatchery, Chelan Fish Hatchery, and the Chiwawa Acclimation Facility. Multiple facilities were used to take advantage of variable water temperatures to manipulate growth of juveniles from different parental crosses. Typically, wild steelhead spawn later than their hatchery cohort and are therefore reared at Chelan Fish Hatchery on warmer water to accelerate their growth so they achieve a size-at-release similar to HxH parental cross progeny reared on cooler water at Eastbank Fish Hatchery. All parental cross groups received final rearing and over-winter acclimation at the Chiwawa Acclimation Facility on Wenatchee River and Chiwawa River surface water before direct release (scatter planting) in the Wenatchee River basin.

The 2015 brood steelhead smolt release in the Wenatchee River basin totaled 195,344 smolts, representing about 79% of the program target of 247,300 smolts identified in the Rocky Reach and Rock Island Dam HCPs and within the maximum 110% allowed in ESA Section 10 Permit 1395. As specified in ESA Section 10 Permit 1395, all steelhead smolts released were externally marked or internally tagged and a representative number were PIT tagged (see Section 3.2).

Hatchery Effluent Monitoring

Per ESA Permits 1196, 1347, 1395, 18118, 18120, and 18121, permit holders shall monitor and report hatchery effluents in compliance with applicable National Pollution Discharge Elimination Systems (NPDES) (EPA 1999) permit limitations. There was no NPDES violations reported at PUD Hatchery facilities during the period 1 January 2016 through 31 December 2016. NPDES monitoring and reporting for Chelan PUD Hatchery Programs during 2016 are provided in Appendix F.

Smolt and Emigrant Trapping

Per ESA Section 10 Permit No. 1395, the permit holders are authorized a direct take of up to 20% of the emigrating steelhead population and a lethal take not to exceed 2% of the fish captured (NMFS 2003). Based on the estimated wild steelhead population (smolt trap expansion) and hatchery juvenile steelhead population estimate (hatchery release data) for the Wenatchee River basin, the reported steelhead encounters during the 2016 emigration complied with take provisions in the Section 10 permit and are detailed in Table 3.30. Additionally, juvenile fish captured at the trap locations were handled consistent with provisions in ESA Section 10 Permit 1395 Section B.

Table 3.30. Estimated take of Upper Columbia River steelhead resulting from juvenile emigration monitoring in the Wenatchee River basin, 2016. NA = not available.

Trap location	Population estimate				Number trapped				Total	Take allowed by Permit
	Wild	Hatchery[a]	Parr	Fry	Wild	Hatchery	Parr	Fry		
Chiwawa Trap										
Population	NA	37,774	NA	NA	195	1,509	1,409	113	3,226	
Encounter rate	NA	NA	NA	NA	NA	0.0399	NA	NA	NA	0.20
Mortality[b]	NA	NA	NA	NA	0	0	9	1	10	
Mortality rate	NA	NA	NA	NA	0.0000	0.0000	0.0064	0.0089	0.0031	0.02
Lower Wenatchee Trap										
Population	NA	195,344	NA	NA	88	256	103	226	673	
Encounter rate	NA	NA	NA	NA	NA	0.0013	NA	NA	NA	0.20
Mortality[b]	NA	NA	NA	NA	0	1	2	4	7	
Mortality rate	NA	NA	NA	NA	0.0000	0.0039	0.0194	0.0177	0.0104	0.02
Wenatchee River Basin Total										
Population	NA	195,344	NA	NA	283	1,765	1,512	339	3,899	
Encounter rate	NA	NA	NA	NA	NA	0.0090	NA	NA	NA	0.20
Mortality[b]	NA	NA	NA	NA	0	1	11	5	17	
Mortality rate	NA	NA	NA	NA	0.0000	0.0006	0.0073	0.0147	0.0044	0.02

[a] 2016 smolt release data for the Wenatchee River basin.

[b] Mortality includes trapping and PIT-tag mortalities.

Spawning Surveys

Steelhead spawning ground surveys were conducted in the Wenatchee River basin during 2016, as authorized by ESA Section 10 Permit No. 1395. Because of the difficulty of quantifying the level of take associated with spawning ground surveys, the Permit does not specify a take level associated with these activities, even though it does authorize implementation of spawning ground surveys. Therefore, no take levels are reported. However, to minimize potential effects to established redds, wading was restricted to the extent practical, and extreme caution was used to avoid established redds when wading was required.

Stock Assessment at Priest Rapids Dam

Upper Columbia River steelhead stock assessment sampling at Priest Rapids Dam (PRD) is authorized through ESA Section 10 Permit No. 1395 (NMFS 2003). Permit authorizations include interception and biological sampling of up to 15% of the Upper Columbia River steelhead passing PRD to determine upriver adult population size, estimate hatchery to wild ratios, determine age-class contribution, and evaluate the need for managing hatchery steelhead consistent with ESA recovery objectives, which include fully seeding spawning habitat with naturally produced Upper Columbia River steelhead supplemented with artificially propagated steelhead (NMFS 2003). The 2014-2015 run-cycle report (BY 2015) for stock assessment sampling at Priest Rapids Dam was compiled under provisions of ESA Section 10 Permit 1395. Data and reporting information are included in Appendix G.

SECTION 4: WENATCHEE SOCKEYE SALMON

The goal of sockeye salmon supplementation in the Wenatchee Basin was to use artificial production to replace adult production lost because of mortality at Rock Island Dam, while not reducing the natural production or long-term fitness of sockeye in the basin. The Rock Island Fish Hatchery Complex began operation in 1989 under funding from Chelan PUD. The Complex operated originally through the Rock Island Settlement Agreement, but since 2004 has operated under the Anadromous Fish Agreement and Habitat Conservation Plans.

Adult sockeye were collected for broodstock from the run-at-large at Tumwater Dam. Beginning in 2011, because of passage delays at Tumwater Dam during trapping operations, sockeye broodstock were collected at Dryden Dam. The goal was to collect up to 260 natural-origin adult sockeye for the program. Broodstock collection occurred from about 7 July through 28 August with trapping occurring no more than 16 hours per day, three days a week at Tumwater Dam and up to seven days per week at the Dryden Dam left and right-bank facilities.

Adult sockeye were held and spawned at Eastbank Fish Hatchery. The fertilized eggs were also incubated at the hatchery. For brood years 1989 through 1998, unfed fry were transferred from the hatchery to Lake Wenatchee net pens. From 1998 to 2011, juvenile sockeye were reared at Eastbank Fish Hatchery until July when they were transferred to the net pens. The initial rearing at Eastbank was to increase growth rates. During most years up through 2005, juvenile sockeye were released from net pens at two different times, August and November. Since 2006, all juvenile sockeye were released in late October.

The production goal for the Wenatchee sockeye supplementation program was to release 200,000 subyearlings into Lake Wenatchee at 20 fish per pound. Targets for fork length and weight were 133 mm (CV = 9.0) and 22.7 g, respectively. Over 90% of these fish were marked with CWTs. In addition, from 2006-2011, about 15,000 juvenile sockeye were PIT tagged annually. Following an evaluation of the supplementation program in 2011, the Hatchery Committees decided to convert the Wenatchee sockeye hatchery program to summer steelhead in 2012. Monitoring occurs annually to track the status of the natural sockeye population.

4.1 Broodstock Sampling

As noted above, the Wenatchee sockeye program was terminated in 2012. Thus, no broodstock have been collected since 2011 and the release of juvenile sockeye into Lake Wenatchee in 2012 (2011 brood) was the last. Therefore, this section presents the history of the program and tracks the juveniles from the 2011 brood that were released as parr into Lake Wenatchee in 2012. Some of these fish began their smolt migrations in 2013.

Origin of Broodstock

Wenatchee sockeye broodstock have not been collected since 2011. Table 4.1 shows the history of the number of broodstock that were collected during the period 1989 to 2011.

Table 4.1. Numbers of wild and hatchery sockeye salmon collected for broodstock, numbers that died before spawning, and numbers of sockeye spawned, 1989-2011. Unknown origin fish (i.e., undetermined by scale analysis, no CWT or fin clips, and no additional hatchery marks) were considered naturally produced. Mortality includes sockeye that died of natural causes typically near the end of spawning and were not needed for the program, surplus sockeye killed at spawning, sockeye that died but were not recovered from the net pens, and sockeye that may have jumped out of the net pens.

Brood year	Wild sockeye					Hatchery sockeye					Total number spawned
	Number collected	Prespawn loss[a]	Mortality	Number spawned	Number released	Number collected	Prespawn loss[a]	Mortality	Number spawned	Number released	
1989	299	93	47	115	44	0	0	0	0	0	115
1990	333	7	7	302	17	0	0	0	0	0	302
1991	357	18	16	199	124	0	0	0	0	0	199
1992	362	18	5	320	19	0	0	0	0	0	320
1993	307	79	21	207	0	0	0	0	0	0	207
1994	329	15	9	236	69	5	0	0	5	0	241
1995	218	5	7	194	12	3	0	0	3	0	197
1996	291	2	0	225	64	20	0	0	0	20	225
1997	283	12	3	192	76	19	0	0	19	0	211
1998	225	37	25	122	41	6	0	0	6	0	128
1999	90	7	1	79	3	60	0	0	60	0	139
2000	256	19	1	170	66	5	0	0	5	0	175
2001	252	27	10	200	15	8	1	0	7	0	207
2002	257	0	1	256	0	0	0	0	0	0	256
2003	261	12	9	198	42	0	0	0	0	0	198
2004	211	13	12	177	9	0	0	0	0	0	177
2005	243	29	12	166	36	0	0	0	0	0	166
2006	260	2	4	214	40	0	0	0	0	0	214
2007	248	15	3	210	20	0	0	0	0	0	210
2008	258	4	11	243	0	2	0	0	2	0	245
2009	258	5	14	239	0	3	0	3	0	0	239
2010	256	3	0	198	55	0	0	0	0	0	198
2011	204	0	8	196	0	0	0	0	0	0	196
Average	***263***	***18***	***10***	***203***	***33***	***6***	***0***	***0***	***5***	***1***	***208***
Median	***258***	***12***	***8***	***199***	***20***	***0***	***0***	***0***	***0***	***0***	***207***

[a] Pre-spawn loss represents the number of fish that died during the holding period before spawning. Mortality is the number of fish that were surplused following spawning.

Age/Length Data

Ages of sockeye were determined from scales and otoliths collected from broodstock and are shown in Table 4.2.

Table 4.2. Percent of hatchery and wild sockeye salmon of different ages (total age) collected from broodstock, 1994-2011.

Return year	Origin	Total age		
		4	5	6
1994	Wild	57.3	41.7	1.0
	Hatchery	40.0	60.0	0.0
1995	Wild	77.3	20.7	2.0
	Hatchery	66.7	33.3	0.0
1996	Wild	65.8	34.2	0.0
	Hatchery	0.0	0.0	0.0
1997	Wild	86.5	13.5	0.0
	Hatchery	57.9	42.1	0.0
1998	Wild	9.9	88.6	1.5
	Hatchery	66.7	33.3	0.0
1999	Wild	21.8	74.7	3.5
	Hatchery	90.0	8.3	1.7
2000	Wild	97.7	2.3	0.0
	Hatchery	100.0	0.0	0.0
2001	Wild	69.9	29.6	0.5
	Hatchery	71.4	28.6	0.0
2002	Wild	31.6	67.6	0.8
	Hatchery	0.0	0.0	0.0
2003	Wild	2.6	90.5	6.9
	Hatchery	0.0	0.0	0.0
2004	Wild	97.5	2.0	0.5
	Hatchery	0.0	0.0	0.0
2005	Wild	74.2	25.8	0.0
	Hatchery	0.0	0.0	0.0
2006	Wild	34.0	65.5	0.5
	Hatchery	0.0	0.0	0.0
2007	Wild	1.9	88.4	9.7
	Hatchery	0.0	0.0	0.0
2008	Wild	95.0	4.0	1.0
	Hatchery	100.0	0.0	0.0
2009	Wild	78.5	21.5	0.0
	Hatchery	100.0	0.0	0.0
2010	Wild	67.4	32.6	0.0
	Hatchery	0.0	0.0	0.0
2011	Wild	53.7	44.3	2.0
	Hatchery	0.0	0.0	0.0

Return year	Origin	Total age		
		4	5	6
Average	***Wild***	***56.8***	***41.5***	***1.7***
	Hatchery	***38.5***	***11.4***	***0.1***
Median	***Wild***	***66.6***	***33.4***	***0.7***
	Hatchery	***20.0***	***0.0***	***0.0***

Lengths and ages of sockeye sampled during the life of the program are provided in Table 4.3.

Table 4.3. Mean fork length (cm) at age (total age) of hatchery and wild sockeye salmon collected for broodstock, 1994-2011; SD = 1 standard deviation.

Return year	Origin	Sockeye fork length (cm)								
		Age-4			Age-5			Age-6		
		Mean	N	SD	Mean	N	SD	Mean	N	SD
1994	Wild	56	125	3	55	91	3	54	2	3
	Hatchery	57	2	1	56	3	1	-	0	-
1995	Wild	51	153	2	55	41	4	54	4	5
	Hatchery	53	2	4	59	1	-	-	0	-
1996	Wild	52	146	4	53	76	3	-	0	-
	Hatchery	-	0	-	-	0	-	-	0	-
1997	Wild	50	166	3	53	26	5	-	0	-
	Hatchery	54	11	4	59	8	2	-	0	-
1998	Wild	51	13	4	55	117	3	53	2	3
	Hatchery	52	4	2	55	2	8	-	0	-
1999	Wild	52	19	4	50	65	4	56	3	1
	Hatchery	50	54	3	56	5	4	56	1	-
2000	Wild	52	167	2	54	4	3	-	0	-
	Hatchery	54	5	1	-	0	-	-	0	-
2001	Wild	54	151	3	56	65	4	58	1	-
	Hatchery	51	5	5	55	2	4	-	0	-
2002	Wild	54	77	2	56	165	4	57	2	0
	Hatchery	-	0	-	-	0	-	-	0	-
2003	Wild	54	5	4	60	172	2	60	13	4
	Hatchery	-	0	-	-	0	-	-	0	-
2004	Wild	53	192	3	56	4	3	63	1	-
	Hatchery	-	0	-	-	0	-	-	0	-
2005	Wild	51	132	3	57	46	4	-	0	-
	Hatchery	-	0	-	-	0	-	-	0	-
2006	Wild	52	70	3	56	135	4	54	2	3
	Hatchery	-	0	-	-	0	-	-	0	-
2007	Wild	57	4	2	58	182	5	58	20	5

Return year	Origin	Sockeye fork length (cm)								
		Age-4			Age-5			Age-6		
		Mean	N	SD	Mean	N	SD	Mean	N	SD
	Hatchery	-	0	-	-	0	-	-	0	-
2008	Wild	52	245	3	52	11	3	62	2	6
	Hatchery	53	2	3	-	-	-	-	-	-
2009	Wild	54	197	3	59	54	4	-	-	-
	Hatchery	54	2	1	-	-	-	-	-	-
2010	Wild	55	130	2	57	63	4	-	-	-
	Hatchery	-	-	-	-	-	-	-	-	-
2011	Wild	55	109	2	59	90	3	61	4	3
	Hatchery	-	-	-	-	-	-	-	-	-
Average	***Wild***	***53***	***116***	***3***	***55***	***78***	***4***	***57***	***3***	***3***
	Hatchery	***53***	***5***	***3***	***57***	***2***	***4***	***56***	***1***	***-***

Sex Ratios

Sex ratios of wild and hatchery sockeye collected during the life of the sockeye hatchery program are presented in Table 4.4.

Table 4.4. Numbers of male and female wild and hatchery sockeye collected for broodstock, 1989-2011. Ratios of males to females are also provided.

Return year	Number of wild sockeye			Number of hatchery sockeye			Total M/F ratio
	Males (M)	Females (F)	M/F	Males (M)	Females (F)	M/F	
1989	162	137	1.18:1.00	0	0	-	1.18:1.00
1990	177	156	1.13:1.00	0	0	-	1.13:1.00
1991	260	97	2.68:1.00	0	0	-	2.68:1.00
1992	180	182	0.99:1.00	0	0	-	0.99:1.00
1993	130	177	0.73:1.00	0	0	-	0.73:1.00
1994	162	167	0.97:1.00	1	4	0.25:1.00	0.95:1.00
1995	102	116	0.88:1.00	1	2	0.50:1.00	0.87:1.00
1996	150	161	0.93:1.00	0	0	-	0.93:1.00
1997	139	144	0.97:1.00	10	9	1.11:1.00	0.97:1.00
1998	115	110	1.05:1.00	2	4	0.50:1.00	1.03:1.00
1999	22	68	0.32:1.00	37	23	1.61:1.00	0.65:1.00
2000	155	101	1.53:1.00	3	2	1.50:1.00	1.53:1.00
2001	114	138	0.83:1.00	4	4	1.00:1.00	0.83:1.00
2002	128	129	0.99:1.00	0	0	-	0.99:1.00
2003	161	100	1.61:1.00	0	0	-	1.61:1.00
2004	108	103	1.05:1.00	0	0	-	1.05:1.00
2005	130	113	1.15:1.00	0	0	-	1.15:1.00
2006	130	130	1.00:1.00	0	0	-	1.00:1.00

Return year	Number of wild sockeye			Number of hatchery sockeye			Total M/F ratio
	Males (M)	Females (F)	M/F	Males (M)	Females (F)	M/F	
2007	127	121	1.05:1.00	0	0	-	1.05:1.00
2008	127	131	0.97:1.00	1	1	1.00:1.00	0.97:1.00
2009	133	125	1.06:1.00	0	3	0.00:1.00	1.04:1.00
2010	127	129	0.98:1.00	0	0	-	0.98:1.00
2011	106	98	1.08:1.00	0	0	-	1.08:1.00
Total	***2,074***	***2,017***	***1.03:1.00***	***58***	***48***	***1.21***	***1.03:1.00***

Fecundity

Fecundities of sockeye collected during the life of the hatchery program are presented in Table 4.5.

Table 4.5. Mean fecundity of female sockeye salmon collected for broodstock, 1989-2011. Fecundities were determined from pooled egg lots and were not identified for individual females.

Return year	Mean fecundity
1989	2,344
1990	2,225
1991	2,598
1992	2,341
1993	2,340
1994	2,798
1995	2,295
1996	2,664
1997	2,447
1998	2,813
1999	2,319
2000	2,673
2001	2,960
2002	2,856
2003	3,511
2004	2,505
2005	2,718
2006	2,656
2007	3,115
2008	2,555
2009	2,459
2010	2,782
2011	2,960
Average	***2,649***
Median	***2,656***

4.2 Hatchery Rearing

Rearing History

Number of eggs taken

Numbers of eggs taken from sockeye broodstock during the life of the sockeye hatchery program are shown in Table 4.6.

Table 4.6. Numbers of eggs taken from sockeye broodstock, 1989-2011.

Return year	Number of eggs taken
1989	133,600
1990	326,267
1991	231,254
1992	381,561
1993	231,700
1994	338,562
1995	247,900
1996	314,390
1997	254,459
1998	163,278
1999	190,732
2000	227,234
2001	301,925
2002	356,982
2003	319,470
2004	225,499
2005	211,985
2006	292,136
2007	302,363
2008	316,476
2009	304,963
2010	278,171
2011	290,046
Average	***271,389***
Median	***290,046***

Number of acclimation days

During the life of the program, Wenatchee sockeye were only acclimated on Lake Wenatchee water in net pens. Acclimation days are presented in Table 4.7.

Table 4.7. Water source and mean acclimation period for Wenatchee sockeye, brood years 1989-2011.

Brood year	Release year	Transfer date	Release date	Number of Days	Water source
1989	1990	5-Apr	24-Oct	202	Lake Wenatchee
1990	1991	10-Apr	19-Oct	192	Lake Wenatchee
1991	1992	1-Apr	20-Oct	202	Lake Wenatchee
1992	1993	5-Apr	7-Sep	155	Lake Wenatchee
		5-Apr	26-Oct	204	Lake Wenatchee
1993	1994	5-Apr	1-Sep	149	Lake Wenatchee
		5-Apr	17-Oct	195	Lake Wenatchee
1994	1995	4-Apr	15-Sep	164	Lake Wenatchee
		4-Apr	23-Oct	202	Lake Wenatchee
1995	1996	4-Apr	25-Oct	204	Lake Wenatchee
1996	1997	4-Apr	22-Oct	201	Lake Wenatchee
1997	1998	1-Apr	9-Nov	222	Lake Wenatchee
1998	1999	1-Apr	29-Oct	211	Lake Wenatchee
1999	2000	25-Jul	28-Aug	34	Lake Wenatchee
		26-Jul	1-Nov	98	Lake Wenatchee
2000	2001	2-Jul	27-Aug	56	Lake Wenatchee
		3-Jul	27-Sep	86	Lake Wenatchee
2001	2002	15-Jul	28-Aug	44	Lake Wenatchee
		16-Jul	22-Sep	68	Lake Wenatchee
2002	2003	30-Jun	25-Aug	56	Lake Wenatchee
		1-Jul	22-Oct	113	Lake Wenatchee
2003	2004	6-Jul	25-Aug	50	Lake Wenatchee
		7-Jul	3-Nov	119	Lake Wenatchee
2004	2005	5-Jul	29-Aug	55	Lake Wenatchee
		6-Jul	2-Nov	120	Lake Wenatchee
2005	2006	11-Jul	30-Oct	111	Lake Wenatchee
2006	2007	9-10 Jul	31-Oct	113-114	Lake Wenatchee
2007	2008	7-8 Jul	29-Oct	113-114	Lake Wenatchee
2008	2009	21-Jul	28-Oct	100	Lake Wenatchee
2009	2010	19-20, 23-Jul	27-Oct	97-101	Lake Wenatchee
2010	2011	6, 11-12-Jul	26-Oct	107-113	Lake Wenatchee
2011	2012	9-10-Jul	29-Oct	112-113	Lake Wenatchee

Release Information

Numbers released

Numbers of juvenile sockeye released into Lake Wenatchee during the life of the program are shown in Table 4.8. Coded wire tag marking rates and numbers of PIT-tagged juvenile sockeye released are also shown in Table 4.8.

Table 4.8. Total number of sockeye parr released and numbers of released fish with CWTs and PIT tags for brood years 1989-2011. The release target for sockeye was 200,000 fish.

Brood year	Release year	CWT mark rate	Number of released fish with PIT tags	Number released
1989	1990	Not marked	0	108,400
1990	1991	0.9308	0	270,802
1991	1992	0.8940	0	167,523
1992	1993	0.9240	0	340,597
1993	1994	0.7278	0	190,443
1994	1995	0.8869	0	252,859
1995[a]	1996	1.0000	0	150,808
1996[a]	1997	0.9680	0	284,630
1997[a]	1998	0.9642	0	197,195
1998[a]	1999	0.8713	0	121,344
1999	2000	0.9527	0	167,955
2000	2001	0.9558	0	190,174
2001	2002	0.9911	0	200,938
2002	2003	0.9306	0	315,783
2003	2004	0.9291	0	240,459
2004	2005	0.8995	0	172,923
2005	2006	0.9811	14,859	140,542
2006	2007	0.9735	14,764	225,670
2007	2008	0.9863	14,947	252,133
2008	2009	0.9576	14,858	154,772
2009	2010	0.9847	14,486	227,743
2010	2011	0.9564	5,039	241,918
2011	2012	0.9690	5,074	256,120
Average		***0.9379***	***11,994[b]***	***208,271***
Median		***0.9561***	***14,764[b]***	***197,195***

[a] These groups were only adipose fin clipped.
[b] Average and median are based on brood years 2004 to 2010.

Fish size and condition at release

The size and condition of the juvenile sockeye released into Lake Wenatchee during the life of the program are presented in Table 4.9.

Table 4.9. Mean lengths (FL, mm), weight (g and fish/pound), and coefficient of variation (CV) of sockeye released, brood years 1989-2011. Size targets are provided in the last row of the table.

Brood year	Release year	Fork length (mm)		Mean weight	
		Mean	CV	Grams (g)	Fish/pound
1989	1990	128	-	18.2	25
1990	1991	131	-	18.9	24
1991	1992	117	3.0	20.6	22
1992	1993	73	6.8	4.2	44
1993	1994	103	-	13.6	40
1994	1995	75	6.1	4.5	38
1995	1996	137	8.2	14.7	30
1996	1997	107	5.6	15.1	30
1997	1998	122	6.1	21.3	21
1998	1999	112	5.4	17.0	27
1999	2000	94	9.5	9.5	48
		134	11.5	31.3	15
2000	2001	123	6.5	22.3	20
		146	8.4	26.0	12
2001	2002	118	7.4	20.7	22
		135	7.3	30.5	15
2002	2003	73	5.6	4.4	104
		118	7.7	13.7	23
		145	9.4	38.6	13
2003	2004	79	4.6	4.8	96
		118	5.9	17.0	26
		158	8.1	44.3	10
2004	2005	116	4.5	17.2	18
		151	7.0	39.3	12
2005	2006	149	7.5	43.7	10
2006	2007	138	10.6	32.4	14
2007	2008	137	9.3	33.0	14
2008	2009	138	9.6	34.6	13

Brood year	Release year	Fork length (mm)		Mean weight	
		Mean	CV	Grams (g)	Fish/pound
2009	2010	143	8.9	35.5	13
2010	2011	132	14.3	30.7	15
2011	2012	142	9.6	35.3	13
Targets		***133***	***9.0***	***22.7***	***20***

Survival Estimates

Life-stage survival estimates for juvenile sockeye during the life of the hatchery program are shown in Table 4.10.

Table 4.10. Hatchery life-stage survival rates (%) for sockeye salmon, brood years 1989-2011. Survival standards or targets are provided in the last row of the table.

Brood year	Collection to spawning		Unfertilized egg-eyed	Eyed egg-ponding	30 d after ponding	100 d after ponding	Ponding to release	Transport to release	Unfertilized egg-release
	Female	Male							
1989	41.6	100.0	88.1	63.9	99.2	98.9	98.1	65.2	83.0
1990	96.2	99.4	90.8	96.3	99.9	99.2	98.4	98.4	81.1
1991	91.8	94.1	79.2	94.8	99.8	99.3	96.4	96.4	72.4
1992	91.1	98.8	92.3	98.0	99.9	99.8	98.6	98.8	89.2
1993	57.1	99.2	89.2	98.3	99.6	99.1	93.7	93.8	82.2
1994	89.8	99.2	79.2	96.0	99.5	98.6	98.3	98.2	74.7
1995	97.5	99.1	87.5	95.0	99.0	93.3	73.2	73.2	60.8
1996	99.2	100.0	95.1	98.7	99.7	99.3	96.4	96.5	90.5
1997	92.8	99.3	84.8	97.9	97.9	97.6	95.5	94.9	77.5
1998	75.4	95.5	77.7	98.4	98.6	98.2	97.1	97.2	74.3
1999	92.3	100.0	92.2	97.3	99.6	99.3	98.2	99.7	88.1
2000	84.5	98.1	93.8	97.7	96.7	96.1	91.4	96.8	83.7
2001	75.4	99.2	78.5	97.6	98.0	97.6	86.9	95.1	66.6
2002	100.0	100.0	95.7	97.8	99.6	99.2	94.6	99.8	88.5
2003	91.0	98.1	87.2	96.9	99.0	98.2	94.8	95.5	74.6
2004	88.7	92.6	88.0	93.1	97.9	97.4	93.7	96.1	76.7
2005	98.5	98.5	85.3	94.9	97.8	96.6	95.5	99.2	66.3
2006	95.3	99.1	73.2	85.4	95.4	94.6	87.8	98.5	54.9
2007	88.4	99.2	89.1	98.6	97.0	95.9	94.9	99.0	83.4
2008	97.0	100.0	59.0	88.3	99.1	97.2	93.8	97.4	48.9
2009	95.8	98.3	89.1	94.8	96.9	96.2	88.4	92.3	74.7
2010	99.0	98.0	92.6	98.2	97.5	96.5	95.6	99.6	87.0
2011	100.0	100.0	92.6	100.0	96.8	96.0	95.4	99.7	88.3
Average	***88.6***	***98.5***	***86.1***	***94.7***	***98.5***	***97.6***	***93.8***	***94.8***	***76.8***

Brood year	Collection to spawning		Unfertilized egg-eyed	Eyed egg-ponding	30 d after ponding	100 d after ponding	Ponding to release	Transport to release	Unfertilized egg-release
	Female	Male							
Median	*92.3*	*99.2*	*88.1*	*97.3*	*99.0*	*97.6*	*95.4*	*97.2*	*77.5*
Standard	*90.0*	*85.0*	*92.0*	*98.0*	*97.0*	*93.0*	*90.0*	*95.0*	*81.0*

4.3 Disease Monitoring

Because the sockeye hatchery program was terminated in 2012, there are no disease-monitoring results.

4.4 Natural Juvenile Productivity

Sockeye smolt abundance was estimated at a rotary screw trap located near the mouth of Lake Wenatchee during the period 1997 to 2011. Because the efficiency of the trap was difficult to assess, the operation was terminated in 2011. In 2012, the trap was relocated downstream near the mouth of the Chiwawa River and operated there for two years. Again, because few marked sockeye smolts were recaptured, the operation was terminated in 2013. Beginning in 2013, smolt abundance has been estimated at the Lower Wenatchee Trap.

Emigrant and Smolt Estimates

The Lower Wenatchee Trap operated between 29 January and 26 July 2016. During that time, the trap was inoperable for 23 days because of high and low river discharge, debris, elevated river temperature, large hatchery releases, and mechanical issues. During the sampling period, a total of 1,346 wild juvenile sockeye were captured at the Lower Wenatchee Trap. A significant relationship between trap efficiency and river discharge was created ($R^2 = 0.52$, $P < 0.043$). Using this model, the number of juvenile sockeye emigrants was estimated at 208,250 (±29,447; 95% CI) during the 2016 trapping season (Table 4.11). Because of high flows coupled with mechanical issues, the trap was not fully operational during peak sockeye emigration. For this reason, the population estimate is considered a minimum. Figure 4.1 shows the monthly captures of sockeye collected at the Lower Wenatchee Trap in 2016. All fish captured in the Lower Wenatchee trap are reported in Appendix B.

Table 4.11. Estimated numbers of wild and hatchery sockeye smolts that emigrated from Lake Wenatchee during run years 1997-2016; NS = no data. Estimates for the run years 1997-2011 were based on sampling at the Upper Wenatchee smolt trap; estimates beginning in 2013 were based on sampling at the Lower Wenatchee smolt trap.

Run year	Numbers of sockeye smolts	
	Wild smolts	Hatchery smolts
1997	55,359	28,828
1998	1,447,259	55,985
1999	1,944,966	112,524
2000	985,490	24,684
2001	39,353	94,046
2002	729,716	121,511

Run year	Numbers of sockeye smolts	
	Wild smolts	Hatchery smolts
2003	5,439,032	140,322
2004	5,771,187	216,023
2005	723,413	122,399
2006	1,266,971	159,500
2007	2,797,313	140,542
2008[a]	549,682	121,843
2009[a]	355,549	119,908
2010[a]	3,958,888	126,326
2011	1,500,730	159,089
2012	ND	ND
2013	873,096 (±95,132)	No program
2014	1,275,027 (±211,615)	No program
2015	1,065,614 (±238,901)	No program
2016	208,250 (±29,447)	No program
Average	***1,630,889***	***116,235[b]***
Median	***1,065,614***	***121.511[b]***

[a] Estimates refined based on PIT tag survival to McNary Dam.
[b] Summary statistics were calculated for years in which hatchery fish were being released (1997-2011).

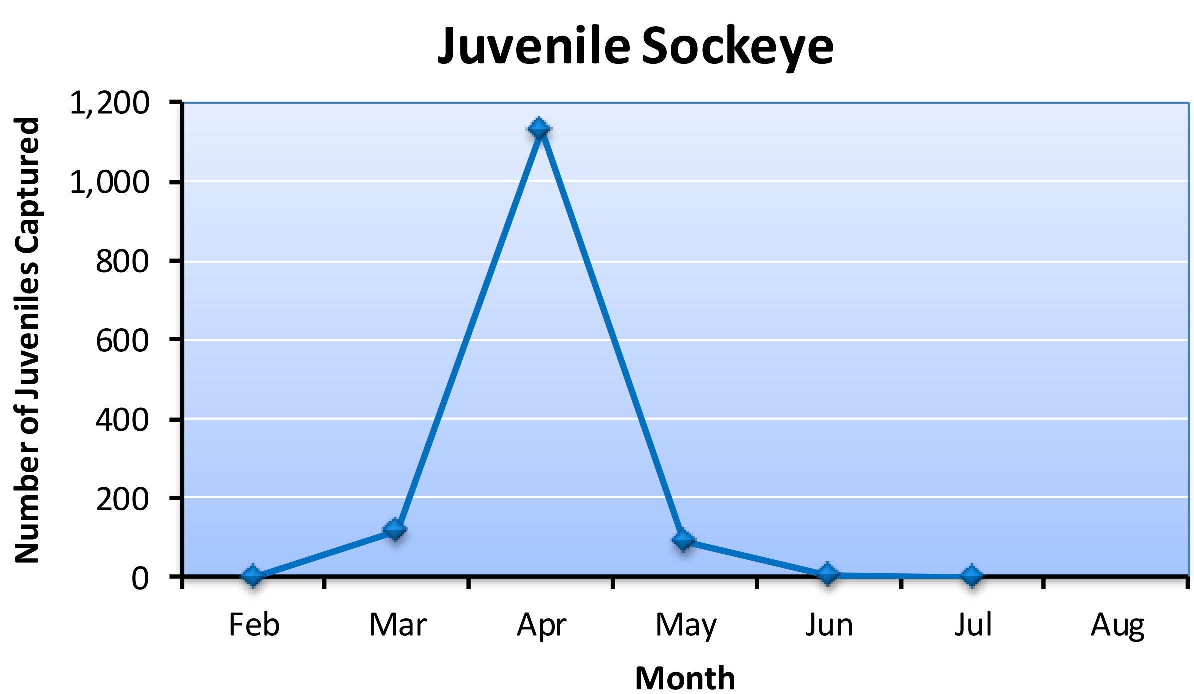

Figure 4.1. Monthly captures of wild sockeye salmon smolts at the Lower Wenatchee Trap, 2016.

Age classes of wild sockeye smolts were determined from a length frequency analysis based on scales collected randomly each year since 1997 (Table 4.12). Each year, a small number of markedly smaller sockeye (<50 mm FL) are collected, and starting with run year 2013, an age-0 class was retroactively assigned based on catch records. For the available run years, most wild sockeye smolts migrated as age 1+ fish. Only in two years (1997 and 2005) did more smolts migrate as age 2+ fish. Relatively few smolts migrated at age 3+.

Table 4.12. Age structure and estimated number of wild sockeye smolts that emigrated from Lake Wenatchee, 1997-2016; ND = no data. Estimates for the run years 1997-2011 were based on sampling at the Upper Wenatchee smolt trap; estimates beginning in 2013 were based on sampling at the Lower Wenatchee smolt trap.

Run year	Proportion of wild smolts				Total wild emigrants
	Age 0	Age 1+	Age 2+	Age 3+	
1997	ND	0.075	0.906	0.019	55,359
1998	ND	0.955	0.037	0.008	1,447,259
1999	ND	0.619	0.381	0.000	1,944,966
2000	ND	0.599	0.400	0.001	985,490
2001	ND	0.943	0.051	0.006	39,353
2002	ND	0.961	0.039	0.000	729,716
2003	ND	0.740	0.026	0.000	5,439,032
2004	ND	0.929	0.071	0.000	5,771,187
2005	ND	0.230	0.748	0.022	723,413
2006	ND	0.994	0.006	0.000	1,266,971
2007	ND	0.996	0.004	0.000	2,797,313
2008	ND	0.804	0.195	0.001	549,682
2009	ND	0.927	0.073	0.000	355,549
2010	ND	0.963	0.036	0.001	3,958,888
2011	ND	0.786	0.214	0.000	1,500,730
2012	ND	ND	ND	ND	ND
2013	0.008	0.919	0.073	0.000	873,096
2014	0.003	0.948	0.049	0.000	1,275,027
2015	0.003	0.777	0.220	0.000	1,065,614
2016	TBD	TBD	TBD	TBD	208,250
Average	***0.467***	***0.787***	***0.196***	***0.003***	***1,630,889***
Median	***0.003***	***0.919***	***0.071***	***0.000***	***1,065,614***

Freshwater Productivity

Egg-smolt survival estimates for wild sockeye salmon are provided in Table 4.13. Estimates of egg deposition were calculated based on the spawner escapement at Tumwater Dam and the sex ratio and fecundity of the broodstock. For the 2012 brood year (a year where brood was not collected), a linear relationship with post-orbital to hypural length as the independent variable was used to calculate average fecundity of sockeye sampled at Tumwater Dam ($r^2 = 0.40$, $P < 0.01$). Smolts for brood years 1995-2009 were based on captures at the Upper Wenatchee Trap. No smolt estimates are available for brood year 2010. Smolt estimates for brood years since 2012 are derived from captures made at the Lower Wenatchee Trap. Egg-smolt survival rates for brood years 1995-2014 have ranged from 0.012 to 0.212 (mean = 0.084).

Table 4.13. Estimated egg deposition (estimated as mean fecundity times estimated number of females), numbers of smolts, and survival rates for wild Wenatchee sockeye salmon, brood years 1995-2014; NA = not available.

Brood year	Number of females	Mean fecundity	Total eggs	Numbers of wild smolts					Egg-smolt survival
				Age 0	Age 1+	Age 2+	Age 3+	Total	
1995	2,136	2,295	4,902,120	NA	4,174	53,549	0	57,723	0.012
1996	3,767	2,664	10,035,288	NA	1,382,133	741,032	985	2,124,150	0.212
1997	5,404	2,447	13,223,588	NA	1,203,934	394,196	236	1,598,366	0.121
1998	2,024	2,813	5,693,512	NA	590,309	2,007	0	592,316	0.104
1999	513	2,319	1,189,647	NA	37,110	28,459	0	65,569	0.055
2000	11,413	2,673	30,506,949	NA	701,257	1,414,148	0	2,115,405	0.069
2001	21,685	2,960	64,187,600	NA	4,024,884	409,754	15,915	4,450,553	0.069
2002	17,226	2,856	49,197,456	NA	5,361,433	541,113	0	5,902,546	0.120
2003	2,158	3,511	7,576,738	NA	166,385	7,602	0	173,987	0.023
2004	15,469	2,505	38,749,845	NA	1,259,369	11,189	275	1,270,833	0.033
2005	5,867	2,718	15,946,506	NA	2,786,123	107,243	0	2,893,366	0.181
2006	2,747	2,656	7,296,032	NA	442,164	25,919	1,507	469,590	0.064
2007	2,001	3,115	6,232,804	NA	329,629	142,916	594	473,139	0.076
2008	11,775	2,555	30,084,691	NA	3,814,226	320,567	NA	4,134,794	0.137
2009	3,939	2,459	9,684,965	NA	1,179,569	NA	0	NA	NA
2010	11,918	2,785	33,190,467	NA	NA[a]	58,497	0	NA	NA
2011	9,722	2,970	28,873,491	NA	816,836[b]	96,902	0	913,738	0.032
2012	14,753	2,745	40,496,573	10,200	1,208,726	234,435	0	1,443,161	0.036
2013	9,477	2,732	25,891,164	3,197	827,982	--	--	--	--
2014	31,203	2,725	85,028,175	625	--	--	--	--	--
Average	***8,105***	***2,725***	***22,261,023***	***4,467***	***1,506,918***	***269,987***	***1,148***	***1,792,280***	***0.084***
Median	***5,867***	***2,718***	***15,946,506***	***3,197***	***1,179,569***	***107,243***	***0***	***1.270,833***	***0.069***

[a] There is no emigrant estimate for trapping during 2012.
[b] Emigrant estimates are derived from captures at the Lower Wenatchee Trap.

Juvenile survival rates for hatchery sockeye salmon are provided in Table 4.14. Release-smolt survival rates for brood years 1995-2009 have ranged from 0.000 to 1.000 (mean = 0.570). Egg-smolt survival rates for the same brood years ranged from 0.000 to 0.710 (mean = 0.294). On average, egg-smolt survival of hatchery sockeye is about three times greater than egg-smolt survival of wild sockeye.

Table 4.14. Juvenile survival rates for hatchery Wenatchee sockeye, brood years 1995-2009.

Brood year	Number of eggs	Number of parr released	Date of release	Estimated number of smolts	Egg-smolt survival	Release-smolt survival
1995	247,900	150,808	10/25/96	28,828	0.116	0.191
1996	314,390	284,630	10/22/97	55,985	0.178	0.197
1997	254,459	197,195	11/9/98	112,524	0.442	0.571
1998	163,278	121,344	10/27/99	24,684	0.151	0.203
1999	190,732	84,466	8/28/00	30,326	0.159	0.359
		83,489	11/1/00	63,720	0.334	0.763
2000	227,234	92,055	8/27/01	30,918	0.136	0.336
		98,119	9/27/01	90,593	0.399	0.923
2001	301,925	96,486	8/28/02	36,484	0.121	0.378
		104,452	9/23/02	103,838	0.344	0.994
2002	356,982	98,509	6/16/03	5,192	0.015	0.053
		104,855	8/25/03	98,412	0.276	0.939
		112,419	10/22/03	112,419	0.315	1.000
2003	319,470	32,755	6/15/04	0	0.000	0.000
		104,879	8/25/04	19,574	0.061	0.187
		102,825	11/3/04	102,825	0.322	1.000
2004	225,499	81,428	8/29/05	159,500	0.707	0.922
		91,495	11/2/05			
2005	211,985	70,386	10/30/06	140,542	0.663	1.000
		70,156	10/30/06			
2006	292,136	225,670	10/31/07	121,843	0.412	0.540
2007	302,363	252,133	10/29/08	119,908	0.397	0.476
2008	316,476	154,772	10/28/09	126,326	0.399	0.813
2009	304,963	227,743	10/27/10	159,089	0.522	0.699

[a] There is no emigrant estimate for the 2010 or 2011 brood years.

PIT Tagging Activities

A total of 1,065 wild juvenile sockeye salmon were PIT tagged and released in 2016 at the Lower Wenatchee Trap. Numbers of wild sockeye salmon PIT-tagged and released as part of the Comparative Survival Study and PUD studies during the period 2006-2016 are shown in Table 4.15. See Appendix C for a complete list of all fish captured, tagged, lost, and released.

Table 4.15. Summary of the numbers of wild sockeye salmon that were tagged and released at the Upper and Lower Wenatchee Traps within the Wenatchee River basin, 2006-2016.

Sampling Location	Numbers of PIT-tagged sockeye salmon released								
	2008	2009	2010	2011	2012	2013	2014	2015	2016
Upper Wenatchee Trap	3,165	3,683	10,006	--	--	--	--	--	--
Lower Wenatchee Trap	0	0	0	0	0	0	4,821	3,922	1,065

4.5 Spawning Escapement

The sockeye salmon hatchery program ended after the 2011 brood year. As a result, monitoring activities that focused on evaluating the effects of the supplementation program on the natural population switched to monitoring the abundance and productivity of the natural population. Broadly, the proposed monitoring and evaluation activities cover juvenile and adult life-history stages and provide the data necessary to track or estimate viable salmonid population parameters (VSP); abundance, productivity, spatial structure, and diversity (McElhaney et al. 2000).

From 2009-2013, mark-recapture methods were used to estimate spawning escapement within the White River, while area-under-the-curve (AUC) methods were used to estimate spawning escapement within the Little Wenatchee River. Beginning in 2014, mark-recapture methods were used to estimate the spawning escapement of sockeye in the White River and Little Wenatchee watersheds (see Appendix H for more details).

Mark-Recapture Estimates

Spawning escapement of sockeye salmon in 2016 was estimated using mark-recapture methods. This method relied on PIT tags to estimate sockeye spawning escapement (see Appendix H for more details).

Using mark-recapture methods, the estimated total escapement of sockeye in the Upper Wenatchee River basin in 2016 was 45,068 (Table 4.16). About 85% of the escapement entered the White River watershed (including the Napeequa River).

Table 4.16. Estimated escapement of adult sockeye into the Little Wenatchee and White River watersheds for return years 2009-2016. Escapement was based on recapture of PIT-tagged fish.

Return year	Tumwater Dam count	Recreational harvest	Little Wenatchee escapement	White River escapement	Total spawning escapement
2009	16,034	2,285	576	13,876	14,452
2010	35,821	4,129	2,062	19,542	21,604
2011[a]	18,634	0	2,431	14,582	17,013
2012	66,520	12,107	4,607	23,866	28,473
2013[a]	29,015	6,262	2,426	14,294	16,720
2014	99,898	16,281	4,319	49,021	53,340
2015	51,435	7,916	4,115	20,097	24,212
2016	73,697	14,630	6,747	38,321	45,068
Average	***48,882***	***7,951***	***3,234***	***24,200***	***27,434***
Median	***43,628***	***7,089***	***2,569***	***19,820***	***22,204***

[a] Spawning escapements in 2011 and 2013 were calculated using AUC counts and a regression model.

The spawning escapement of 45,068 Wenatchee sockeye was greater than the overall average of 27,434 (Table 4.17).

Table 4.17. Spawning escapements for sockeye salmon in the Wenatchee River basin for return years 1989-2016; NA = not available and AUC = area under the curve.

Return year	Escapement estimation method	Spawning escapement		
		Little Wenatchee	White	Total
1989	Counts at Tumwater Dam	NA	NA	**21,802**
1990	Counts at Tumwater Dam	NA	NA	**27,325**
1991	Counts at Tumwater Dam	NA	NA	**26,689**
1992	Counts at Tumwater Dam	NA	NA	**16,461**
1993	Counts at Tumwater Dam	NA	NA	**27,726**
1994	Counts at Tumwater Dam	NA	NA	**7,330**
1995	Counts at Tumwater Dam	NA	NA	**3,448**
1996	Counts at Tumwater Dam	NA	NA	**6,573**
1997	Counts at Tumwater Dam	NA	NA	**9,693**
1998	Counts at Tumwater Dam	NA	NA	**4,014**
1999	Counts at Tumwater Dam	NA	NA	**1,025**
2000	Counts at Tumwater Dam	NA	NA	**20,735**
2001	Counts at Tumwater Dam	NA	NA	**29,103**
2002	Counts at Tumwater Dam	NA	NA	**27,565**
2003	Counts at Tumwater Dam	NA	NA	**4,855**
2004	Counts at Tumwater Dam	NA	NA	**27,556**
2005	Counts at Tumwater Dam	NA	NA	**14,011**
2006	AUC	574	5,634	**6,208**
2007	AUC	150	1,720	**1,870**
2008	AUC	3,491	16,757	**20,248**
2009	AUC and Mark-Recap	763	7,004	**7,767**
2010	AUC and Mark-Recap	2,543	19,157	**21,700**
2011	AUC and Mark-Recap	2,431	14,582	**17,013**
2012	AUC and Mark-Recap	4,607	23,866	**28,473**
2013	AUC and Mark-Recap	2,426	14,294	**16,720**
2014	Mark-Recapture	4,391	49,021	**53,340**
2015	Mark-Recapture	4,115	20,097	**24,212**
2016	Mark-Recapture	6,747	38,321	**45,068**
Average		***2,803***	***19,132***	***18,469***
Median		***2,543***	***16,757***	***18,631***

4.6 Carcass Surveys

As described earlier, carcass surveys were not conducted in 2016. The information contained in this section represents carcass data collected before 2014.

Number sampled

Table 4.18 shows the number of carcasses sampled within different survey streams during the period 1993-2013.

Table 4.18. Numbers of sockeye carcasses sampled within different streams/watersheds within the Wenatchee River basin, 1989-2013.

Survey year	Numbers of sockeye carcasses			
	Little Wenatchee	White	Napeequa	Total
1993	90	195	0	**285**
1994	121	165	0	**286**
1995	0	56	0	**56**
1996	43	1,387	3	**1,433**
1997	69	1,425	41	**1,535**
1998	61	524	4	**589**
1999	40	186	0	**226**
2000	821	5,494	0	**6,315**
2001	650	3,127	0	**3,777**
2002	506	7,258	55	**7,819**
2003	86	1,002	14	**1,102**
2004	625	6,960	138	**7,723**
2005	1	7	0	**8**
2006	101	2,158	38	**2,297**
2007	17	363	3	**383**
2008	476	5,132	125	**5,733**
2009	84	3,103	103	**3,290**
2010	217	7,832	70	**8,119**
2011	372	3,322	48	**3,742**
2012	1,309	7,479	31	**8,819**
2013	179	2,996	27	**3,202**
Average	***279***	***2,865***	***33***	***3,178***
Median	***101***	***2,158***	***14***	***2,297***

Carcass Distribution and Origin

Based on the available data (1993-2013), the largest percentage of both wild and hatchery sockeye spawned in Reach 2 on the White River (Table 4.19 and Figure 4.2). However, a greater percentage of wild fish was found in Reach 2 than hatchery fish.

Table 4.19. Numbers of wild and hatchery sockeye carcasses sampled within different reaches in the Wenatchee River basin, 1993-2013. Reach codes are described in Table 2.9.

Survey year	Origin	Numbers of sockeye carcasses					
		Little Wenatchee		White River			Total
		L2	L3	H1	H2	Q1	
1993	Wild	86	0	0	183	0	**269**
	Hatchery	4	0	0	12	0	**16**
1994	Wild	112	0	0	155	0	**267**
	Hatchery	9	0	0	9	0	**18**
1995	Wild	0	0	0	55	0	**55**
	Hatchery	0	0	0	1	0	**1**
1996	Wild	41	0	0	1,299	3	**1,343**
	Hatchery	2	0	0	88	0	**90**
1997	Wild	65	0	0	1,411	40	**1,516**
	Hatchery	4	0	0	11	1	**16**
1998	Wild	61	0	0	515	4	**580**
	Hatchery	0	0	0	9	0	**9**
1999	Wild	30	0	0	164	0	**194**
	Hatchery	10	0	0	22	0	**32**
2000	Wild	694	0	3	5,239	0	**5,936**
	Hatchery	127	0	0	252	0	**379**
2001	Wild	625	0	0	3,063	0	**3,688**
	Hatchery	25	0	0	64	0	**89**
2002	Wild	504	0	0	7,207	55	**7,766**
	Hatchery	2	0	0	51	0	**53**
2003	Wild	81	0	0	993	14	**1,088**
	Hatchery	5	0	0	9	0	**14**
2004	Wild	606	0	0	6,755	166	**7,527**
	Hatchery	19	0	0	205	22	**246**
2005	Wild	201	0	5	2,966	21	**3,193**
	Hatchery	1	0	0	8	0	**9**
2006	Wild	80	0	0	2,112	36	**2,228**
	Hatchery	21	0	0	46	2	**69**
2007	Wild	17	0	0	346	3	**366**
	Hatchery	0	0	0	17	0	**17**
2008	Wild	472	0	0	5,118	124	**5,714**
	Hatchery	4	0	0	14	1	**19**
2009	Wild	80	0	0	3,084	103	**3,267**
	Hatchery	4	0	0	19	0	**23**
2010	Wild	210	0	0	7,711	69	**7,990**
	Hatchery	7	0	0	121	1	**129**
2011	Wild	266	0	0	3,079	43	**3,388**
	Hatchery	106	0	0	243	5	**354**

Survey year	Origin	Numbers of sockeye carcasses					
		Little Wenatchee		White River			Total
		L2	L3	H1	H2	Q1	
2012	Wild	1,270	0	21	7,368	30	**8,689**
	Hatchery	39	0	3	87	1	**130**
2013	Wild	174	0	1	2,936	26	**3,137**
	Hatchery	3	0	0	56	1	**60**
Average	***Wild***	***270***	***0***	***1***	***2,941***	***35***	***3,248***
	Hatchery	***18***	***0***	***0***	***61***	***2***	***81***
Median	***Wild***	***112***	***0***	***0***	***2,936***	***21***	***3,137***
	Hatchery	***4***	***0***	***0***	***22***	***0***	***32***

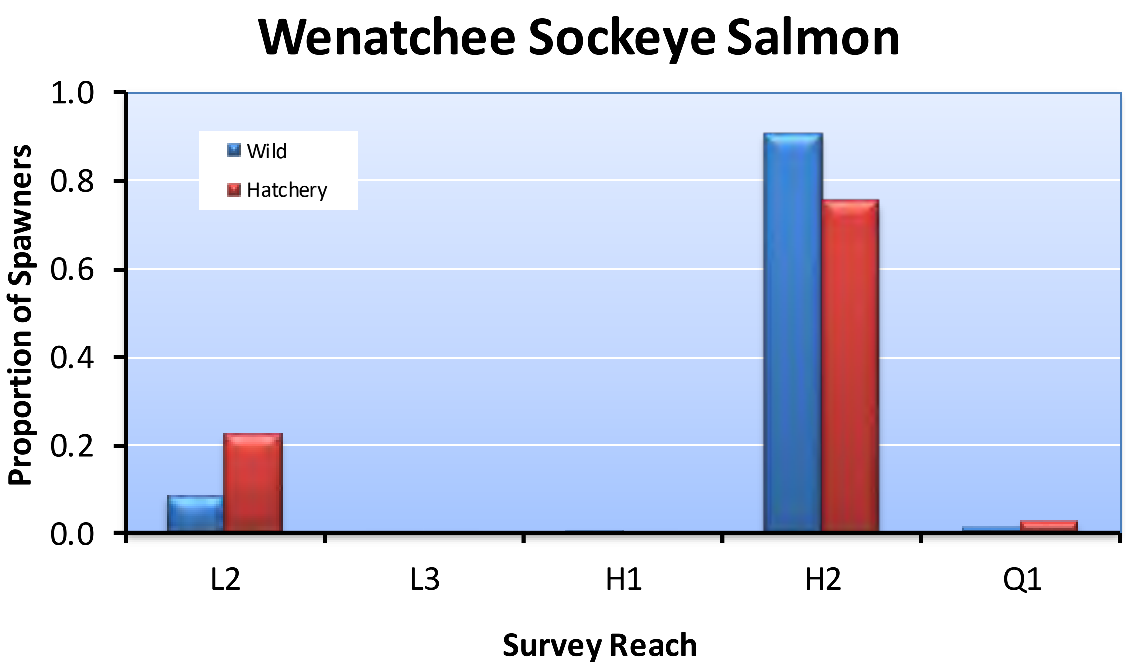

Figure 4.2. Distribution of wild and hatchery produced carcasses in different reaches in the Wenatchee River basin, pooled data from 1993-2013. Reach codes are described in Table 2.9; L = Little Wenatchee, H = White River, and Q = Napeequa River.

4.7 Life History Monitoring

Life history characteristics of Wenatchee sockeye were assessed by examining carcasses on spawning grounds and fish sampled at broodstock collection sites or during stock assessment, and by reviewing tagging data and fisheries statistics.

Migration Timing

There was little difference in migration timing of hatchery and wild sockeye past Tumwater Dam (Table 4.20a and b; Figure 4.3). On average, early in the run, hatchery and wild sockeye arrived at the dam at about the same time. Toward the end of the migration period, hatchery sockeye tended to arrive at the dam slightly later than did wild sockeye. Most hatchery and wild sockeye migrated upstream past Tumwater Dam during July through early August. The peak migration time for both hatchery and wild sockeye was the last two weeks of July (Figure 4.3).

Table 4.20a. The Julian day and date that 10%, 50% (median), and 90% of the wild and hatchery sockeye salmon passed Tumwater Dam, 1998-2016. The average Julian day and date are also provided. Migration timing is based on video sampling at Tumwater. Data for 1998 through 2003 were based on videotapes and broodstock trapping and may not reflect the actual number of hatchery sockeye salmon. All sockeye were visually examined during trapping from 2004 to present.

Survey year	Origin	Sockeye Migration Time (days)								Sample size
		10 Percentile		50 Percentile		90 Percentile		Mean		
		Julian	Date	Julian	Date	Julian	Date	Julian	Date	
1998	Wild	195	14-Jul	201	20-Jul	208	27-Jul	202	21-Jul	4,173
	Hatchery	196	15-Jul	204	23-Jul	220	8-Aug	206	25-Jul	31
1999	Wild	226	14-Aug	233	21-Aug	241	29-Aug	234	22-Aug	908
	Hatchery	228	16-Aug	234	22-Aug	242	30-Aug	235	23-Aug	264
2000	Wild	200	18-Jul	206	24-Jul	213	31-Jul	207	25-Jul	18,390
	Hatchery	199	17-Jul	206	24-Jul	213	31-Jul	206	24-Jul	2,589
2001	Wild	189	8-Jul	194	13-Jul	214	2-Aug	198	17-Jul	32,554
	Hatchery	199	18-Jul	212	31-Jul	240	28-Aug	214	2-Aug	79
2002	Wild	204	23-Jul	208	27-Jul	219	7-Aug	210	29-Jul	27,241
	Hatchery	204	23-Jul	209	28-Jul	222	10-Aug	211	30-Jul	580
2003	Wild	194	13-Jul	200	19-Jul	208	27-Jul	201	20-Jul	4,699
	Hatchery	194	13-Jul	201	20-Jul	211	30-Jul	203	22-Jul	375
2004	Wild	191	9-Jul	196	14-Jul	207	25-Jul	198	16-Jul	31,408
	Hatchery	189	7-Jul	194	12-Jul	203	21-Jul	196	14-Jul	1,758
2005	Wild	192	11-Jul	199	18-Jul	227	15-Aug	204	23-Jul	14,176
	Hatchery	187	6-Jul	200	19-Jul	251	8-Sep	212	31-Jul	42
2006	Wild	201	20-Jul	204	23-Jul	214	2-Aug	206	25-Jul	9,151
	Hatchery	202	21-Jul	219	7-Aug	228	16-Aug	215	3-Aug	507
2007	Wild	201	20-Jul	210	29-Jul	227	15-Aug	213	1-Aug	2,542
	Hatchery	205	24-Jul	213	1-Aug	231	19-Aug	216	4-Aug	65
2008	Wild	200	18-Jul	207	25-Jul	219	6-Aug	208	26-Jul	29,229
	Hatchery	201	19-Jul	206	24-Jul	215	2-Aug	208	26-Jul	103
2009	Wild	198	17-Jul	204	23-Jul	213	1-Aug	206	25-Jul	15,552
	Hatchery	199	18-Jul	205	24-Jul	215	3-Aug	207	26-Jul	534
2010	Wild	199	18-Jul	205	24-Jul	220	8-Aug	208	27-Jul	34,519
	Hatchery	200	19-Jul	215	3-Aug	244	1-Sep	218	6-Aug	1,302
2011	Wild	213	1-Aug	216	4-Aug	224	12-Aug	217	5-Aug	17,680
	Hatchery	213	1-Aug	213	1-Aug	231	19-Aug	216	4-Aug	954
2012[a]	Wild	207	25-Jul	212	30-Jul	216	3-Aug	212	30-Jul	21,246
	Hatchery	207	25-Jul	207	25-Jul	228	15-Aug	213	31-Jul	348

Survey year	Origin	Sockeye Migration Time (days)								Sample size
		10 Percentile		50 Percentile		90 Percentile		Mean		
		Julian	Date	Julian	Date	Julian	Date	Julian	Date	
2013	Wild	196	15-Jul	200	19-Jul	207	26-Jul	201	20-Jul	28,245
	Hatchery	197	16-Jul	201	20-Jul	211	30-Jul	203	22-Jul	770
2014	Wild	194	13-Jul	199	18-Jul	210	29-Jul	201	20-Jul	97,670
	Hatchery	196	15-Jul	201	20-Jul	211	30-Jul	203	22-Jul	2,229
2015	Wild	191	10-Jul	199	18-Jul	215	3-Aug	203	22-Jul	49,628
	Hatchery	181	30-Jun	199	18-Jul	212	31-Jul	200	19-Jul	1,782
2016	Wild	190	8-Jul	196	14-Jul	208	26-Jul	198	16-Jul	73,619
	Hatchery	192	10-Jul	195	13-Jul	207	25-Jul	197	15-Jul	78
Average	***Wild***	***199***		***205***		***216***		***207***		***26,981***
	Hatchery	***199***		***207***		***223***		***209***		***757***
Median	***Wild***	***198***		***204***		***214***		***206***		***21,246***
	Hatchery	***199***		***206***		***220***		***208***		***507***

[a] The origin of sockeye passing Tumwater Dam during 8 through 11 August 2012 was not assessed. The total number of sockeye passing Tumwater Dam in 2012 was 30,617 adults. Thus, about 9,023 adults of unknown origin passed Tumwater Dam in 2012.

Table 4.20b. The week that 10%, 50% (median), and 90% of the wild and hatchery sockeye salmon passed Tumwater Dam, 1998-2016. The average week is also provided. Migration timing is based on video sampling at Tumwater. Data for 1998 through 2003 were based on videotapes and broodstock trapping and may not reflect the actual number of hatchery sockeye salmon. All sockeye were visually examined during trapping from 2004 to present.

Survey year	Origin	Sockeye Migration Time (week)				Sample size
		10 Percentile	50 Percentile	90 Percentile	Mean	
1998	Wild	28	29	30	29	4,173
	Hatchery	28	30	32	30	31
1999	Wild	33	34	35	34	908
	Hatchery	33	34	35	34	264
2000	Wild	29	30	31	30	18,390
	Hatchery	29	30	31	30	2,589
2001	Wild	27	28	31	29	32,554
	Hatchery	29	31	35	31	79
2002	Wild	30	30	32	30	27,241
	Hatchery	30	30	32	31	580
2003	Wild	28	29	30	29	4,699
	Hatchery	28	29	31	29	375
2004	Wild	28	28	28	29	31,408
	Hatchery	27	28	29	28	1,758
2005	Wild	28	29	33	30	14,176
	Hatchery	27	29	36	31	42

Survey year	Origin	Sockeye Migration Time (week)				Sample size
		10 Percentile	50 Percentile	90 Percentile	Mean	
2006	Wild	29	29	31	30	9,151
	Hatchery	29	32	33	31	507
2007	Wild	29	30	33	31	2,542
	Hatchery	30	31	33	31	65
2008	Wild	29	30	32	30	29,229
	Hatchery	29	30	31	30	103
2009	Wild	29	30	31	30	15,552
	Hatchery	29	29	31	30	534
2010	Wild	29	30	32	30	34,519
	Hatchery	29	31	35	32	1,302
2011	Wild	31	31	32	31	17,680
	Hatchery	31	31	33	31	954
2012[a]	Wild	30	31	31	31	21,246
	Hatchery	30	30	33	31	348
2013	Wild	28	29	30	29	28,245
	Hatchery	29	29	31	29	770
2014	Wild	28	29	30	29	97,670
	Hatchery	28	29	29	29	2,229
2015	Wild	28	29	31	30	49,628
	Hatchery	26	29	31	29	1,782
2016	Wild	28	28	30	29	73,619
	Hatchery	28	28	30	29	78
Average	***Wild***	***29***	***30***	***31***	***30***	***26,981***
	Hatchery	***29***	***30***	***32***	***30***	***757***
Median	***Wild***	***29***	***29***	***31***	***30***	***21,246***
	Hatchery	***29***	***30***	***32***	***30***	***507***

[a] The origin of sockeye passing Tumwater Dam during 8 through 11 August 2012 was not assessed. The total number of sockeye passing Tumwater Dam in 2012 was 30,617 adults. Thus, about 9,023 adults of unknown origin passed Tumwater Dam in 2012.

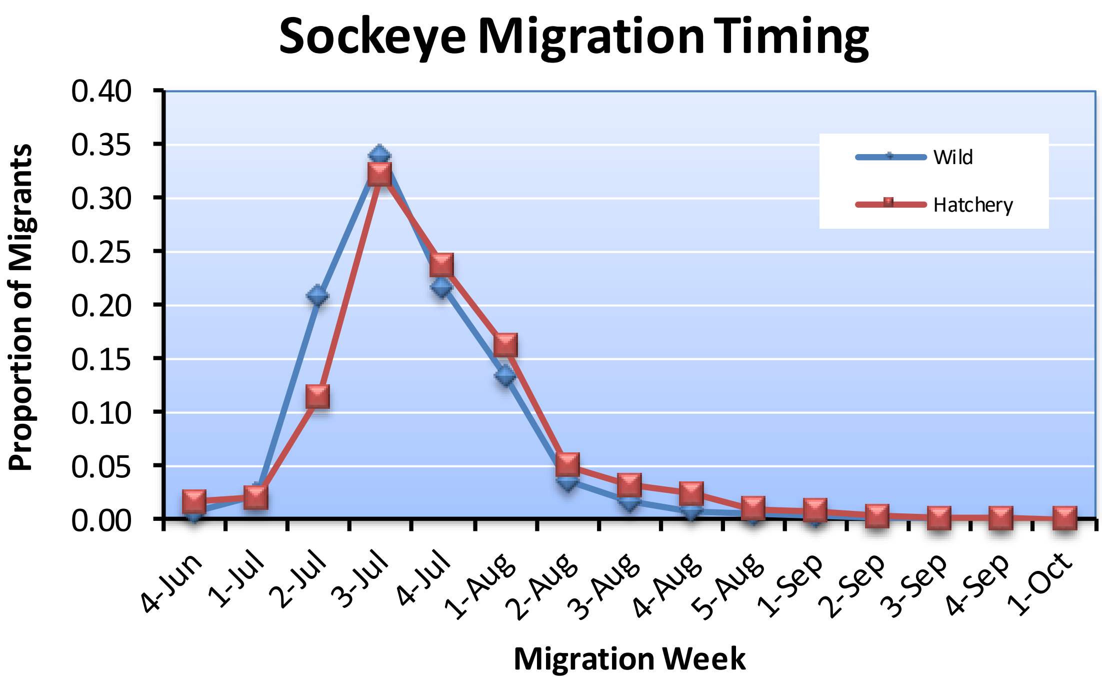

Figure 4.3. Proportion of wild and hatchery sockeye observed (using video) passing Tumwater Dam each week during their migration period late-June through early-October; data were pooled over survey years 1998-2016.

Age at Maturity

Although sample sizes are small, most hatchery sockeye returned as age-4 fish, while most wild sockeye returned as age-4 and 5 fish (Table 4.21; Figure 4.4). Only wild fish have returned at age-6.

Table 4.21. Proportions of wild and hatchery sockeye of different ages (total age) sampled in broodstock (1994-2011), on spawning grounds (1994-2012), and at Tumwater Dam (2013-2016).

Survey year	Origin	Total age						Sample size
		2	3	4	5	6	7	
1994	Wild	0.00	0.00	0.00	0.00	0.00	0.00	0
	Hatchery	0.00	0.00	0.88	0.13	0.00	0.00	16
1995	Wild	0.00	0.00	0.00	0.00	0.00	0.00	0
	Hatchery	0.00	0.00	0.00	1.00	0.00	0.00	1
1996	Wild	0.00	0.00	0.00	0.00	0.00	0.00	0
	Hatchery	0.00	0.00	1.00	0.00	0.00	0.00	82
1997	Wild	0.00	0.00	0.00	0.00	0.00	0.00	0
	Hatchery	0.00	0.00	0.77	0.23	0.00	0.00	13
1998	Wild	0.00	0.08	0.85	0.08	0.00	0.00	26
	Hatchery	0.00	0.00	0.64	0.36	0.00	0.00	11
1999	Wild	0.00	0.00	0.18	0.73	0.10	0.00	113

Survey year	Origin	Total age						Sample size
		2	3	4	5	6	7	
	Hatchery	0.00	0.00	0.65	0.35	0.00	0.00	31
2000	Wild	0.00	0.00	0.00	1.00	0.00	0.00	1
	Hatchery	0.00	0.00	0.98	0.02	0.00	0.00	359
2001	Wild	0.00	0.00	0.76	0.24	0.00	0.00	29
	Hatchery	0.00	0.00	0.75	0.25	0.00	0.00	171
2002	Wild	0.00	0.00	0.20	0.80	0.00	0.00	5
	Hatchery	0.00	0.00	0.29	0.71	0.00	0.00	63
2003	Wild	0.00	0.00	0.00	1.00	0.00	0.00	5
	Hatchery	0.00	0.33	0.67	0.00	0.00	0.00	6
2004	Wild	0.00	0.00	0.00	0.00	0.00	0.00	0
	Hatchery	0.00	0.02	0.93	0.05	0.00	0.00	244
2005	Wild	0.00	0.00	0.00	0.00	0.00	0.00	0
	Hatchery	0.00	0.13	0.75	0.13	0.00	0.00	8
2006	Wild	0.00	0.00	0.34	0.65	0.01	0.00	207
	Hatchery	0.00	0.00	1.00	0.00	0.00	0.00	65
2007	Wild	0.00	0.00	0.02	0.88	0.10	0.00	206
	Hatchery	0.00	0.00	0.35	0.65	0.00	0.00	17
2008	Wild	0.00	0.00	0.95	0.04	0.01	0.00	258
	Hatchery	0.00	0.08	0.92	0.00	0.00	0.00	12
2009	Wild	0.00	0.00	0.79	0.21	0.00	0.00	251
	Hatchery	0.00	0.00	1.00	0.00	0.00	0.00	2
2010	Wild	0.00	0.00	0.67	0.33	0.00	0.00	193
	Hatchery	0.00	0.00	0.98	0.02	0.00	0.00	130
2011	Wild	0.00	0.00	0.63	0.36	0.01	0.00	270
	Hatchery	0.00	0.02	0.96	0.02	0.00	0.00	274
2012	Wild	0.00	0.00	0.92	0.08	0.00	0.00	13
	Hatchery	0.00	0.00	0.96	0.03	0.01	0.00	128
2013	Wild	0.00	0.002	0.56	0.44	0.002	0.00	457
	Hatchery	0.00	0.00	0.50	0.50	0.00	0.00	2
2014	Wild	0.00	0.00	0.88	0.12	0.00	0.00	1,332
	Hatchery	0.00	0.03	0.95	0.02	0.00	0.00	40
2015	Wild	0.00	0.00	0.81	0.19	0.00	0.00	882
	Hatchery	0.00	0.00	1.00	0.00	0.00	0.00	53
2016	Wild	0.00	0.00	0.77	0.23	0.00	0.00	765
	Hatchery	0.00	0.00	0.00	1.00	0.00	0.00	1
Average	***Wild***	***0.00***	***0.00***	***0.72***	***0.27***	***0.01***	***0.00***	***218***
	Hatchery	***0.00***	***0.01***	***0.90***	***0.09***	***0.00***	***0.00***	***75***
Median	***Wild***	***0.00***	***0.00***	***0.75***	***0.25***	***0.00***	***0.00***	***29***

Survey year	Origin	Total age						Sample size
		2	3	4	5	6	7	
	Hatchery	***0.00***	***0.00***	***0.90***	***0.10***	***0.00***	***0.00***	***31***

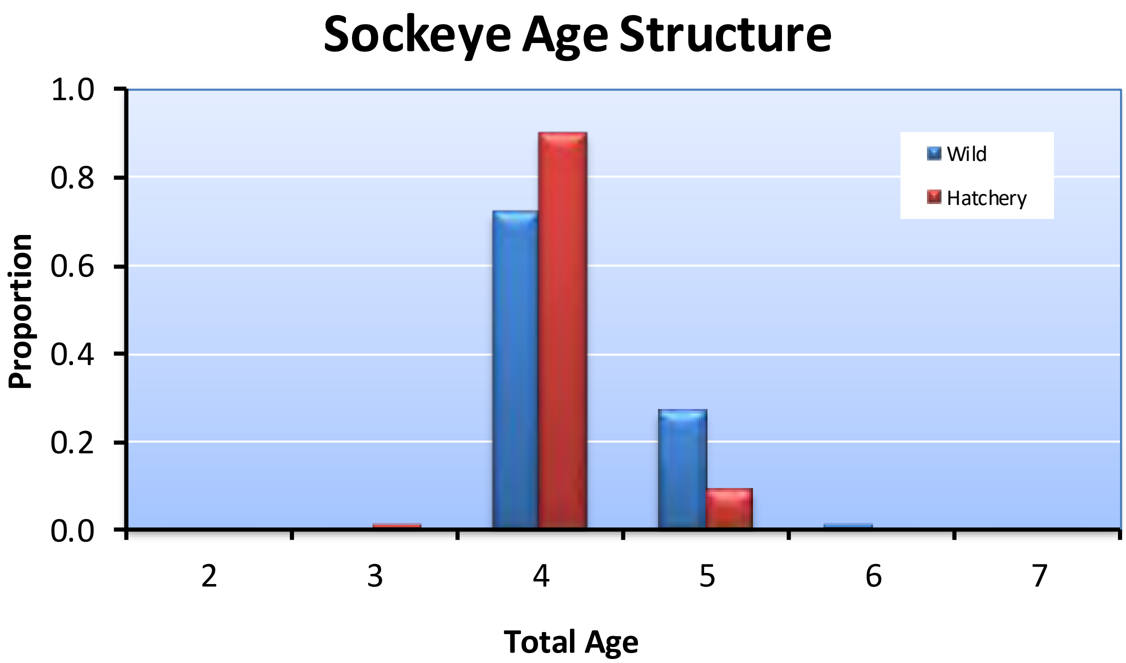

Figure 4.4. Proportions of wild and hatchery sockeye salmon of different total ages sampled at Tumwater Dam and on spawning grounds in the Wenatchee River basin for the combined years 1994-2016.

Size at Maturity

Although sample sizes are small, wild and hatchery sockeye differed in mean length in 2016 (Table 4.22). However, the pooled data indicate that there is little difference in mean sizes of hatchery and wild sockeye salmon sampled in the Wenatchee River basin (Table 4.22). Analyses for the five-year reports will compare sizes of hatchery and wild fish of the same age groups and sex.

Table 4.22. Mean lengths (POH; cm) and variability statistics for wild and hatchery sockeye salmon sampled at Dryden Dam (broodstock) and on spawning grounds in the Wenatchee River basin, 1994-2016; SD = 1 standard deviation. From 2014 to present, data are collected from sockeye sampled at Tumwater Dam.

Survey year	Origin	Sample size	Sockeye length (POH; cm)			
			Mean	SD	Minimum	Maximum
1994	Wild	0	-	-	-	-
	Hatchery	14	42	3	37	47
1995	Wild	0	-	-	-	-
	Hatchery	1	53	-	53	53
1996	Wild	0	-	-	-	-
	Hatchery	5	51	3	49	55

Survey year	Origin	Sample size	Sockeye length (POH; cm)			
			Mean	SD	Minimum	Maximum
1997	Wild	6	40	3	38	45
	Hatchery	17	41	3	37	50
1998	Wild	585	43	3	34	50
	Hatchery	20	43	3	40	51
1999	Wild	99	42	3	36	50
	Hatchery	31	41	3	36	47
2000	Wild	1	48	-	48	48
	Hatchery	377	40	2	30	49
2001	Wild	29	42	2	38	47
	Hatchery	184	43	3	35	51
2002	Wild	5	42	1	40	43
	Hatchery	52	44	3	37	49
2003	Wild	5	44	4	38	47
	Hatchery	13	42	5	30	48
2004	Wild	0	-	-	-	-
	Hatchery	230	40	3	33	49
2005	Wild	0	-	-	-	-
	Hatchery	8	43	9	35	64
2006	Wild	248	45	4	34	52
	Hatchery	17	41	5	31	48
2007	Wild	248	45	3	32	52
	Hatchery	16	41	5	31	48
2008	Wild	261	52	3	44	66
	Hatchery	20	39	3	30	41
2009	Wild	260	43	3	33	53
	Hatchery	22	41	2	36	46
2010	Wild	200	56	3	48	66
	Hatchery	131	41	2	35	45
2011	Wild	277	43	3	35	51
	Hatchery	282	40	3	32	49
2012	Wild	15	40	4	34	48
	Hatchery	130	40	3	31	48
2013	Wild	2	49	3	47	51
	Hatchery	64	50	4	43	65
2014	Wild	1,367	42	2	31	51
	Hatchery	43	41	3	32	45
2015	Wild	920	43	2	37	53
	Hatchery	54	43	2	39	47

Survey year	Origin	Sample size	Sockeye length (POH; cm)			
			Mean	SD	Minimum	Maximum
2016	Wild	798	43	3	36	51
	Hatchery	1	38	-	38	38
Pooled	***Wild***	***5,326***	***43***	***3***	***31***	***66***
	Hatchery	***1,732***	***41***	***3***	***30***	***65***

Contribution to Fisheries

The total number of hatchery and wild sockeye captured in different fisheries is provided in Tables 4.23 and 4.24. Harvest on hatchery-origin sockeye has been less than the harvest on wild sockeye.

Table 4.23. Estimated number and percent (in parentheses) of hatchery-origin Wenatchee sockeye captured in different fisheries, brood years 1989-2010.

Brood year	Ocean fisheries	Columbia River Fisheries			Total
		Tribal	Commercial (Zones 1-5)	Recreational[a] (sport)	
1989	0 (0)	279 (30)	4 (0)	639 (69)	922
1990	0 (0)	23 (100)	0 (0)	0 (0)	23
1991	0 (0)	6 (100)	0 (0)	0 (0)	6
1992	0 (0)	38 (97)	1 (3)	0 (0)	39
1993	0 (0)	4 (100)	0 (0)	0 (0)	4
1994	0 (0)	3 (100)	0 (0)	0 (0)	3
1995	0 (0)	10 (100)	0 (0)	0 (0)	10
1996	0 (0)	62 (82)	9 (12)	5 (7)	76
1997	0 (0)	69 (73)	11 (12)	15 (16)	95
1998	0 (0)	7 (100)	0 (0)	0 (0)	7
1999	0 (0)	3 (20)	0 (0)	12 (80)	15
2000	0 (0)	59 (12)	9 (2)	414 (86)	482
2001	0 (0)	0 (0)	0 (0)	3 (100)	3
2002	0 (0)	16 (100)	0 (0)	0 (0)	16
2003	0 (0)	3 (100)	0 (0)	0 (0)	3
2004	0 (0)	6 (3)	1 (1)	192 (96)	199
2005	3 (2)	61 (41)	7 (5)	79 (53)	150
2006	2 (0)	124 (23)	2 (0)	409 (76)	537
2007	2 (2)	96 (80)	13 (11)	9 (8)	120
2008	0 (0)	96 (19)	12 (2)	400 (79)	508
2009	1 (0)	20 (16)	2 (2)	104 (82)	127
2010	0 (0)	97 (36)	5 (2)	170 (63)	272
Average	***0 (0)***	***49 (61)***	***3 (2)***	***111 (37)***	***164***
Median	***0 (0)***	***22 (77)***	***1 (0)***	***7 (12)***	***58***

[a] Includes the Lake Wenatchee fishery.

Table 4.24. Estimated number and percent (in parentheses) of wild Wenatchee sockeye captured in different fisheries, brood years 1989-2010.

Brood year	Ocean fisheries	Columbia River Fisheries			Total
		Tribal	Commercial (Zones 1-5)	Recreational[a] (sport)	
1989	0 (0)	2,192 (31)	26 (0)	4,838 (69)	7,056
1990	0 (0)	191 (100)	0 (0)	0 (0)	191
1991	0 (0)	293 (99)	2 (1)	0 (0)	295
1992	0 (0)	345 (99)	5 (1)	0 (0)	350
1993	0 (0)	661 (99)	4 (1)	0 (0)	665
1994	0 (0)	146 (100)	0 (0)	0 (0)	146
1995	0 (0)	63 (85)	4 (5)	7 (9)	74
1996	0 (0)	1,553 (56)	247 (9)	993 (36)	2,793
1997	0 (0)	3,060 (54)	376 (6)	2,266 (40)	5,702
1998	0 (0)	937 (98)	7 (1)	10 (1)	954
1999	0 (0)	22 (19)	3 (3)	90 (78)	115
2000	0 (0)	1,188 (19)	165 (3)	4,881 (78)	6,234
2001	0 (0)	827 (100)	1 (0)	0 (0)	828
2002	0 (0)	379 (83)	2 (0)	73 (16)	454
2003	0 (0)	129 (24)	15 (3)	383 (73)	527
2004	0 (0)	1,559 (24)	174 (3)	4,825 (74)	6,558
2005	0 (0)	2,498 (44)	198 (3)	2,996 (53)	5,692
2006	0 (0)	2,844 (52)	135 (2)	2,505 (46)	5,484
2007	0 (0)	1,534 (57)	214 (8)	960 (35)	2,710
2008	0 (0)	5,447 (25)	613 (3)	13,544 (72)	19,206
2009	0 (0)	854 (20)	53 (1)	5,336 (80)	6,664
2010	0 (0)	5,468 (26)	262 (1)	15,603 (73)	21,333
Average	***0 (0)***	***1,463 (60)***	***115 (3)***	***2,694 (38)***	***4,272***
Median	***0 (0)***	***896 (55)***	***21 (2)***	***664 (36)***	***1,823***

[a] Includes the Lake Wenatchee fishery.

Straying

Stray rates were determined by examining CWTs recovered on spawning grounds within and outside the Wenatchee River basin. In addition, PIT tagging of hatchery sockeye, which began with brood year 2005, allows estimation of stray rates by brood return. Targets for strays based on return year (recovery year) outside the Wenatchee River basin should be less than 5%. The target for brood year strays should also be less than 5%.

Based on CWTs and brood year analysis, virtually no hatchery-origin Wenatchee sockeye strayed into non-target spawning areas or hatchery programs before brood year 2006 (Table 4.25). However, sockeye from brood years 2006 and 2007 strayed into the Entiat River and a few into the Methow River (non-target streams) and a non-target hatchery (Umpqua Trap) (Table 4.25).

Stray rates of Wenatchee sockeye from brood year 2006-2010 exceeded the target of 5%. The number of returning hatchery sockeye has decreased since brood year 2008.

Table 4.25. Number and percent of hatchery-origin Wenatchee sockeye that homed to target spawning areas and the target hatchery program, and number and percent that strayed to non-target spawning areas and hatchery programs, by brood years 1990-2010. Hatchery-origin sockeye from brood years 1995-1998 were not tagged because of columnaris disease (NA = not available). Percent stays should be less than 5%.

Brood year	Homing				Straying			
	Target streams		Target hatchery*		Non-target streams		Non-target hatcheries	
	Number	%	Number	%	Number	%	Number	%
1990	402	99.5	2	0.5	0	0.0	0	0.0
1991	1	100.0	0	0.0	0	0.0	0	0.0
1992	92	98.9	0	0.0	0	0.0	1	1.1
1993	29	96.7	1	3.3	0	0.0	0	0.0
1994	66	94.3	4	5.7	0	0.0	0	0.0
1995	NA	NA	NA	NA	NA	NA	NA	NA
1996	NA	NA	NA	NA	NA	NA	NA	NA
1997	NA	NA	NA	NA	NA	NA	NA	NA
1998	NA	NA	NA	NA	NA	NA	NA	NA
1999	65	100.0	0	0.0	0	0.0	0	0.0
2000	571	100.0	0	0.0	0	0.0	0	0.0
2001	17	100.0	0	0.0	0	0.0	0	0.0
2002	251	100.0	0	0.0	0	0.0	0	0.0
2003	11	100.0	0	0.0	0	0.0	0	0.0
2004	56	100.0	0	0.0	0	0.0	0	0.0
2005	67	97.1	2	2.9	0	0.0	0	0.0
2006	117	41.9	0	0.0	160	57.3	2	0.7
2007	260	82.0	1	0.3	56	17.7	0	0.0
2008	86	90.5	0	0.0	9	9.5	0	0.0
2009	11	73.3	0	0.0	4	26.7	0	0.0
2010	0	0.0	0	0.0	2	100.0	0	0.0
Average	***124***	***86.7***	***1***	***0.8***	***14***	***12.4***	***0***	***0.1***
Median	***66***	***98.9***	***0***	***0.0***	***0***	***0.0***	***0***	***0.0***

* Homing to the target hatchery includes Wenatchee hatchery sockeye that are captured and included as broodstock in the Wenatchee Hatchery program. These hatchery fish were collected at Tumwater Dam.

Based on PIT-tag analyses, on average, about 11% of the hatchery sockeye returns were last detected in streams outside the Wenatchee River basin (Table 4.26). The numbers in Table 4.26 should be considered rough estimates because they are not based on confirmed spawning (only last detections). Nevertheless, these data do indicate that some hatchery sockeye from the Wenatchee program have strayed into the Entiat and Methow rivers and possibly into the Okanogan system (based on sockeye detected at Wells Dam but not in the Methow River).

Table 4.26. Number and percent of hatchery-origin Wenatchee sockeye that homed to target spawning areas and the target hatchery program, and number and percent that strayed to non-target spawning areas and hatchery programs for brood years 2005-2011. Estimates were based on last detections of PIT-tagged hatchery sockeye. Percent strays should be less than 5%.

Brood Year	Homing				Straying			
	Target streams		Target hatchery*		Non-target stream		Non-target hatchery	
	Number	%	Number	%	Number	%	Number	%
2005	166	92.2	0	0.0	14	7.8	0	0.0
2006	440	94.6	0	0.0	25	5.4	0	0.0
2007	192	95.0	0	0.0	10	5	0	0.0
2008	127	89.4	0	0.0	15	10.6	0	0.0
2009	41	82.0	0	0.0	9	18	0	0.0
2010	53	100.0	0	0.0	0	0.0	0	0.0
2011	65	71.6	0	0.0	25	28.4	0	0.0
Average	***155***	***89.3***	***0***	***0.0***	***14***	***10.7***	***0***	***0.0***
Median	***127***	***92.2***	***0***	***0.0***	***14***	***7.8***	***0***	***0.0***

* Homing to the target hatchery includes Wenatchee hatchery sockeye that are captured and included as broodstock in the Wenatchee Hatchery program. These hatchery fish were collected at Tumwater Dam.

Genetics

Genetic studies were conducted in 2008 to determine the potential effects of the Wenatchee sockeye supplementation program on natural-origin sockeye in the upper Wenatchee River basin (Blankenship et al. 2008; the entire report is appended as Appendix I). Specifically, the objective of the study was to determine if the genetic composition of the Lake Wenatchee sockeye population had been altered by the supplementation program, which was based on the artificial propagation of a small subset of the Wenatchee population. Microsatellite DNA allele frequencies were used to differentiate between temporally replicated collections of natural and hatchery-origin sockeye in the Wenatchee River basin. A total of 13 collections of Wenatchee sockeye were analyzed; eight temporally replicated collections of natural-origin sockeye (N = 786) and five temporally replicated collections of hatchery-origin sockeye (N = 248). Paired natural-hatchery collections were available from return years 2000, 2001, 2004, 2006, and 2007. All collections were taken at Tumwater Dam and consisted of dried scales and fin clips.

Overall, the study showed that allele frequency distributions were consistent over time, regardless of origin, resulting in small, insignificant measures of genetic differentiation among collections. This indicates that there were no year-to-year differences in allele frequencies between natural and hatchery-origin sockeye. In addition, the analyses found no differences between pre- and post-supplementation collections. Thus, it was concluded that the allele frequencies of the broodstock collections equaled the allele frequency of the natural collections.

It is important to note that no new information will be reported on genetics until the next five-year report (2018).

Proportionate Natural Influence

Another method for assessing the genetic risk of a supplementation program is to determine the influence of the hatchery and natural environments on the adaptation of the composite population. This is estimated by the proportion of natural-origin fish in the hatchery broodstock (pNOB) and the proportion of hatchery-origin fish in the natural spawning escapement (pHOS). We calculated Proportionate Natural Influence (PNI) by iterating Ford's (2002) equations 5 and 6 to equilibrium, using a heritability of 0.3 and a selection strength of three standard deviations. The larger the PNI value, the greater the strength of selection in the natural environment relative to that of the hatchery environment. For the natural environment to dominate selection, PNI should be greater than 0.50, and important integrated populations should have a PNI of at least 0.67 (HSRG/WDFW/NWIFC 2004).

The PNI values for the life of the program (brood years 1989-2011) are shown in Table 4.27. Throughout the program, PNI was consistently greater than 0.67. The hatchery program was terminated in 2012.

Table 4.27. Proportionate Natural Influence (PNI) values for the Wenatchee sockeye supplementation program for brood years 1989-2016. NOS = number of natural-origin sockeye counted at Tumwater Dam; HOS = number of hatchery-origin sockeye counted at Tumwater Dam; NOB = number of natural-origin sockeye collected for broodstock; and HOB = number of hatchery-origin sockeye included in hatchery broodstock. NP = no hatchery program.

Brood year	Escapement[a]			Broodstock			PNI[b]
	NOS	HOS	pHOS	NOB	HOB	pNOB	
1989	21,802	0	0.00	115	0	1.00	1.00
1990	27,325	0	0.00	302	0	1.00	1.00
1991	26,689	0	0.00	199	0	1.00	1.00
1992	16,461	0	0.00	320	0	1.00	1.00
1993	25,064	2,662	0.10	207	0	1.00	0.91
1994	6,934	396	0.05	236	5	0.98	0.95
1995	3,262	186	0.05	194	3	0.98	0.95
1996	6,027	546	0.08	225	0	1.00	0.93
1997	8,376	68	0.01	192	19	0.91	0.99
1998	3,982	32	0.01	122	6	0.95	0.99
1999	961	64	0.06	79	60	0.57	0.91
2000	19,620	1,164	0.06	170	5	0.97	0.94
2001	28,288	815	0.03	200	7	0.97	0.97
2002	27,371	193	0.01	256	0	1.00	0.99
2003	4,797	58	0.01	198	0	1.00	0.99
2004	26,095	1,460	0.05	177	0	1.00	0.95
2005	13,983	28	0.00	166	0	1.00	1.00
2006	9,182	255	0.03	214	0	1.00	0.97
2007	2,320	59	0.02	210	0	1.00	0.98
2008	22,931	92	0.00	243	2	0.99	1.00
2009	13,043	445	0.03	239	0	1.00	0.97

Brood year	Escapement[a]			Broodstock			PNI[b]
	NOS	HOS	pHOS	NOB	HOB	pNOB	
2010	30,357	1,134	0.04	198	0	1.00	0.96
2011	17,490	940	0.05	196	0	1.00	0.95
Average	***15,755***	***461***	***0.03***	***203***	***5***	***0.97***	***0.97***
Median	***16,461***	***186***	***0.03***	***199***	***0***	***1.00***	***0.97***
2012	30,903	502	0.02	NP	NP	NP	NP
2013	22,118	614	0.03	NP	NP	NP	NP
2014	81,804	1,840	0.02	NP	NP	NP	NP
2015	42,132	1,528	0.03	NP	NP	NP	NP
2016	59,008	59	0.00	NP	NP	NP	NP
Average	***47,193***	***909***	***0.02***	***NP***	***NP***	***NP***	***NP***
Median	***42,132***	***614***	***0.02***	***NP***	***NP***	***NP***	***NP***

[a] Proportions of natural-origin and hatchery-origin spawners were determined from reading video tape at Tumwater Dam, adjusted for fish harvested in the Lake Wenatchee recreational fishery.

[b] PNI was calculated previously using PNI approximate equation 11 (HSRG 2009; their Appendix A). All PNI values presented here were recalculated by iterating Ford's (2002) equations 5 and 6 to equilibrium using a heritability of 0.3 and a selection strength of three standard deviations. C. Busack, NOAA Fisheries, 21 March 2016, provided the model for calculating PNI.

Post-Release Survival and Travel Time

We used PIT-tagged fish to estimate survival rates and travel time (arithmetic mean days) of hatchery sockeye salmon from Lake Wenatchee to McNary Dam, and smolt to adult ratios (SARs) from release to detection at Bonneville Dam (Table 4.28).[9] Over the seven brood years for which PIT-tagged hatchery fish were released, survival rates from Lake Wenatchee to McNary Dam ranged from 0.211 to 0.370; SARs from release to detection at Bonneville Dam ranged from 0.005 to 0.044. Average travel time from Lake Wenatchee to McNary Dam ranged from 176 to 202 days.

Table 4.28. Total number of hatchery sockeye parr released with PIT tags, their survival and travel times (mean days) to McNary Dam, and smolt-to-adult (SAR) ratios for brood years 2005-2011. Standard errors are shown in parentheses.

Brood year	Number of sockeye released with PIT tags	Survival to McNary Dam	Travel time[1] to McNary Dam (d)	SAR to Bonneville Dam
2005	14,859	0.334 (0.013)	176.4 (61.9)	0.020 (0.001)
2006	14,764	0.370 (0.030)	202.0 (9.1)	0.044 (0.002)
2007	14,947	0.312 (0.013)	199.9 (8.6)	0.024 (0.001)
2008	14,858	0.307 (0.020)	192.9 (35.7)	0.015 (0.001)
2009	14,486	0.211 (0.015)	194.2 (29.1)	0.005 (0.001)
2010	5,039	0.302 (0.048)	191.7 (26.6)	0.014 (0.002)
2011	5,074	0.318 (0.038)	196.7 (7.3)	0.036 (0.003)

[9] It is important to point out that because of fish size differences among rearing tanks or raceways, fish PIT tagged in one tank or raceway may not represent untagged fish rearing in other tanks or raceways.

[1] Travel time is calculated from the date of release from the net pens in the fall, overwintering in Lake Wenatchee, to spring outmigration.

Natural and Hatchery Replacement Rates

Natural replacement rates (NRR) were calculated as the ratio of natural-origin recruits (NOR) to the parent spawning population. Natural-origin recruits are naturally produced (wild) fish that survive to contribute to harvest (directly or indirectly), to broodstock, and to spawning grounds. We do not account for fish that died in route to the spawning grounds (migration mortality) or died just before spawning (pre-spawn mortality) (see Appendix B in Hillman et al. 2012). We calculated NORs with and without harvest. NORs without harvest include all returning fish that either returned to the basin or were collected as wild broodstock. NORs with harvest include all fish harvested and are based on a brood year harvest rates from the hatchery program. For brood years 1989-2010, NRR in the Wenatchee averaged 1.58 (range, 0.13-5.72) if harvested fish were not included in the estimate and 1.87 (range, 0.14-6.88) if harvested fish were included in the estimate (Table 4.29).

Hatchery replacement rates (HRR) were estimated as hatchery adult-to-adult returns. These rates should be greater than the NRRs and greater than or equal to 5.4 (the calculated target value in Hillman et al. 2013). The target value of 5.4 includes harvest. HRRs exceeded NRRs in 14 or 15 of the 23 years of data depending on if harvest was or was not included in the estimates (Table 4.29). Hatchery replacement rates for Wenatchee sockeye have equaled or exceeded the estimated target value of 5.4 in five of the 23 years (Table 4.29).

Table 4.29. Broodstock collected, spawning escapements, natural and hatchery-origin recruits (NOR and HOR), and natural and hatchery replacement rates (NRR and HRR; with and without harvest) for sockeye salmon in the Wenatchee River basin, 1989-2010.

Brood year	Broodstock Collected	Spawning Escapement	Harvest not included				Harvest included			
			HOR	NOR	HRR	NRR	HOR	NOR	HRR	NRR
1989	255	21,802	2,757	23,616	10.81	1.08	3,680	30,672	14.43	1.41
1990	316	27,325	401	3,509	1.27	0.13	423	3,701	1.34	0.14
1991	233	26,689	95	4,820	0.41	0.18	101	5,116	0.43	0.19
1992	343	16,461	576	5,336	1.68	0.32	615	5,685	1.79	0.35
1993	307	27,726	71	11,151	0.23	0.40	75	11,815	0.24	0.43
1994	265	7,330	47	1,191	0.18	0.16	50	1,337	0.19	0.18
1995	209	3,448	121	840	0.58	0.24	131	913	0.63	0.26
1996	227	6,573	1,351	28,093	5.95	4.27	1,427	30,886	6.29	4.70
1997	226	8,444	739	36,097	3.27	4.27	834	41,798	3.69	4.95
1998	190	4,014	104	16,165	0.55	4.03	111	17,120	0.58	4.27
1999	147	1,025	68	566	0.46	0.55	83	682	0.56	0.67
2000	195	20,784	1,425	29,082	7.31	1.40	1,907	35,316	9.78	1.70
2001	245	29,103	24	17,241	0.10	0.59	28	18,068	0.11	0.62
2002	257	27,564	281	5,752	1.09	0.21	297	6,207	1.16	0.23
2003	219	4,855	32	2,054	0.15	0.42	35	2,590	0.16	0.53
2004	202	27,555	94	23,589	0.47	0.86	293	30,149	1.45	1.09
2005	207	14,011	460	20,793	2.22	1.48	606	26,486	2.93	1.89
2006	220	9,437	1,147	26,966	5.21	2.86	1,682	32,450	7.65	3.44
2007	228	2,379	917	13,619	4.02	5.72	1,037	16,311	4.55	6.88
2008	260	23,023	808	45,020	3.11	1.96	1,314	66,511	5.05	2.50

Brood year	Broodstock Collected	Spawning Escapement	Harvest not included				Harvest included			
			HOR	NOR	HRR	NRR	HOR	NOR	HRR	NRR
2009	261	13,488	344	15,346	1.32	1.14	469	19,704	1.80	1.46
2010	201	31,491	1,748	79,993	8.70	2.54	2,020	101,325	10.05	3.22
Average	***237***	***16,115***	***619***	***18,675***	***2.69***	***1.58***	***783***	***22,947***	***3.40***	***1.87***
Median	***228***	***15,236***	***373***	***15,756***	***1.30***	***0.97***	***446***	***17,594***	***1.62***	***1.25***

Juvenile-to-Adult Survivals

When possible, both parr-to-adult ratios (PAR) and smolt-to-adult ratios (SAR) were calculated for hatchery sockeye salmon. Ratios were calculated as the number of hatchery adult recaptures divided by the number of tagged hatchery parr released or the estimated number of smolts emigrating from Lake Wenatchee. Here, survival ratios were based on CWT returns, when available, or on the estimated number of hatchery adults recovered on the spawning grounds, in broodstock, and harvested. For the available brood years, PARs have ranged from 0.0001 to 0.0339 for hatchery sockeye salmon and SARs have ranged from 0.0002 to 0.0255 (Table 4.30).

Table 4.30. Parr-to-adult ratios (PAR) and smolt-to-adult ratios (SAR) for Wenatchee hatchery sockeye salmon, brood years 1990-2010; NA = not available.

Brood year	Number of parr released	Number of smolts	Estimated adult recaptures	PAR	SAR
1989	108,400	NA	3,680	0.0339	NA
1990	270,802	NA	423	0.0016	NA
1991	167,523	NA	101	0.0006	NA
1992	340,597	NA	615	0.0018	NA
1993	190,443	NA	75	0.0004	NA
1994	252,859	NA	50	0.0002	NA
1995	150,808	28,828	131	0.0009	0.0045
1996	284,630	55,985	1,427	0.0050	0.0255
1997	197,195	112,524	834	0.0042	0.0074
1998	121,344	24,684	111	0.0009	0.0045
1999	167,955	94,046	83	0.0005	0.0009
2000	190,174	121,511	1,907	0.0100	0.0157
2001	200,938	140,322	28	0.0001	0.0002
2002	315,783	216,023	297	0.0009	0.0014
2003	240,459	122,399	35	0.0001	0.0003
2004	172,923	159,500	293	0.0017	0.0018
2005	140,542	140,542	606	0.0043	0.0043
2006	225,670	121,843	1,682	0.0075	0.0138
2007	252,133	119,908	1,037	0.0041	0.0086
2008	154,772	126,326	1,314	0.0085	0.0104

Brood year	Number of parr released	Number of smolts	Estimated adult recaptures	PAR	SAR
2009	227,743	159,089	426	0.0019	0.0027
2010	243,260	NA	2,062	0.0085	NA
Average	***209,862***	***116,235***	***783***	***0.0044***	***0.0068***
Median	***199,067***	***121,843***	***425***	***0.0018***	***0.0045***

4.8 ESA/HCP Compliance

Smolt and Emigrant Trapping

ESA-listed spring Chinook and steelhead were encountered during operation of the Lower Wenatchee trap. ESA takes are reported in the steelhead (Section 3.8) and spring Chinook (Section 5.8) sections and will not be repeated here.

Spawning Surveys

Sockeye spawning ground surveys conducted in the Wenatchee River basin during 2016 were consistent with ESA Section 10 Permit No. 1347. Because of the difficulty of quantifying the level of take associated with spawning ground surveys, the Permit does not specify a take level associated with these activities, even though it does authorize implementation of spawning ground surveys. Therefore, no take levels are reported. However, to minimize potential effects to established redds, wading was restricted to the extent practical and extreme caution was used to avoid established redds when wading was required.

SECTION 5: WENATCHEE (CHIWAWA) SPRING CHINOOK

The goal of Chiwawa spring Chinook salmon supplementation is to achieve “No Net Impact” to the productivity of spring Chinook caused by the operation of the Rock Island Hydroelectric Project. The Rock Island Fish Hatchery Complex began operation in 1989 under funding from Chelan PUD. The Complex operated originally through the Rock Island Settlement Agreement, but since 2004 has operated under the Rock Island and Rocky Reach Anadromous Fish Agreement and Habitat Conservation Plans.

Adult spring Chinook are collected for broodstock at the Chiwawa Weir and Tumwater Dam. From 2011 through 2013, all spring Chinook broodstock were collected at the Chiwawa Weir in order to reduce passage delays caused by trapping at Tumwater Dam. Before 2009, the goal was to collect up to 379 adult spring Chinook for the program with natural-origin fish making up not less than 33% of the broodstock. In 2011, the Hatchery Committees reevaluated the amount of hatchery compensation needed to achieve NNI. Based on that evaluation, the goal of the program was revised. The current goal (beginning with brood year 2013) is to collect 74 natural-origin spring Chinook. The number collected cannot exceed 33% of the natural-origin spring Chinook returns to Tumwater. Beginning in 2014, previously PIT-tagged hatchery-origin Chiwawa spring Chinook are collected at Tumwater Dam, while the Chiwawa Weir is used to collect natural-origin brood for the Chiwawa spring Chinook program. Broodstock collection occurs from May through July at Tumwater with trapping occurring up to 24 hours per day, seven days a week and at the Chiwawa Weir with trapping occurring from 15 June to 1 August (not to exceed 15 cumulative trapping days) on a 24-hour-up/24-hour-down schedule consistent with annual broodstock collection protocols.

Adult spring Chinook are spawned and reared at Eastbank Fish Hatchery. Juvenile spring Chinook are transferred from the hatchery to the Chiwawa Acclimation Facility in late September or early October. They are released volitionally from the Chiwawa Acclimation Facility during April the following year.

The production goal for the Chiwawa spring Chinook supplementation program up to brood year 2009 was to release 672,000 yearling smolts into the Chiwawa River at 12 fish per pound. Brood years 2010-2011, and 2012 were transition years to a reduced program of 298,000 smolts and 205,000 smolts, respectively. Beginning with the 2013 brood, the revised production goal is to release 144,026 smolts as part of a conservation program at 18 fish per pound. The Wenatchee spring Chinook safety-net program is now part of the Nason Creek spring Chinook program. Targets for fork length and weight are 155 mm (CV = 9.0) and 37.8 g, respectively. Over 90% of these fish are marked with CWTs. In addition, since 2006, juvenile spring Chinook have been PIT tagged annually.

With issuance of new ESA Section 10 permits in 2013, adult management (i.e., removal of excess hatchery-origin adults at dams, traps, and weirs, and in conservation fisheries) was implemented in 2014 to achieve pHOS and PNI goals for the Wenatchee spring Chinook programs.

Although this section of the report focuses on results from monitoring the Chiwawa spring Chinook program, information on spring Chinook collected throughout the Wenatchee River basin is also provided. Information specific to the Nason Creek spring Chinook conservation program is presented in Section 6 and the White River Captive Broodstock Program is presented in Section 7.

5.1 Broodstock Sampling

This section focuses on results from sampling 2014-2016 Chiwawa spring Chinook broodstock, which were collected at the Chiwawa Weir and at Tumwater Dam, consistent with methods in the broodstock collections protocols (Tonseth 2014, 2015, and 2016). Some information for the 2016 return is not available at this time (e.g., age structure and final origin determination). This information will be provided in the 2017 annual report.

Origin of Broodstock

Natural-origin adults made up between 31.3% and 100.0% of the Chiwawa spring Chinook broodstock for brood years 2014-2016 (Table 5.1). Natural and hatchery-origin adults were collected at Tumwater Dam and the Chiwawa Weir for return year 2016. Broodstock were trapped at Tumwater Dam from end of-May through mid-July 2016, and at the Chiwawa Weir from mid-June through late-July. Hatchery-origin broodstock were collected at Tumwater Dam in 2016 to meet the Nason Creek Safety Net broodstock requirements and to fill potential shortfalls of natural-origin broodstock requirements for the Chiwawa River Conservation program. Additional hatchery-origin broodstock were collected to ensure production obligations were achieved in the event that insufficient natural-origin collections could be made. A total of 21 hatchery-origin fish collected in 2016 were surplused at Eastbank Fish Hatchery.

Table 5.1. Numbers of wild and hatchery Chiwawa spring Chinook collected for broodstock, numbers that died before spawning, and numbers of Chinook spawned, 1989-2016. Unknown origin fish (i.e., undetermined by scale analysis, no CWT or fin clips, and no additional hatchery marks) were considered naturally produced.

Brood year	Wild spring Chinook					Hatchery spring Chinook					Total number spawned
	Number collected	Prespawn loss[a]	Mortality	Number spawned	Number released	Number collected	Prespawn loss[a]	Mortality	Number spawned	Number released	
1989	28	0	0	28	0	0	0	0	0	0	28
1990	19	1	0	18	0	0	0	0	0	0	18
1991	32	0	5	27	0	0	0	0	0	0	27
1992	113	0	0	78	35	0	0	0	0	0	78
1993	100	3	3	94	0	0	0	0	0	0	94
1994	9	0	1	8	0	4	0	0	4	0	12
1995	No Program										
1996	8	0	0	8	0	10	0	0	10	0	18
1997	37	0	5	32	0	83	1	3	79	0	111
1998	13	0	0	13	0	35	1	0	34	0	47
1999	No Program										
2000	10	0	1	9	0	38	1	16	21	0	30
2001	115	2	0	113	0	267	8	0	259	0	372
2002	21	0	1	20	0	63	1	11	51	0	71
2003	44	1	2	41	0	75	2	20	53	0	94
2004	100	1	16	83	0	196	30	34	132	0	215
2005	98	1	6	91	0	185	3	1	181	0	279
2006	95	0	4	91	0	303	0	29	224	50	315
2007	45	1	1	43	0	124	2	18	104	0	147

Brood year	Wild spring Chinook					Hatchery spring Chinook					Total number spawned
	Number collected	Prespawn loss[a]	Mortality	Number spawned	Number released	Number collected	Prespawn loss[a]	Mortality	Number spawned	Number released	
2008	88	2	3	83	0	241	5	16	220	0	303
2009	113	6	11	96	0	151	3	37	111	0	207
2010	83	0	6	77	0	103	0	5	98	0	175
2011	80	0	0	80	0	101	2	6	93	0	173
Average[b]	***60***	***1***	***3***	***54***	***2***	***94***	***3***	***9***	***80***	***2***	***134***
Median[b]	***45***	***0***	***1***	***43***	***0***	***75***	***1***	***3***	***53***	***0***	***94***
2012	75	1	1	73	0	41	3	0	38	0	111
2013	170	5	0	70	95	52	1	50	0	1	70
2014[d]	61	0	0	61	0	203	1	68	134	0	195
2015[e]	81	1	7	72	1	47	0	3	37	7	109
2016	62	0	0	62	0	61	2	24	37	0	99
Average[c]	***90***	***1***	***2***	***68***	***19***	***81***	***1***	***29***	***49***	***2***	***117***
Median[c]	***75***	***1***	***0***	***70***	***0***	***52***	***1***	***24***	***37***	***0***	***109***

[a] Pre-spawn loss represents the number of fish that died during the holding period before spawning. Mortality is the number of fish that were surplused following spawning.
[b] The average and median represent the program before recalculation in 2011.
[c] The average and median represent the current program, which began in 2012. Origin determinations should be considered preliminary pending scale analyses.
[d] HOR Chiwawa spring Chinook were collected to meet both Chiwawa and Nason Creek obligations; broodstock and subsequent progeny were pooled together in the hatchery. About 12 Chiwawa HOR's were used to fulfill the Chiwawa Program; about 122 Chiwawa HOR's were used to fulfill the Nason Creek safety net obligation.
[e] For the Chiwawa program, 36 hatchery-origin returns were collected in case the program fell short on natural-origin returns. After eye-up, all of the hatchery-origin recruit eggs were culled because fecundity of natural-origin recruits was high enough to meet the WxW program.

Age/Length Data

Ages were determined from scales and/or coded wire tags (CWT) collected from broodstock. For both the 2014 and 2015 returns, most adults, regardless of origin, were age-4 Chinook (Table 5.2). All age-5 Chinook were natural-origin fish; hatchery-origin Chinook were all age-4 fish. There were no age-3 natural or hatchery-origin fish collected for broodstock.

Table 5.2. Percent of hatchery and wild spring Chinook of different ages (total age) collected from broodstock, 1991-2015.

Return year	Origin	Total age			
		2	3	4	5
1991	Wild	0.0	0.0	22.0	78.0
	Hatchery	0.0	0.0	0.0	0.0
1992	Wild	0.0	0.0	28.6	71.4
	Hatchery	0.0	0.0	50.0	50.0
1993	Wild	0.0	0.0	22.0	78.0
	Hatchery	0.0	0.0	0.0	0.0
1994	Wild	0.0	0.0	28.6	71.4
	Hatchery	0.0	0.0	50.0	50.0
1995	Wild	No program			
	Hatchery				

Return year	Origin	Total age			
		2	3	4	5
1996	Wild	0.0	28.6	71.4	0.0
	Hatchery	0.0	50.0	50.0	0.0
1997	Wild	0.0	0.0	87.5	12.5
	Hatchery	0.0	1.2	98.8	0.0
1998	Wild	0.0	0.0	63.6	36.4
	Hatchery	0.0	0.0	62.9	37.1
1999	Wild	No program			
	Hatchery				
2000	Wild	0.0	20.0	70.0	10.0
	Hatchery	0.0	59.1	40.9	0.0
2001	Wild	0.0	2.8	94.4	2.8
	Hatchery	0.0	1.5	98.5	0.0
2002	Wild	0.0	0.0	66.7	33.3
	Hatchery	0.0	0.0	93.4	6.6
2003	Wild	0.0	27.0	2.7	70.3
	Hatchery	0.0	21.3	5.3	73.3
2004	Wild	1.0	6.1	88.8	4.1
	Hatchery	0.0	40.4	59.6	0.0
2005	Wild	0.0	1.0	85.0	14.0
	Hatchery	0.0	4.4	95.6	0.0
2006	Wild	0.0	2.0	70.4	27.6
	Hatchery	0.0	1.3	81.2	17.4
2007	Wild	0.0	15.6	53.3	31.1
	Hatchery	0.0	27.4	60.5	12.1
2008	Wild	0.0	6.3	78.8	15.0
	Hatchery	0.0	8.2	86.8	4.9
2009	Wild	0.0	8.6	79.0	12.4
	Hatchery	0.0	18.5	79.5	2.0
2010	Wild	0.0	5.3	94.7	0.0
	Hatchery	0.0	0.0	99.0	1.0
2011	Wild	0.0	2.7	52.7	44.6
	Hatchery	0.0	20.4	60.2	19.4
2012	Wild	0.0	0.0	79.0	21.0
	Hatchery	0.0	4.3	95.7	0.0
2013	Wild	0.0	0.0	65.7	34.3
	Hatchery	0.0	2.2	86.7	11.1
2014	Wild	0.0	0.0	91.2	8.8
	Hatchery[a]	0.0	0.0	98.5	1.5

Return year	Origin	Total age			
		2	3	4	5
2015	Wild	0.0	0.0	88	11.0
	Hatchery[a]	0.0	0.0	100	0.0
Average	***Wild***	***0.0***	***5.5***	***64.5***	***29.9***
	Hatchery	***0.0***	***11.3***	***67.5***	***12.5***
Median	***Wild***	***0.0***	***1.0***	***70.4***	***21.0***
	Hatchery	***0.0***	***1.5***	***79.5***	***1.5***

[a] Comprised of age results for both Chiwawa and Nason Creek obligations.

There was little difference in mean lengths between hatchery and natural-origin broodstock of age-4 Chinook in 2014 and 2015; however, age-5 natural-origin Chinook in 2014 were larger than hatchery-origin broodstock (Table 5.3). All age-5 Chinook in 2015 were natural-origin fish.

Table 5.3. Mean fork length (cm) at age (total age) of hatchery and wild spring Chinook collected from broodstock, 1991-2015; N = sample size and SD = 1 standard deviation.

Return year	Origin	Spring Chinook fork length (cm)											
		Age-2			Age-3			Age-4			Age-5		
		Mean	N	SD	Mean	N	SD	Mean	N	SD	Mean	N	SD
1991	Wild	-	0	-	-	5	-	-	19	-	-	8	-
	Hatchery	-	0	-	-	0	-	-	0	-	-	0	-
1992	Wild	-	0	-	-	0	-	-	0	-	-	0	-
	Hatchery	-	0	-	-	0	-	-	0	-	-	0	-
1993	Wild	-	0	-	-	0	-	79	4	3	92	8	4
	Hatchery	-	0	-	-	0	-	-	0	-	-	0	-
1994	Wild	-	0	-	-	0	-	79	2	3	96	5	6
	Hatchery	-	0	-	-	0	-	82	2	11	92	2	2
1995	Wild	No program											
	Hatchery												
1996	Wild	-	0	-	51	2	1	79	5	7	-	0	-
	Hatchery	-	0	-	56	5	4	74	5	6	-	0	-
1997	Wild	-	0	-	-	0	-	80	28	5	99	4	8
	Hatchery	-	0	-	56	1	-	82	82	4	-	0	-
1998	Wild	-	0	-	-	0	-	78	7	13	83	4	18
	Hatchery	-	0	-	-	0	-	77	22	8	93	13	7
1999	Wild	No program											
	Hatchery												
2000	Wild	-	0	-	51	2	3	82	7	4	98	1	-
	Hatchery	-	0	-	59	13	4	79	9	8	-	0	-
2001	Wild	-	0	-	49	3	6	82	101	6	95	3	3
	Hatchery	-	0	-	56	4	7	83	261	5	-	0	-

Return year	Origin	Spring Chinook fork length (cm)											
		Age-2			Age-3			Age-4			Age-5		
		Mean	N	SD	Mean	N	SD	Mean	N	SD	Mean	N	SD
2002	Wild	-	0	-	-	0	-	79	12	4	96	6	10
	Hatchery	-	0	-	-	0	-	81	57	6	94	4	9
2003	Wild	-	0	-	55	10	5	83	1	-	99	26	6
	Hatchery	-	0	-	59	16	5	86	4	18	96	55	6
2004	Wild	47	1	-	60	6	6	80	87	5	99	4	3
	Hatchery	-	0	-	51	80	7	80	118	5	-	0	-
2005	Wild	-	0	-	49	1	-	80	85	6	96	14	8
	Hatchery	-	0	-	56	8	5	82	175	6	-	0	-
2006	Wild	-	0	-	50	2	2	79	69	7	97	27	5
	Hatchery	-	0	-	46	1	-	80	205	6	95	43	7
2007	Wild	-	0	-	54	7	3	79	24	6	93	14	7
	Hatchery	-	0	-	59	34	8	81	75	5	93	15	7
2008	Wild	-	0	-	54	5	9	83	63	5	93	12	6
	Hatchery	-	0	-	56	20	10	82	211	6	96	12	7
2009	Wild	-	0	-	52	9	6	81	83	5	94	13	6
	Hatchery	-	0	-	56	28	6	82	120	5	87	3	11
2010	Wild	-	0	-	58	4	9	80	72	6	-	0	-
	Hatchery	-	0	-	-	0	-	82	102	6	101	1	-
2011	Wild	-	0	-	56	2	3	79	39	5	95	33	7
	Hatchery	-	0	-	63	21	7	80	62	6	95	20	6
2012	Wild	-	0	-	-	0	-	81	49	6	97	13	8
	Hatchery	-	0	-	51	2	0	80	41	5	-	0	-
2013	Wild	-	0	-	-	1	-	74	44	6	92	23	8
	Hatchery	-	0	-	60	1	-	78	39	6	88	5	7
2014	Wild	-	0	-	-	0	-	82	52	7	93	5	6
	Hatchery[a]	-	0	-	-	0	-	81	192	6	85	3	2
2015	Wild	-	0	-	-	0	-	83	45	4	93	10	5
	Hatchery	-	0	-	-	0	-	80	35	6	-	0	-
Average	***Wild***	***47***	***0***	***-***	***53***	***3***	***5***	***80***	***39***	***6***	***95***	***10***	***7***
	Hatchery	***-***	***0***	***-***	***56***	***10***	***6***	***81***	***79***	***7***	***93***	***8***	***6***

[a] Comprised of age results from HOR's used for both Chiwawa and Nason Creek obligations.

Sex Ratios

Male spring Chinook in the 2014-2016 return years made up 49.2%, 53.5%, and 47.2%, respectively, of the adults collected. This resulted in overall male to female ratios of 0.97:1.00, 1.15:1.00, and 0.89:1.00, respectively (Table 5.4). For the 2016 return year, natural-origin and hatchery-origin fish both consisted of a slightly lower proportion of males than females (Table 5.4).

Table 5.4. Numbers of male and female wild and hatchery spring Chinook collected for broodstock, 1989-2016. Ratios of males to females are also provided.

Return year	Number of wild spring Chinook			Number of hatchery spring Chinook			Total M/F ratio
	Males (M)	Females (F)	M/F	Males (M)	Females (F)	M/F	
1989	11	17	0.65:1.00	-	-	-	0.65:1.00
1990	7	12	0.58:1.00	-	-	-	0.58:1.00
1991	13	19	0.68:1.00	-	-	-	0.68:1.00
1992	39	39	1.00:1.00	-	-	-	1.00:1.00
1993	50	50	1.00:1.00	-	-	-	1.00:1.00
1994	5	4	1.25:1.00	2	2	1.00:1.00	1.17:1.00
1995	No program						
1996	6	2	3.00:1.00	8	2	4.00:1.00	3.50:1.00
1997	14	23	0.61:1.00	34	49	0.69:1.00	0.67:1.00
1998	9	4	2.25:1.00	18	17	1.06:1.00	1.29:1.00
1999	No program						
2000	5	5	1.00:1.00	32	6	5.33:1.00	3.36:1.00
2001	45	70	0.64:1.00	90	177	0.51:1.00	0.55:1.00
2002	9	12	0.75:1.00	30	33	0.91:1.00	0.87:1.00
2003	28	16	1.75:1.00	42	33	1.27:1.00	1.43:1.00
2004	58	42	1.38:1.00	102	94	1.09:1.00	1.18:1.00
2005	58	40	1.45:1.00	89	96	0.93:1.00	1.08:1.00
2006	49	46	1.07:1.00	123	179	0.69:1.00	0.77:1.00
2007	20	25	0.80:1.00	66	58	1.14:1.00	1.04:1.00
2008	41	47	0.87:1.00	109	132	0.83:1.00	0.84:1.00
2009	53	60	0.88:1.00	79	72	1.10:1.00	1.00:1.00
2010	41	42	0.98:1.00	53	50	1.06:1.00	1.02:1.00
2011	38	42	0.90:1.00	53	48	1.10:1.00	1.01:1.00
2012	35	40	0.87:1.00	20	21	0.95:1.00	0.90:1.00
2013	83	87	0.95:1.00	26	26	1.00:1.00	0.96:1.00
2014[a]	29	32	0.91:1.00	101	102	0.99:1.00	0.97:100
2015	44	36	1.22:1.00	24	23	1.04:1.00	1.15:1.00
2016	29	33	0.88:1.00	29	32	0.90:1.00	0.89:1.00
Total	***819***	***845***	***0.97:1.00***	***1,130***	***1,252***	***0.90:1.00***	***0.93:1.00***

[a] Comprised of HOR's used for both Chiwawa and Nason Creek obligations.

Fecundity

Mean fecundities for the 2014-2016 returns of spring Chinook ranged from 4,045-4,847 eggs per female (Table 5.5). These fecundities were generally more than the overall average of 4,655 eggs per female, but were close to the expected fecundity of 4,400 eggs per female assumed in the broodstock protocols. For the 2016 return year, natural-origin Chinook produced more eggs per female than did hatchery-origin fish. This could be attributed to differences in size and age of hatchery and natural-origin fish described above (Tables 5.2 and 5.3).

Table 5.5. Mean fecundity of wild, hatchery, and all female spring Chinook collected for broodstock, 1989-2016; NA = not available.

Return year	Mean fecundity		
	Wild	**Hatchery**	**Total**
1989*	NA	NA	2,832
1990*	NA	NA	5,024
1991*	NA	NA	4,600
1992*	NA	NA	5,199[a]
1993*	NA	NA	5,249
1994*	NA	NA	5,923
1995	No program		
1996*	NA	NA	4,645
1997	4,752	4,479	4,570
1998	5,157	5,376	5,325
1999	No program		
2000	5,028	5,019	5,023
2001	4,530	4,663	4,624
2002	5,024	4,506	4,654
2003	6,191	5,651	5,844
2004	4,846	4,775	4,799
2005	4,365	4,312	4,327
2006	4,773	4,151	4,324
2007	4,656	4,351	4,441
2008	4,691	4,560	4,592
2009	4,691	4,487	4,573
2010	4,548	4,114	4,314
2011	4,969	3,884	4,385
2012	4,522	3,682	4,223
2013	4,716	No program	4,716
2014	4,467	3,834	4,045
2015	5,132	4,278	4,847
2016	4,674	4,126	4,467
Average	***4,828***	***4,458***	***4,655***
Median	***4,716***	***4,415***	***4,583***

* Individual fecundities were not tracked with females until 1997.
[a] Estimated as the mean of fecundities two years before and two years after 1992.

5.2 Hatchery Rearing

Rearing History

Number of eggs taken

Based on the unfertilized egg-to-release survival standard of 81%, a total of 829,630 eggs were required to meet the program release goal of 672,000 smolts for brood years 1989-2010. For the 2011 and 2012 brood years, a total of 367,536 and 252,410 eggs were required to meet the release goals of 298,000 and 204,452 smolts, respectively. Since 2013, 169,442 eggs have been required to achieve a release goal of 144,026 smolts for the Chiwawa spring Chinook Program. Between 1989 and 2016, the egg take goal was reached only in 2001, 2015, and 2016[10] (Table 5.6). The green egg takes for 2014-2016 brood years were 99.7%, 109.0%, and 109.0% of program goals, respectively.

At the beginning of the Chiwawa spring Chinook program, the production level was set at 372,000 smolts. The primary reason for not meeting the egg take requirements included a lack of returning hatchery adults (because of program start up) and low wild fish abundance (along with no weir in the Chiwawa for first few years). Post ESA listing and issuance of Section 10(a)(1(A) permit 1196 in 1999, continued low abundance (hatchery and natural origin), as well as the permit limitation requiring a minimum of 33% natural-origin fish in the broodstock further constrained meeting the requisite egg take goal for a 672,000 program. In 2010, it was expected that recalculation of the mitigation obligation beginning with the 2012 brood year was going to result in a significant reduction in the production level and the Hatchery Committees subsequently agreed to reduce the production target to 298,000 in advance of recalculation to increase the likelihood of meeting the overall production goal. In 2011, the Joint Fisheries Parties developed the Wenatchee Basin Spring Chinook Management Plan, which split the program into a conservation and safety-net component; the conservation program using natural origin fish to meet recovery objectives and the safety net using returning adults from the conservation program to satisfy the balance of the production requirement.

Per amended Section 10(a)(1)(A) permit 18121, natural-origin broodstock is currently collected for the Chiwawa spring Chinook Program using PIT-tagged wild fish (tagged as juveniles) intercepted at Tumwater Dam and at the Chiwawa Weir. Operational limitations (e.g., flows, days per season, and bull trout encounters) reduce the opportunity to meet the natural-origin broodstock requirement, particularly in years of low adult abundance. Subsequently, to ensure the mitigation obligation is met, a component of hatchery adult returns are trapped and retained from Tumwater Dam during broodstock collection for the Nason Creek Program, which uses a composited broodstock (for the conservation component) identified through genetic analysis. The genetic analysis is used to prioritize those adults assigned with the highest probability to either the Nason or Chiwawa spawning aggregates, and excludes those assigned to the White River spawning aggregate.

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[10] In 2016, the natural-origin egg-take goal was not achieved, but the program egg-take goal was achieved.

Table 5.6. Numbers of eggs taken from spring Chinook broodstock, 1989-2016; NP = no program.

Return year	Number of eggs taken for the Chiwawa Program
1989	45,311
1990	60,287
1991	73,601
1992	111,624
1993	257,208
1994	35,539
1995	NP
1996	18,579
1997	312,182
1998	90,521
1999	NP
2000	55,256
2001	1,099,630
2002	196,186
2003	247,501
2004	538,176
2005	536,490
2006	744,344
2007	359,739
2008	761,821
2009	564,912
2010	383,944
2011	366,244
Average (1989-2011)	***326,624***
Median (1989-2011)	***257,208***
2012	250,695
2013	165,047
2014	163,358
2015	184,734
2016*	184,712
Average (2012-present)	***189,709***
Median (2012-present)	***184,712***

* Although the program egg-take goal was achieved, the natural-origin egg-take goal was not.

Number of acclimation days

Early rearing of the 2014 brood Chiwawa spring Chinook was similar to previous years with fish being held on well water before being transferred to the Chiwawa Acclimation Facility for final acclimation. Beginning in 2006 (2005 brood acclimation), modifications were made to the Chiwawa Acclimation Facility intakes so that Wenatchee River water could be applied to the Chiwawa River intakes during severe cold periods to prevent the formation of frazzle ice. During acclimation of the 2014 brood, fish were acclimated for 190 to 198 days on Chiwawa River water (Table 5.7).

Table 5.7. Number of days spring Chinook broods were acclimated and water source, brood years 1989-2014; NA = not available.

Brood year	Release year	Transfer date	Release date	Number of days and water source		
				Total	Chiwawa	Wenatchee
1989	1991	19-Oct	11-May	204	NA	NA
1990	1992	13-Sep	27-Apr	227	NA	NA
1991	1993	24-Sep	24-Apr	212	NA	NA
1992	1994	30-Sep	20-Apr	202	NA	NA
1993	1995	28-Sep	20-Apr	204	NA	NA
1994	1996	1-Oct	25-Apr	207	NA	NA
1995	1997	No Program				
1996	1998	25-Sep	29-Apr	216	NA	NA
1997	1999	28-Sep	22-Apr	206	NA	NA
1998	2000	27-Sep	24-Apr	210	NA	NA
1999	2001	No Program				
2000	2002	26-Sep	25-Apr	211	NA	NA
2001	2003	22-Oct	1-May	191	NA	NA
2002	2004	25-Sep	2-May	220	NA	NA
2003	2005	30-Sep	3-May	215	NA	NA
		30-Sep	18-Apr-18-May	200	NA	NA
2004	2006	3-Sep	1-May	240	88-104	124
		3-Sep	17-Apr-17-May	226	NA	NA
2005	2007	25-Sep	1-May	217	217	98[a]
		26-Sep	16-Apr-15-May	202-232	202-232	98[a]
2006	2008	24-27-Sep	14-Apr-13-May	231	231	95[a]
2007	2009	1-Oct	15-Apr-13-May	223	223	103[a]
2008	2010	14-15-Sep	14-Apr-12-May	212-241	212-241	129
2009	2011	14-15-Sep	26-Apr-19-May	225-249	225-249	88

Brood year	Release year	Transfer date	Release date	Number of days and water source		
				Total	Chiwawa	Wenatchee
2010	2012	3, 5-6-Oct	17-Apr-1-May	195-212	195-212	132
2011	2013	24-26-Sep	16-22-Apr	202-210	202-210	40
2012	2014	23-25-Sep	14-21-Apr	204-211	204-211	107[a]
2013	2015	29-Sep	13-20-Apr	196-203	196-203	0
2014	2016	5-8-Oct	15-20-Apr	190-198	190-198	0

[a] Represents the number of days Wenatchee River water was applied to the Chiwawa River intake screen to prevent the formation of frazzle ice.

Release Information

Numbers released

The 2014 brood Chiwawa spring Chinook program achieved 100% of the 144,026 goal with about 144,360 smolts (126,330 WxW and 18,030 HxH) being released volitionally into the Chiwawa River in 2016 (Table 5.8). Water-intake issues with the Nason spring Chinook program resulted in the transfer of the safety-net program to the Chiwawa Acclimation Facility. Release numbers in Table 5.8 reflect the inclusion of Nason Spring Chinook.

Table 5.8. Numbers of spring Chinook smolts tagged and released from the hatchery, brood years 1989-2013. The release target for Chiwawa spring Chinook is 144,026 smolts. For brood years 2012 to present, conservation program fish are not adipose fin clipped (they receive CWT only).

Brood year	Release year	Type of release	CWT mark rate	Number released that were PIT tagged	Number of smolts released	Total number of smolts released
1989	1991	Volitional	0.9932	0	43,000	43,000
1990	1992	Volitional	0.9931	0	53,170	53,170
1991	1993	Volitional	0.9831	0	62,138	62,138
1992	1994	Volitional	0.9747	0	85,113	85,113
1993	1995	Volitional	0.9892	0	223,610	223,610
1994	1996	Volitional	0.9967	0	27,226	27,226
1995	1997	No program				
1996	1998	Forced	0.8413	0	15,176	15,176
1997	1999	Volitional	0.9753	0	266,148	266,148
1998	2000	Volitional	0.9429	0	75,906	75,906
1999	2001	No program				
2000	2002	Volitional	0.9920	0	47,104	47,104
2001	2003	Forced	0.9961	0	192,490[a]	377,544
		Volitional	0.9856	0	185,054[a]	
2002	2004	Volitional	0.9693	0	149,668	149,668
2003	2005	Forced	0.9783	0	69,907	222,131

Brood year	Release year	Type of release	CWT mark rate	Number released that were PIT tagged	Number of smolts released	Total number of smolts released
		Volitional	0.9743	0	152,224	
2004	2006	Forced	0.9533	0	243,505	494,517
		Volitional	0.9493	0	251,012	
2005	2007	Forced	0.9882	4,993	245,406	494,012
		Volitional	0.9864	4,988	248,606	
2006	2007	Direct	0.0000	0	12,977[b]	612,482
	2008	Volitional	0.9795	9,894	612,482	
2007	2008	Direct	0.0000	0	9,494	305,542
	2009	Volitional	0.9948	10,035	296,048	
2008	2010	Volitional	0.9835	10,006	609,789	609,789
2009	2011	Forced	0.9874	0	241,181	438,561
		Volitional	0.9874	9,412	197,380	
2010[c]	2012	Volitional	0.9904	5,020	346,248	346,248
2011	2013	Volitional	0.9902	9,945	281,821	281,821
2012[d]	2014	Volitional	0.9841	5,061	222,504	222,504
2013[d]	2015	Volitional	0.9753	10,021	147,480	147,480
2014[d]	2016	Volitional	0.9818	10,179	144,360	341,226[e]
		Volitional	0.9853	0	196,866[f]	

[a] This does not include the 226,456 eyed eggs that were planted in the Chiwawa River.
[b] This high ELISA group was only adipose fin clipped and directly planted into Big Meadow Creek in May.
[c] This does not include 18,480 eyed eggs that were culled because of high ELISA.
[d] Brood years 2013 to present WxW spring Chinook are not adipose fin clipped (they receive CWT only); HxH Chinook are adipose fin clipped and receive a CWT.
[e] The total number of smolts released includes the HxH Nason Creek program that was transferred to the Chiwawa Acclimation Facility on 2-3 March 2016 because of water-intake concerns at the Nason Creek Acclimation Facility.
[f] The HxH Nason Creek program that was released from the Chiwawa Acclimation Facility.

Numbers tagged

The 2014 brood Chiwawa spring Chinook were 98% CWT (Table 5.8).

In 2016, a total of 10,207 WxW Chiwawa spring Chinook from the 2015 brood were PIT tagged at Eastbank Hatchery on 11-14 July 2016. These were tagged and released into raceway #11. Fish were not fed during tagging or for two days before and after tagging. Fish averaged 87 mm in length and 8.0 g at time of tagging. These fish were transferred to the Chiwawa Acclimation Facility in October 2016.

Table 5.9 summarizes the number of hatchery spring Chinook that have been PIT-tagged and released into the Chiwawa River.

Table 5.9. Summary of PIT-tagging activities for Chiwawa hatchery spring Chinook, brood years 2005-2014.

Brood year	Release year	Number of fish tagged	Number of tagged fish that died	Number of tags shed	Number of tagged fish released
2005	2007	10,063	74	8	9,981[a]
2006	2008	10,055	134	27	9,894
2007	2009	10,112	61	16	10,035
2008	2010	10,101	81	14	10,006
2009	2011	10,101	655	34	9,412
2010	2012	5,102	82	0	5,020
2011	2013	10,200	254	1	9,945
2012	2014	5,100	37	2	5,061
2013	2015	10,114	93	0	10,021
2014	2016	10,200	21	0	10,179

[a] This release consisted of 4,988 tagged Chinook that were released volitionally and 4,993 that were forced released.

Fish size and condition at release

Spring Chinook from the 2014 brood were released as yearling smolts between 15 and 20 April 2016. Size at release (13 fpp) was larger than the target of 18 fpp established for the program. The CV for fork length was 55% over the target (Table 5.10).

Table 5.10. Mean lengths (FL, mm), weight (g and fish/pound), and coefficient of variation (CV) of spring Chinook smolts released from the hatchery, brood years 1989-2014. Size targets are provided in the last row of the table.

Brood year	Release year	Fork length (mm)		Mean weight	
		Mean	CV	Grams (g)	Fish/pound
1989	1991	147	4.4	37.8	12
1990	1992	137	5.0	32.4	14
1991	1993	135	4.2	30.3	15
1992	1994	133	5.0	28.4	16
1993	1995	136	4.5	30.2	15
1994	1996	139	7.1	34.4	13
1995	1997	No Program			
1996	1998	157	5.3	52.1	9
1997	1999	146	7.2	38.7	12
1998	2000	143	9.1	39.5	12
1999	2001	No Program			
2000	2002	150	6.8	46.7	10
2001	2003	142	7.1	37.6	12
2002	2004	146	8.5	40.3	11

Brood year	Release year	Fork length (mm)		Mean weight	
		Mean	CV	Grams (g)	Fish/pound
2003	2005	167[a]	5.9	59.4	8
		151[b]	7.4	44.2	10
2004	2006	146[a]	6.4	39.1	12
		139[b]	5.7	34.3	13
2005	2007	136[a]	4.6	30.8	15
		129[b]	5.8	26.6	17
2006	2008	124	8.8	23.5	19
2007	2008	70[a]	4.0	3.7	122
	2009	140[b]	11.0	33.6	14
2008	2010	141	10.7	36.0	13
2009	2011	167	12.9	56.8	8
2010	2012	129	8.1	25.8	18
2011	2013	134	6.4	29.5	15
2012	2014	130	6.7	28.5	16
2013	2015	130	8.2	25.3	18
2014[c]	2016	141	16.3	34.8	13
Average		***140***	***7.3***	***35.0***	***17***
Median		***140***	***6.8***	***34.4***	***13***
Targets		***155***	***9.0***	***37.8***	***18***

[a] Forced-release group.
[b] Volitional-release group.
[c] This represents the combination of the WxW Chiwawa, HxH Chiwawa, and the HxH Nason Creek programs. The HxH Nason Creek program was transferred to the Chiwawa Acclimation Facility on 2-3 March 2016 because of water-intake concerns at the Nason Creek Acclimation Facility.

Survival Estimates

Overall survival of the 2014 brood Chiwawa spring Chinook from green (unfertilized) egg to release was above the standard set for the program (Table 5.11). There was higher than expected survivals throughout most stages except unfertilized to eye-egg, contributing to increased program performance. Pre-spawn survival of adults was also above the standard set for the program.

Table 5.11. Hatchery life-stage survival rates (%) for spring Chinook, brood years 1989-2014. Survival standards or targets are provided in the last row of the table.

Brood year	Collection to spawning		Unfertilized egg-eyed	Eyed egg-ponding	30 d after ponding	100 d after ponding	Ponding to release	Transport to release	Unfertilized egg-release
	Female	Male							
1989	100.0	100.0	98.0	99.1	99.1	99.0	96.4	99.3	94.8
1990	100.0	85.7	91.8	98.1	99.5	98.9	97.9	99.2	88.2
1991	100.0	100.0	94.4	96.1	99.6	97.9	93.2	95.0	84.4
1992	100.0	100.0	98.4	96.7	99.9	99.9	80.0	80.6	76.2
1993	96.0	98.0	89.7	98.0	99.7	99.3	98.9	99.7	86.9

Brood year	Collection to spawning		Unfertilized egg-eyed	Eyed egg-ponding	30 d after ponding	100 d after ponding	Ponding to release	Transport to release	Unfertilized egg-release
	Female	Male							
1994	100.0	100.0	98.6	100.0	99.8	99.4	77.0	78.9	76.6
1995	No program								
1996	100.0	100.0	88.3	100.0	93.8	93.0	89.9	97.7	81.7
1997	98.6	100.0	93.2	95.7	98.3	99.6	95.6	99.3	85.3
1998	95.2	100.0	94.5	99.0	98.5	98.3	89.6	99.1	83.9
1999	No program								
2000	100.0	100.0	91.0	98.1	97.2	96.6	95.4	99.3	85.2
2001	97.6	97.0	88.9	98.1	99.7	99.6	51.3	51.8	34.3
2002	97.8	100.0	82.1	98.0	97.4	96.7	94.8	99.1	76.3
2003	93.9	100.0	93.2	97.7	99.5	99.3	98.5	98.1	89.7
2004	97.8	82.5	93.3	98.4	98.8	94.3	93.9	97.2	91.9
2005	97.1	100.0	95.9	98.0	99.2	99.0	97.9	99.1	92.1
2006	100.0	100.0	90.1	98.1	99.2	99.0	95.3	97.7	84.2
2007	98.8	97.7	92.9	97.2	99.4	99.0	98.0	99.4	88.5
2008	96.6	99.3	90.8	93.2	97.4	97.1	95.6	97.6	80.0
2009	94.4	97.6	92.5	88.3	97.6	97.4	89.2	92.8	77.6
2010[a]	98.9	100.0	99.2	100.0	97.9	97.5	95.6	98.2	94.8
2011	98.9	98.9	93.2	88.4	96.8	96.4	93.4	97.1	76.9
2012	98.3	100.0	94.6	98.3	99.7	99.3	98.5	99.4	91.6
2013	91.7	94.6	96.5	97.0	97.9	96.8	95.5	98.9	89.4
2014[b]	100.0	100.0	91.1	98.8	99.6	99.1	98.0	99.3	88.3
Average	***98.0***	***98.0***	***93.0***	***97.1***	***98.6***	***98.0***	***92.1***	***94.7***	***83.3***
Median	***98.7***	***100.0***	***93.2***	***98.1***	***99.2***	***99.0***	***95.5***	***98.6***	***85.3***
Standard	***90.0***	***85.0***	***92.0***	***98.0***	***97.0***	***93.0***	***90.0***	***95.0***	***81.0***

[a] Survival estimates do not include the 18,840 eyed eggs that were culled because of high ELISA levels.
[b] Survival estimates do not include the HxH Nason Creek program that was transferred to the Chiwawa Acclimation Facility because of water-intake concerns at the Nason Creek Acclimation Facility.

5.3 Disease Monitoring

Results of 2016 adult broodstock bacterial kidney disease (BKD) monitoring indicated that most females had ELISA values less than 0.199. About 81.1% of females had ELISA values less than 0.120, which would have required about 18.9% of the progeny to be reared at densities not to exceed 0.06 fish per pound (Table 5.12).

For the 2014 brood, a formalin drip was used shortly after transfer to the Chiwawa Acclimation Facility to prevent infection associated with stress caused by the transfer. No significant health issues were encountered for the remainder of juvenile rearing.

Table 5.12. Proportion of bacterial kidney disease (BKD) titer groups for the Chiwawa spring Chinook broodstock, brood years 1996-2016. Also included are the proportions to be reared at either 0.125 fish per pound or 0.060 fish per pound.

Brood year[a]	Optical density values by titer group				Proportion at rearing densities (fish per pound, fpp)[b]	
	Very Low (≤ 0.099)	Low (0.1-0.199)	Moderate (0.2-0.449)	High (≥ 0.450)	≤ 0.125 fpp (<0.119)	≤ 0.060 fpp (>0.120)
1996	0.0000	0.2500	0.2500	0.5000	0.0000	1.0000
1997	0.1176	0.7353	0.0588	0.0882	0.3529	0.6471
1998	0.1176	0.8235	0.0588	0.0000	0.4706	0.5294
1999	No Program					
2000	0.0000	0.9091	0.0909	0.0000	0.1818	0.8182
2001	0.4066	0.5436	0.0373	0.0124	0.6515	0.3485
2002	0.2195	0.6585	0.0732	0.0488	0.5610	0.4390
2003	0.6957	0.1087	0.0652	0.1304	0.7174	0.2826
2004	0.8182	0.1515	0.0227	0.0076	0.8939	0.1061
2005	0.9084	0.0916	0.0000	0.0000	0.9695	0.0305
2006	0.7222	0.2556	0.0000	0.0222	0.8444	0.1556
2007	0.5854	0.3415	0.0244	0.0488	0.7073	0.2927
2008	0.8304	0.1520	0.0058	0.0117	0.9357	0.0643
2009	0.7600	0.1840	0.0080	0.0480	0.8480	0.1520
2010	0.8791	0.0769	0.0000	0.0439	0.9451	0.0549
2011	0.7640	0.2022	0.0000	0.0337	0.8764	0.1236
2012	0.8333	0.1333	0.0167	0.0167	0.9170	0.0830
2013	0.0829	0.1429	0.0286	0.0000	0.8857	0.1143
2014[c]	0.8282	0.1720	0.0000	0.0000	0.8889	0.1111
2015	0.9818	0.0000	0.0000	0.0182	0.9818	0.0182
2016	0.7547	0.2075	0.0189	0.0189	0.8113	0.1887
Average	***0.5653***	***0.3070***	***0.0380***	***0.0525***	***0.7220***	***0.2780***
Median	***0.7385***	***0.1931***	***0.0208***	***0.0186***	***0.8462***	***0.1538***

[a] Individual ELISA samples were not collected before the 1996 brood.
[b] ELISA values from broodstock BKD testing dictate what density the progeny of the broodstock are reared. Progeny of broodstock with high ELISA values are reared at lower density.
[c] Comprised of HOR's used for both Chiwawa and Nason Creek obligations.

5.4 Natural Juvenile Productivity

During 2016, juvenile spring Chinook were sampled at the Lower Wenatchee, Nason Creek, White River, and Chiwawa River traps and counted during snorkel surveys within the Chiwawa River basin. Results from sampling at the Nason Creek Trap are provided in Section 6 and from the White River Trap in Section 7.

Parr Estimates

Based on snorkel surveys, a total of 140,172 (±10%) subyearling and 282 (±43%) yearling spring Chinook were estimated in the Chiwawa River basin in August 2016 (Table 5.13 and 5.14). During the survey period 1992-2016, numbers of subyearling and yearling Chinook have ranged from 5,815 to 149,563 and 5 to 967, respectively, in the Chiwawa River basin (Table 5.13 and 5.14; Figure 5.1). Numbers of all fish counted in the Chiwawa River basin are reported in Appendix A.

Table 5.13. Total numbers of subyearling spring Chinook estimated in different streams in the Chiwawa River basin during snorkel surveys in August 1992-2016; NS = not sampled.

Sample Year	Number of subyearling spring Chinook									
	Chiwawa River	Phelps Creek	Chikamin Creek	Rock Creek	Unnamed Creek	Big Meadow Creek	Alder Creek	Brush Creek	Clear Creek	Total
1992	45,483	NS	NS	NS	NS	NS	NS	NS	NS	**45,483**
1993	77,269	0	1,258	586	NS	NS	NS	NS	NS	**79,113**
1994	53,492	0	398	474	68	624	0	0	0	**55,056**
1995	52,775	0	1,346	210	0	683	67	160	0	**55,241**
1996	5,500	0	29	10	0	248	28	0	0	**5,815**
1997	15,438	0	56	92	0	480	0	0	0	**16,066**
1998	65,875	0	1,468	496	57	506	0	13	0	**68,415**
1999	40,051	0	366	592	0	598	22	0	0	**41,629**
2000	NS	NS	NS	NS	NS	NS	NS	NS	NS	**NS**
2001	106,753	168	2,077	2,855	354	2,332	78	0	0	**114,617**
2002	117,230	75	8,233	2,953	636	5,021	429	0	297	**134,874**
2003	80,250	4,508	1,570	3,255	118	1,510	22	45	0	**91,278**
2004	43,360	102	717	215	54	637	21	71	0	**45,177**
2005	45,999	71	2,092	660	17	792	0	0	0	**49,631**
2006	73,478	113	2,500	1,681	51	1,890	62	127	0	**79,902**
2007	53,863	125	5,235	870	51	538	20	28	22	**60,752**
2008	72,431	214	3,287	4,730	163	1,221	28	255	22	**82,351**
2009	101,085	125	2,486	1,849	14	1,082	29	18	17	**106,705**
2010	117,499	526	4,571	4,052	0	1,449	56	42	25	**128,220**
2011	136,424	64	2,762	1,330	53	581	42	214	40	**141,510**
2012	96,036	78	4,125	2,227	49	1,322	35	31	37	**103,940**
2013	140,485	120	3,301	3,214	0	2,345	31	21	46	**149,563**
2014	113,869	361	2,384	3,124	28	1,367	11	28	68	**121,240**
2015	103,710	285	1,917	4,158	0	1,013	71	62	8	**111,224**
2016	135,819	107	1,644	991	0	1,508	20	58	25	**140,172**
Average	***78,924***	***306***	***2,340***	***1,766***	***78***	***1,261***	***49***	***53***	***28***	***84,499***
Median	***75,374***	***102***	***2,077***	***1,330***	***39***	***1,048***	***28***	***28***	***4***	***81,127***

Table 5.14. Total numbers of yearling spring Chinook estimated in different streams in the Chiwawa River basin during snorkel surveys in August 1992-2016; NS = not sampled.

Sample Year	Number of yearling spring Chinook									
	Chiwawa River	Phelps Creek	Chikamin Creek	Rock Creek	Unnamed Creek	Big Meadow Creek	Alder Creek	Brush Creek	Y Creek	Total
1992	563	NS	NS	NS	NS	NS	NS	NS	NS	**563**
1993	174	0	0	0	NS	NS	NS	NS	NS	**174**
1994	14	0	0	4	0	0	0	0	0	**18**
1995	13	0	0	0	0	0	0	0	0	**13**
1996	22	0	0	0	0	0	0	0	0	**22**
1997	5	0	0	0	0	0	0	0	0	**5**
1998	63	0	0	0	0	0	0	0	0	**63**
1999	41	0	0	0	0	0	0	0	0	**41**
2000	NS	NS	NS	NS	NS	NS	NS	NS	NS	**NS**
2001	66	0	3	0	0	0	0	0	0	**69**
2002	32	0	0	0	0	0	0	0	0	**32**
2003	134	0	0	0	0	0	0	0	0	**134**
2004	14	0	0	0	0	7	0	0	0	**21**
2005	62	0	17	0	0	0	0	0	0	**79**
2006	345	0	0	43	0	0	0	0	0	**388**
2007	41	0	0	0	0	0	0	0	0	**41**
2008	144	0	45	0	0	0	0	0	0	**189**
2009	49	0	0	5	0	0	0	0	0	**54**
2010	207	27	19	38	0	0	0	0	0	**291**
2011	645	0	71	194	0	57	0	0	0	**967**
2012	748	0	0	19	0	0	0	0	0	**767**
2013	836	0	0	8	0	8	0	0	0	**852**
2014	867	28	4	38	0	2	0	0	0	**939**
2015	488	0	22	110	0	0	0	0	0	**620**
2016	254	0	0	0	0	28	0	0	0	**282**
Average	***243***	***2***	***8***	***20***	***0***	***5***	***0***	***0***	***0***	***276***
Median	***100***	***0***	***0***	***0***	***0***	***0***	***0***	***0***	***0***	***107***

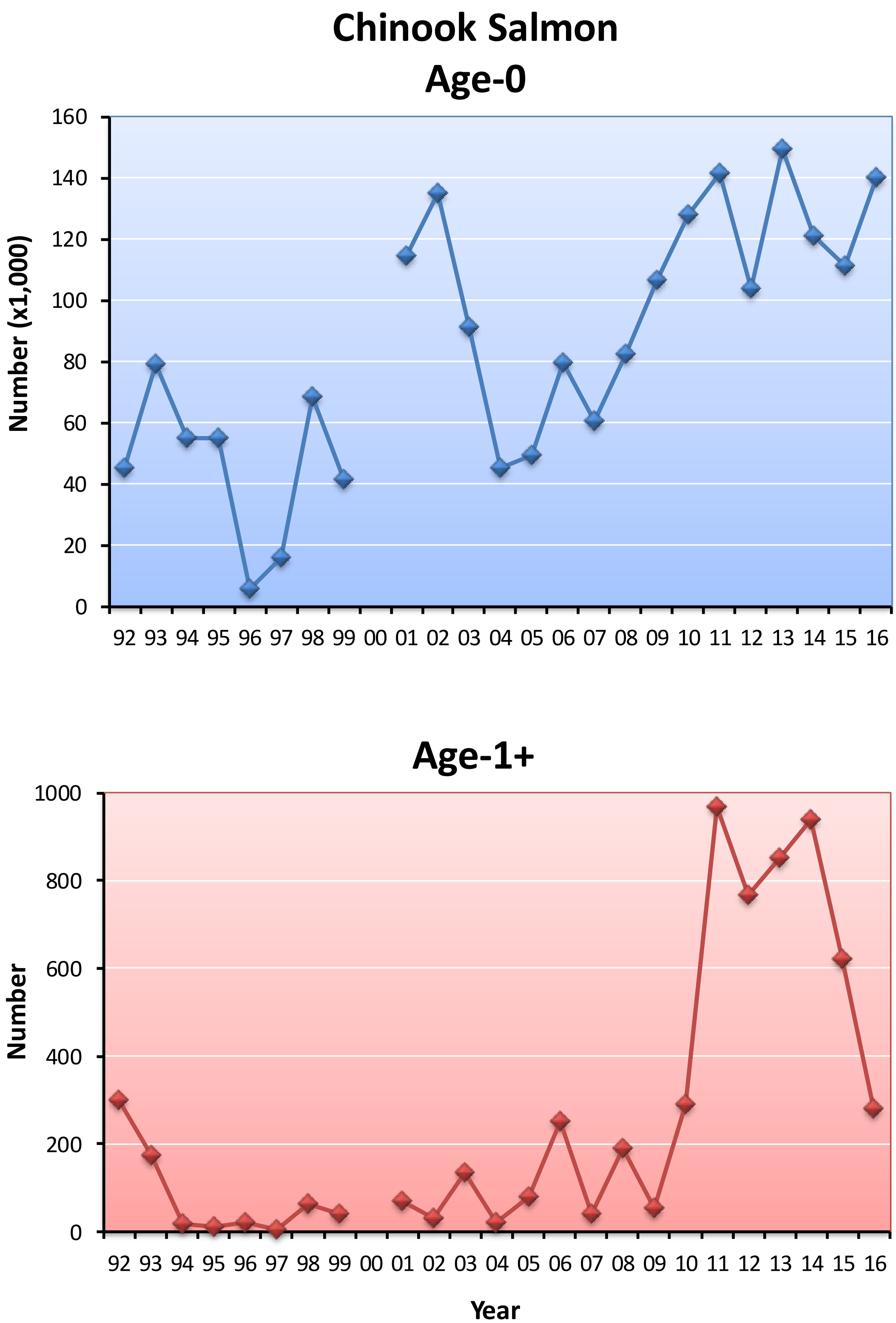


Figure 5.1. Numbers of subyearling and yearling Chinook salmon within the Chiwawa River Basin in August 1992-2016; ND = no data.

Juvenile Chinook were distributed contagiously among reaches in the Chiwawa River. Their densities were highest in the upper portions of the basin, with the highest densities within tributaries. Juvenile Chinook were most abundant in multiple channels and least abundant in glides and riffles. Most Chinook associated closely with woody debris in multiple channels. These sites (multiple channels) made up 16% of the total area of the Chiwawa River basin, but they provided habitat for 56% of all subyearling Chinook in the basin in 2016. In contrast, riffles made up 54% of the total area, but provided habitat for only 8% of all juvenile Chinook in the Chiwawa River basin. Pools made up 24% of the total area and provided habitat for 35% of all juvenile Chinook in the basin. Virtually no Chinook used glides that lacked woody debris.

Mean densities of juvenile Chinook in two reaches of the Chiwawa River were generally less than those in corresponding reference areas on Nason Creek and the Little Wenatchee River (Figure 5.2). Within both the Chiwawa River and its reference areas, pools and multiple channels consistently had the highest densities of juvenile Chinook.

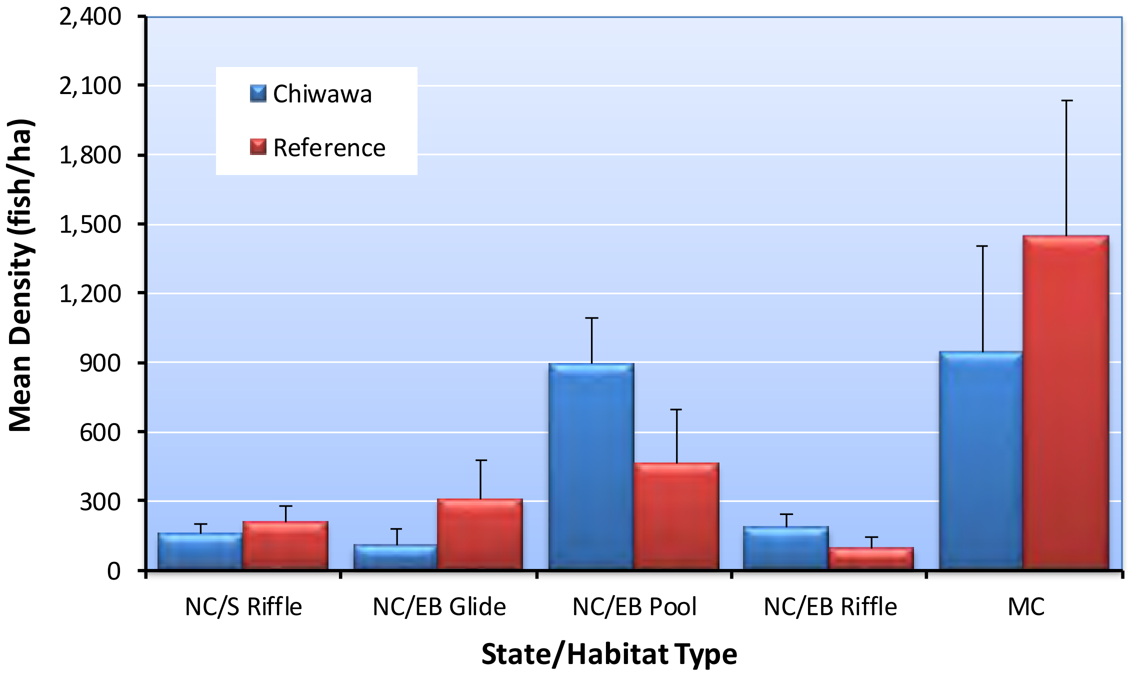


Figure 5.2. Comparison of the 23-year means of subyearling spring Chinook densities within state/habitat types in reaches 3 and 8 of the Chiwawa River and their matched reference areas on Nason Creek and the Little Wenatchee River. NC = natural channel; S = straight channel; EB = eroded banks; MC = multiple channel. There was no sampling in 2000 and no sampling within reference areas in 1992.

Smolt and Emigrant Estimates

Numbers of spring Chinook smolts and emigrants were estimated at the Chiwawa and Lower Wenatchee traps in 2016.

Chiwawa Trap

The Chiwawa Trap operated between 2 March and 21 November 2016. During that time, the trap was inoperable for 72 days because of high and low river flows, debris, major hatchery releases, and mechanical issues. The trap operated in a single position throughout the sampling season. Daily trap efficiencies were estimated for each age class of fish (e.g., subyearling and yearling). The daily number of fish captured was expanded by the estimated trap efficiency to estimate daily total emigration. Monthly captures of all fish and results of mark-recapture efficiency tests at the Chiwawa Trap are reported in Appendix B.

Wild yearling spring Chinook (2014 brood year) were primarily captured in March and April 2016 (Figure 5.3). A significant relationship between trap efficiency and river flow was found (R^2 = 0.875; $P < 0.028$) and the total number of wild yearling Chinook emigrating from the Chiwawa River was estimated at 37,170 (±6,524; 95% CI). Combining the total number of subyearling spring Chinook (77,510 ±9,074) that emigrated during the fall of 2015 with the total number of yearling Chinook (37,170 ±6,524) that emigrated during 2016, the total emigrant estimate for brood year 2014 was 114,680 (± 12,268) (Table 5.15). No non-trapping estimate was calculated for brood year 2014 (see Appendix B).

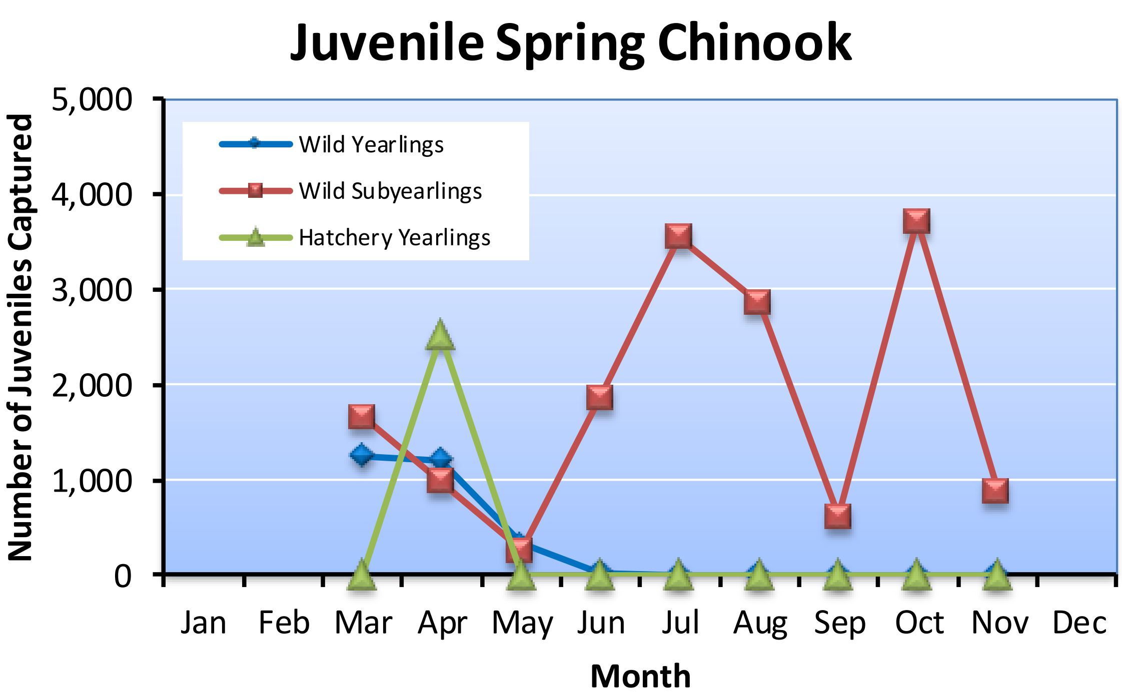


Figure 5.3. Monthly captures of wild subyearling, wild yearling, and hatchery yearling spring Chinook at the Chiwawa Trap, 2016.

Table 5.15. Numbers of redds and juvenile spring Chinook at different life stages in the Chiwawa River basin for brood years 1991-2016; NS = not sampled.

Brood year	Number of redds	Egg deposition	Number of parr	Number of smolts produced within Chiwawa River basin[a]	Number of emigrants
1991	104	478,400	45,483[b]	42,525	NS
1992	302	1,570,098	79,113	39,723	65,541
1993	106	556,394	55,056	8,662	22,698
1994	82	485,686	55,240	16,472	25,067
1995	13	66,248	5,815	3,830	5,951
1996	23	106,835	16,066	15,475	19,183
1997	82	374,740	68,415	28,334	44,562
1998	41	218,325	41,629	23,068	25,923
1999	34	166,090	NS	10,661	15,649
2000	128	642,944	114,617	40,831	55,685
2001	1,078	4,984,672	134,874	86,482	546,266
2002	345	1,605,630	91,278	90,948	184,279
2003	111	648,684	45,177	16,755	33,637
2004	241	1,156,559	49,631	72,080	116,158
2005	332	1,436,564	79,902	69,064	177,659
2006	297	1,284,228	60,752	45,050	107,972
2007	283	1,256,803	82,351	25,809	86,006
2008	689	3,163,888	106,705	35,023	120,184
2009	421	1,925,233	128,220	30,959	61,955
2010	502	2,165,628	141,510	47,511	101,130
2011	492	2,157,420	103,940	37,185	108,832
2012	880	3,716,240	149,563	34,334	109,413
2013	714	3,367,224	121,240	39,396	113,091
2014	485	1,961,825	111,224	37,170	114,680
2015	543	2,631,921	140,172	-	-
Average	***333***	***1,525,131***	***84,499***	***37,389***	***98,327***
Median	***297***	***1,284,228***	***81,127***	***36,097***	***86,006***

[a] The estimated number of smolts (yearlings) that are produced entirely within the Chiwawa River basin. Smolt estimates for brood years 1992-1996 were calculated with a mark-recapture model; brood years 1997-present were calculated with a flow model.
[b] Estimate only includes numbers of Chinook in the Chiwawa River. Tributaries were not sampled at that time.

Wild subyearling spring Chinook (2015 brood year) were captured between March and November 2016. Based on capture efficiencies, the total number of wild subyearling (fry and parr) Chinook from the Chiwawa River basin was 145,971 (±48,393). Removing fry from the estimate, a total of 80,543 (±27,967) subyearling parr emigrated from the Chiwawa River basin in 2016. Although subyearling parr migrated during all months of sampling, the majority (83%) migrated during March, June, July, August, and October (Figure 5.3).

Yearling spring Chinook sampled in 2016 averaged 91 mm in length, 8.3 g in weight, and had a mean condition of 1.06 (Table 5.16). These size estimates were similar to the overall mean of yearling spring Chinook sampled in previous years (overall means: 93 mm, 9.1 g, and condition of 1.08). Subyearling spring Chinook sampled in 2016 at the Chiwawa Trap averaged 71 mm in length, averaged 4.5 g, and had a mean condition of 1.10 (Table 5.16). In general, subyearlings were slightly smaller than previous years (overall means, 76 mm, 5.3 g, and condition of 1.09).

Table 5.16. Mean fork length (mm), weight (g), and condition factor of subyearling (excluding fry) and yearling spring Chinook collected in the Chiwawa Trap, 1996-2016. Numbers in parentheses indicate 1 standard deviation.

Sample year	Life stage	Sample size[a]	Mean size		
			Length (mm)	Weight (g)	Condition (K)
1996	Subyearling	514	78 (25)	6.9 (4.2)	1.11 (0.11)
	Yearling	1,589	94 (9)	9.5 (3.0)	1.11 (0.08)
1997	Subyearling	840	86 (8)	7.5 (2.1)	1.16 (0.08)
	Yearling	1,114	100 (7)	10.2 (2.6)	1.02 (0.10)
1998	Subyearling	3,743	82 (11)	6.2 (2.2)	1.08 (0.09)
	Yearling	2,663	97 (7)	10.3 (2.8)	1.12 (0.23)
1999	Subyearling	569	89 (9)	8.5 (2.4)	1.15 (0.07)
	Yearling	3,664	95 (8)	9.6 (3.4)	1.09 (0.19)
2000	Subyearling	1,810	85 (10)	7.4 (2.4)	1.15 (0.10)
	Yearling	1,891	97 (8)	10.5 (5.2)	1.13 (0.07)
2001	Subyearling	4,657	82 (11)	6.6 (3.4)	1.14 (0.09)
	Yearling	2,935	97 (7)	10.5 (2.4)	1.15 (0.08)
2002	Subyearling	6,130	64 (12)	3.0 (1.6)	1.06 (0.10)
	Yearling	1,735	94 (8)	9.0 (2.3)	1.09 (0.08)
2003	Subyearling	3,679	64 (12)	3.2 (1.7)	1.08 (0.10)
	Yearling	2,657	87 (9)	7.2 (3.5)	1.07 (0.10)
2004	Subyearling	2,278	75 (16)	4.3 (2.1)	0.92 (0.16)
	Yearling	1,032	91 (9)	8.5 (2.7)	1.09 (0.10)
2005	Subyearling	2,702	73 (12)	4.6 (2.2)	1.08 (0.09)
	Yearling	803	96 (9)	9.9 (2.8)	1.08 (0.08)
2006	Subyearling	3,462	76 (11)	5.1 (2.0)	1.12 (0.21)
	Yearling	4,645	95 (7)	9.4 (2.3)	1.10 (0.13)
2007	Subyearling	1,718	72 (12)	4.5 (2.1)	1.13 (0.16)
	Yearling	2,245	91 (8)	8.6 (2.5)	1.10 (0.09)
2008	Subyearling	10,443	79 (12)	5.9 (2.3)	1.15 (0.15)
	Yearling	8,792	93 (7)	8.8 (2.1)	1.08 (0.10)
2009	Subyearling	10,536	75 (10)	5.0 (2.2)	0.91 (0.11)
	Yearling	3,630	92 (7)	8.8 (2.1)	0.89 (0.07)
2010	Subyearling	3,888	77 (12)	5.4 (2.3)	1.11 (0.16)
	Yearling	5,799	91 (8)	8.9 (2.2)	1.15 (0.14)

Sample year	Life stage	Sample size[a]	Mean size		
			Length (mm)	Weight (g)	Condition (K)
2011	Subyearling	6,870	73 (11)	4.8 (2.2)	1.15 (0.16)
	Yearling	4,734	94 (8)	8.7 (2.2)	1.04 (0.10)
2012	Subyearling	8,756	75 (10)	4.8 (2.2)	1.13 (0.28)
	Yearling	7,290	90 (7)	8.0 (2.6)	1.06 (0.24)
2013	Subyearling	10,181	71 (10)	4.1 (1.7)	1.09 (0.39)
	Yearling	3,135	88 (9)	7.7 (2.8)	1.09 (0.20)
2014	Subyearling	7,122	71 (10)	3.7 (1.6)	1.08 (0.10)
	Yearling	3,956	89 (8)	7.7 (2.2)	1.05 (0.08)
2015	Subyearling	15,241	71 (11)	4.2 (2.4)	1.10 (0.39)
	Yearling	6,304	93 (9)	8.8 (2.9)	1.09 (0.15)
2016	Subyearling	12,198	71 (13)	4.5 (2.3)	1.08 (0.08)
	Yearling	2,789	91 (9)	8.3 (3.1)	1.06 (0.26)
Average	***Subyearling***	***5,587***	***76 (12)***	***5.2 (2.3)***	***1.09 (0.15)***
	Yearling	***3,495***	***93 (8)***	***9.0 (2.7)***	***1.08 (0.13)***
Median	***Subyearling***	***3,888***	***75 (11)***	***4.8 (2.2)***	***1.11 (0.11)***
	Yearling	***2,935***	***93 (8)***	***8.8 (2.6)***	***1.09 (0.10)***

[a] Sample size represents the number of fish that were measured for both length and weight.

Lower Wenatchee Trap

The lower Wenatchee Trap operated in a new location beginning in 2013. Hence, historic flow-discharge relationships are invalid and new models to estimate trap efficiency are being developed for all species.

The Lower Wenatchee Trap operated between 29 January and 26 July 2016. During that time, the trap was inoperable for 23 days because of high and low river discharge, debris, elevated river temperature, large hatchery releases, and mechanical issues. During the sampling period, a total of 610 wild yearling Chinook, 27,407 wild subyearling Chinook (mostly summer Chinook), and 7,701 hatchery yearling Chinook were captured at the Lower Wenatchee Trap. Based on capture efficiencies and river discharge, a significant model was developed (R^2 = 0.620, $P < 0.02$). The flow efficiency model estimated the total number of wild yearling Chinook that emigrated past the Lower Wenatchee Trap at 36,752 (±5,330; 95% CI) (Table 5.17). Monthly captures of all fish collected at the Lower Wenatchee Trap are reported in Appendix B.

Table 5.17. Numbers of redds and wild spring Chinook smolts produced in the Wenatchee River basin for brood years 2000-2014; NS = not sampled. From 2000-2010 the trap operated at Monitor; from 2013 to present the trap operated near Cashmere.

Brood year	Number of redds	Egg deposition	Number of smolts produced within Wenatchee River basin
2000	350	1,758,050	76,643
2001	2,109	8,674,624	243,516
2002	1,139	5,300,906	165,116
2003	323	1,887,612	70,738

Brood year	Number of redds	Egg deposition	Number of smolts produced within Wenatchee River basin
2004	574	2,663,445	55,619
2005	830	3,587,083	302,116
2006	588	2,542,512	85,558
2007	466	2,069,506	60,219
2008	1,411	6,479,312	82,137
2009	733	NS	NS
2010	968	NS	NS
2011	872	3,823,720	89,917
2012	1,704	7,195,992	67,973
2013	1,159	5,512,204	58,595
2014	885	3,894,000	36,752
Average	***941***	***4,260,690***	***107,300***
Median	***872***	***3,823,720***	***76,643***

Yearling spring Chinook sampled in 2016 at the Lower Wenatchee Trap averaged 94 mm in length, 9.0 g in weight, and had a mean condition of 1.06 (Table 5.18). These size estimates were similar to the overall mean of yearling spring Chinook sampled in previous years (overall means: 98 mm, 10.5 g, and condition of 1.10).

Table 5.18. Mean fork length (mm), weight (g), and condition factor of yearling spring Chinook collected in the Lower Wenatchee Trap, 2000-2016. From 2000-2010 the trap operated at Monitor; from 2013 to present the trap operated near Cashmere. Numbers in parentheses indicate 1 standard deviation.

Sample year	Sample size[a]	Mean size		
		Length (mm)	Weight (g)	Condition (K)
2000	29	111 (15.1)	15.6 (7.4)	1.15 (0.1)
2001	204	106 (9.6)	13.0 (3.6)	1.10 (0.1)
2002	301	99 (10.0)	10.7 (3.3)	1.11 (0.1)
2003	1,427	96 (9.4)	9.7 (10.0)	1.11 (0.1)
2004	1,046	97 (10.3)	10.0 (3.4)	1.11 (0.1)
2005	325	101 (10.5)	11.3 (3.7)	1.08 (0.1)
2006	642	99 (9.5)	10.6 (4.9)	1.08 (0.1)
2007	1,902	94 (8.4)	9.4 (2.5)	1.12 (0.1)
2008	615	97 (9.3)	10.5 (3.1)	1.14 (0.1)
2009	483	98 (10.8)	10.8 (3.9)	1.16 (0.1)
2010	1,057	98 (9.4)	10.5 (3.1)	1.10 (0.1)
2011	ND	ND	ND	ND
2012	ND	ND	ND	ND
2013	1729	94 (9.6)	9.0 (2.9)	1.07 (0.1)
2014	1,643	94 (9.8)	8.7 (2.8)	1.04 (0.1)

Sample year	Sample size[a]	Mean size		
		Length (mm)	Weight (g)	Condition (K)
2015	1,491	96 (9.8)	9.4 (3.7)	1.06 (0.1)
2016	598	94 (9.4)	9.0 (2.9)	1.08 (0.1)
Average	***900***	***98.3 (10.1)***	***10.5 (4.0)***	***1.10 (0.1)***
Median	***642***	***97.2 (9.6)***	***10.5 (3.4)***	***1.10 (0.1)***

[a] Sample size represents the number of fish that were measured for both length and weight.

PIT Tagging Activities

As part of the Comparative Survival Study (CSS) and PUD studies, a total of 14,158 wild juvenile Chinook (10,888 subyearling and 3,270 yearlings) were PIT tagged and released in 2016 in the Wenatchee River basin (Table 5.19a). Most of these (71.2%) were tagged at the Chiwawa trap. See Appendix C for a complete list of all fish captured, tagged, lost, and released.

Table 5.19a. Numbers of wild Chinook that were captured, tagged, and released at different locations within the Wenatchee River basin, 2016. Numbers of fish that died or shed tags are also given.

Sampling Location	Chinook Salmon Life Stage	Number captured	Number of recaptures	Number tagged	Number died	Shed tags	Total tags released	Percent mortality
Chiwawa Trap	Subyearling	16,393	89	7,355	82	1	7354	0.50
	Yearling	2,807	79	2,729	4	3	2,729	0.14
	Total	**19,200**	**168**	**10,084**	**86**	**4**	**10,083**	**0.45**
Chiwawa River (Electrofishing)	Subyearling	1,829	24	1,776	5	0	1,776	0.27
	Yearling	0	0	0	0	0	0	0.00
	Total	**1,829**	**24**	**1,776**	**5**	**0**	**1,776**	**0.27**
Nason Creek Trap	Subyearling	791	48	434	6	0	434	0.76
	Yearling	61	4	61	0	0	61	0.00
	Total	**852**	**52**	**495**	**6**	**0**	**495**	**0.70**
Nason Creek (Electrofishing)	Subyearling	828	10	802	14	0	802	1.66
	Yearling	0	0	0	0	0	0	0.00
	Total	**828**	**10**	**802**	**14**	**0**	**802**	**1.69**
White River Trap	Subyearling	197	3	137	2	1	136	1.02
	Yearling	3	0	3	0	0	3	0.00
	Total	**200**	**3**	**140**	**2**	**1**	**139**	**0.01**
Lower Wenatchee Trap	Subyearling	27,407	38	18	184	0	18	0.07
	Yearling	610	4	538	2	0	538	0.33
	Total	**28,017**	**42**	**556**	**186**	**0**	**556**	**0.66**
Total:	**Subyearling**	**47,482**	**174**	**10,890**	**301**	**2**	**10,888**	**0.01**
	Yearling	**3,420**	**83**	**3,270**	**6**	**3**	**3,270**	**0.00**
Grand Total:		***50,902***	***257***	***14,160***	***307***	***5***	***14,158***	***0.01***

Numbers of wild Chinook salmon PIT-tagged and released as part of CSS and PUD studies during the period 2006-2016 are shown in Table 5.19b.

Table 5.19b. Summary of the numbers of wild Chinook that were tagged and released at different locations within the Wenatchee River basin, 2006-2016.

Sampling Location	Life Stage	Numbers of PIT-tagged wild Chinook salmon released										
		2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Chiwawa Trap	Subyearling	5,130	6,137	8,755	8,765	3,324	6,030	7,644	9,086	11,358	10,471	7,354
	Yearling	2,793	4,659	8,397	3,694	6,281	4,318	7,980	3,093	4,383	6,204	2,729
	Total	**7,923**	**10,796**	**17,152**	**12,459**	**9,605**	**10,348**	**15,624**	**12,179**	**15,741**	**16,675**	**10,083**
Chiwawa River (Angling or Electrofishing)	Subyearling	111	20	43	128	531	0	3,181	3,017	1,032	1,054	1,776
	Yearling	0	0	0	3	4	0	0	0	0	0	0
	Total	**111**	**20**	**43**	**131**	**535**	**0**	**3,181**	**3,017**	**1,032**	**1,054**	**1,776**
Upper Wenatchee Trap	Subyearling	0	15	0	37	3	1	1	0	--	--	--
	Yearling	81	1,434	159	296	486	714	75	94	--	--	--
	Total	**81**	**1,449**	**159**	**333**	**489**	**715**	**76**	**94**	**--**	**--**	**--**
Nason Creek Trap	Subyearling	1,434	545	1,741	1,890	2,828	822	1,939	3,290	1,113	219	**434**
	Yearling	365	577	894	185	364	147	357	237	456	142	**61**
	Total	**1,799**	**1,122**	**2,635**	**2,075**	**3,192**	**969**	**2,296**	**3,527**	**1,569**	**361**	**495**
Nason Creek (Angling or Electrofishing)	Subyearling	68	6	4	701	595	0	0	0	1,816	1,089	802
	Yearling	1	7	0	13	3	0	0	0	0	0	0
	Total	**69**	**13**	**4**	**714**	**598**	**0**	**0**	**0**	**1,816**	**1,089**	**802**
White River Trap	Subyearling	0	0	0	441	143	144	285	374	156	149	**136**
	Yearling	0	0	0	265	359	65	180	22	49	34	**3**
	Total	**0**	**0**	**0**	**706**	**502**	**209**	**465**	**396**	**205**	**183**	**139**
Upper Wenatchee (Angling or Electrofishing)	Subyearling	0	61	1	0	2	--	--	--	--	--	--
	Yearling	27	0	0	0	0	--	--	--	--	--	--
	Total	**27**	**61**	**1**	**0**	**2**	**--**	**--**	**--**	**--**	**--**	**--**
Middle Wenatchee (Angling or Electrofishing)	Subyearling	0	0	65	284	233	--	--	--	--	--	--
	Yearling	0	0	0	0	0	--	--	--	--	--	--
	Total	**0**	**0**	**65**	**284**	**233**	**--**	**--**	**--**	**--**	**--**	**--**
Lower Wenatchee (Angling or Electrofishing)	Subyearling	0	0	0	0	0	--	--	--	--	--	--
	Yearling	0	0	0	0	0	--	--	--	--	--	--
	Total	**0**	**0**	**0**	**0**	**0**	**--**	**--**	**--**	**--**	**--**	**--**
Peshastin Creek (Angling or Electrofishing)	Subyearling	0	0	0	0	1	--	--	--	--	--	--
	Yearling	0	0	0	0	0	--	--	--	--	--	--
	Total	**0**	**0**	**0**	**0**	**1**	**--**	**--**	**--**	**--**	**--**	**--**
Lower Wenatchee Trap	Subyearling	0	0	2	0	0	0	0	0	36	0	18
	Yearling	522	1,641	506	468	917	0	0	1,712	1,506	1,301	538
	Total	**522**	**1,641**	**508**	**468**	**917**	**0**	**0**	**1,712**	**1,542**	**1,301**	**556**

Sampling Location	Life Stage	Numbers of PIT-tagged wild Chinook salmon released										
		2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Total:	Subyearling	6,743	6,784	10,611	12,246	7,660	6,997	13,050	15,767	15,511	12,982	10,520
	Yearling	3,789	8,318	9,956	4,924	8,414	5,244	8,592	5,158	6,394	7,681	3,331
Grand Total:		*10,532*	*15,102*	*20,567*	*17,170*	*16,074*	*12,241*	*21,642*	*20,925*	*21,905*	*20,663*	*13,851*

Freshwater Productivity

Both productivity and survival estimates for different life stages of spring Chinook in the Chiwawa River basin are provided in Table 5.20. Estimates for brood year 2014 fall within the ranges estimated over the period of brood years 1991-2014. During that period, freshwater productivities ranged from 125-1,015 parr/redd, 39-673 smolts/redd, and 124-834 emigrants/redd. Survivals during the same period ranged from 2.7-19.1% for egg-parr, 0.9-14.5% for egg-smolt, and 2.9-18.0% for egg-emigrants. Overwinter survival rates for juvenile spring Chinook within the Chiwawa River basin have ranged from 15.7-100.0%.

Table 5.20. Productivity (fish/redd) and survival (%) estimates for different juvenile life stages of spring Chinook in the Chiwawa River basin for brood years 1991-2014; ND = no data. These estimates were derived from data in Table 5.15.

Brood year	Parr/Redd	Smolts/Redd[a]	Emigrants/ Redd	Egg-Parr (%)	Parr-Smolt[b] (%)	Egg-Smolt[a] (%)	Egg-Emigrant (%)
1991	437	409	ND	9.5	93.5	8.9	ND
1992	262	132	217	5.0	50.2	2.5	4.2
1993	519	82	214	9.9	15.7	1.6	4.1
1994	674	201	306	11.4	29.8	3.4	5.2
1995	447	295	458	8.8	65.9	5.8	9.0
1996	699	673	834	15.0	96.3	14.5	18.0
1997	834	346	543	18.3	41.4	7.6	11.9
1998	1,015	563	632	19.1	55.4	10.6	11.9
1999	ND	314	460	ND	ND	6.4	9.4
2000	895	319	435	17.8	35.6	6.4	8.7
2001	125	80	507	2.7	64.1	1.7	11.0
2002	265	264	534	5.7	99.6	5.7	11.5
2003	407	151	303	7.0	37.1	2.6	5.2
2004	206	299	482	4.3	100.0	6.2	10.0
2005	241	208	535	5.6	86.4	4.8	12.4
2006	205	152	364	4.7	74.2	3.5	8.4
2007	291	91	304	6.6	31.3	2.1	6.8
2008	155	51	174	3.4	32.8	1.1	3.8
2009	305	74	147	6.7	24.1	1.6	3.2
2010	282	95	201	6.5	33.6	2.2	4.7
2011	211	76	221	4.8	35.8	1.7	5.0

Brood year	Parr/Redd	Smolts/Redd[a]	Emigrants/ Redd	Egg-Parr (%)	Parr-Smolt[b] (%)	Egg-Smolt[a] (%)	Egg-Emigrant (%)
2012	170	39	124	4.0	23.0	0.9	2.9
2013	170	55	158	3.6	32.5	1.2	3.4
2014	229	77	236	5.7	33.4	1.9	5.8
Average	***388***	***210***	***365***	***8.0***	***51.8***	***4.4***	***7.7***
Median	***273***	***151***	***306***	***6.1***	***37.1***	***3.0***	***6.8***

[a] These estimates include Chiwawa smolts produced only within the Chiwawa River basin.
[b] These estimates represent overwinter survival within the Chiwawa River basin. It does not include Chiwawa smolts produced outside the Chiwawa River basin.

Seeding level (egg deposition) explained most of the variability in productivity and survival of juvenile spring Chinook in the Chiwawa River basin. That is, for estimates based on “within-Chiwawa-Basin” life stages (e.g., parr and smolts), survival and productivity decreased as seeding levels increased (Figure 5.4). This suggests that density dependence regulates juvenile productivity and survival within the Chiwawa River basin. This form of population regulation is less apparent with total emigrants. However, one would expect the number of emigrants to increase as seeding levels exceed the rearing capacity of the Chiwawa River basin.

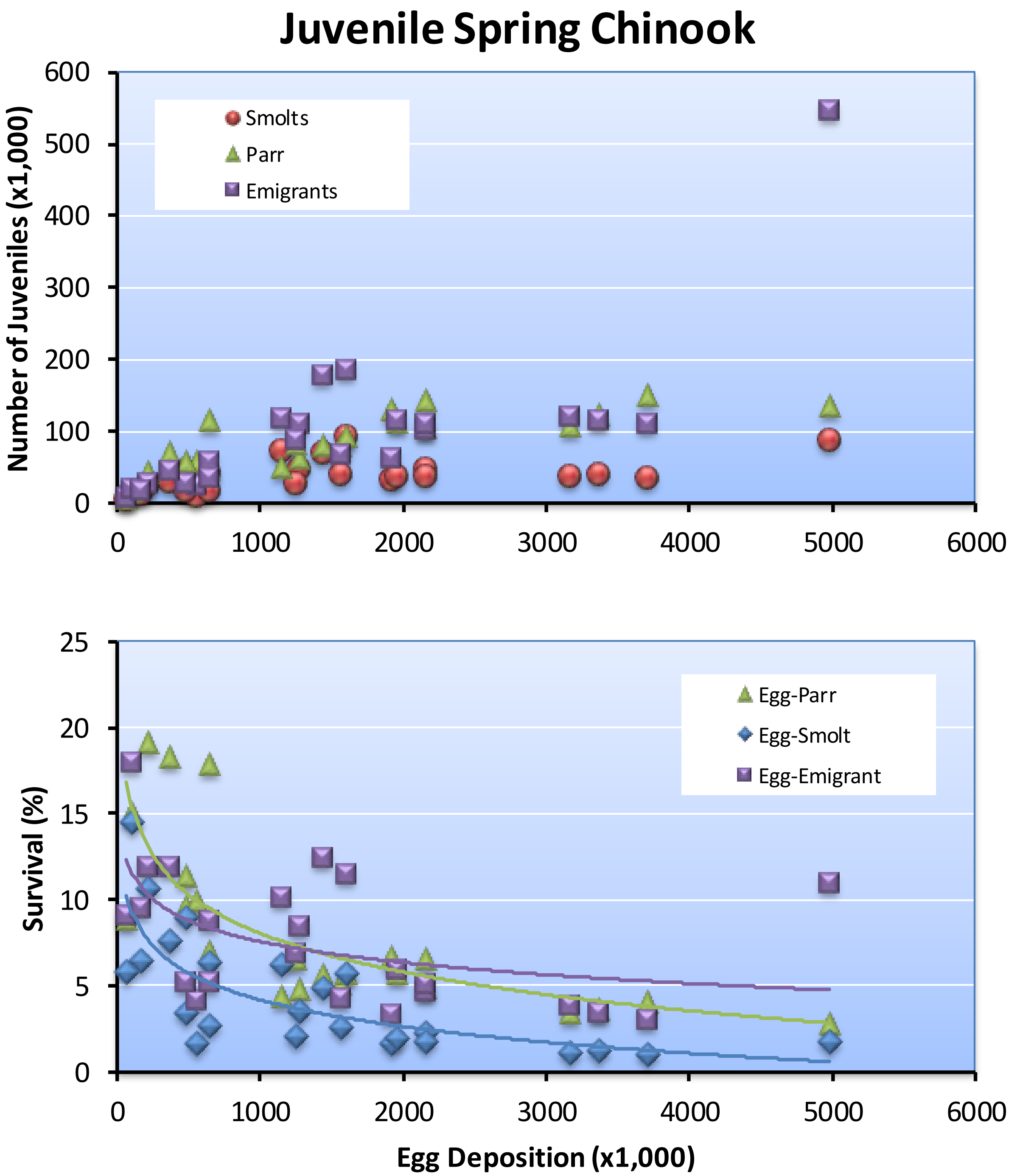


Figure 5.4. Relationships between seeding levels (egg deposition) and juvenile life-stage survivals and productivities for Chiwawa spring Chinook, brood years 1991-2014. Smolts represent yearling Chinook produced within the Chiwawa River basin.

Population Carrying Capacity

Population carrying capacity (*K*) is defined as the maximum equilibrium population size estimated with population models (e.g., logistic equation, Beverton-Holt model, hockey stick model, and the

Ricker model).[11] Maximum equilibrium population size is generated from density dependent mechanisms that reduce population growth rates as population size increases (negative density dependence). This is referred to as compensation. Population size fluctuates about the maximum equilibrium size because of variability in vital rates that are unrelated to density (density independent factors) and measurement error. In this section, we estimate parr and smolt carrying capacities using the smooth hockey stick stock-recruitment model (see Appendix C in Hillman et al. 2012 for a detailed description of methods). This model explains most of the information contained in the juvenile spring Chinook data (see Appendix A).

Based on the smooth hockey stick model, the population carrying capacity for spring Chinook parr in the Chiwawa River basin is 113,801 parr (95% CI: 94,343 – 139,922) (Figure 5.5). The capacity for spring Chinook smolts is 45,161 (95% CI: 34,226 – 55,445) (Figure 5.6). Here, smolts are defined as the number of yearling spring Chinook produced entirely within the Chiwawa River basin. These estimates reflect current conditions (most recent two decades) within the Chiwawa River basin. Land use activities such as logging, mining, roads, development, and recreation have altered the historical conditions of the watershed. Thus, the estimated population capacity estimates may not reflect historical capacities for spring Chinook parr and smolts in the Chiwawa River basin.

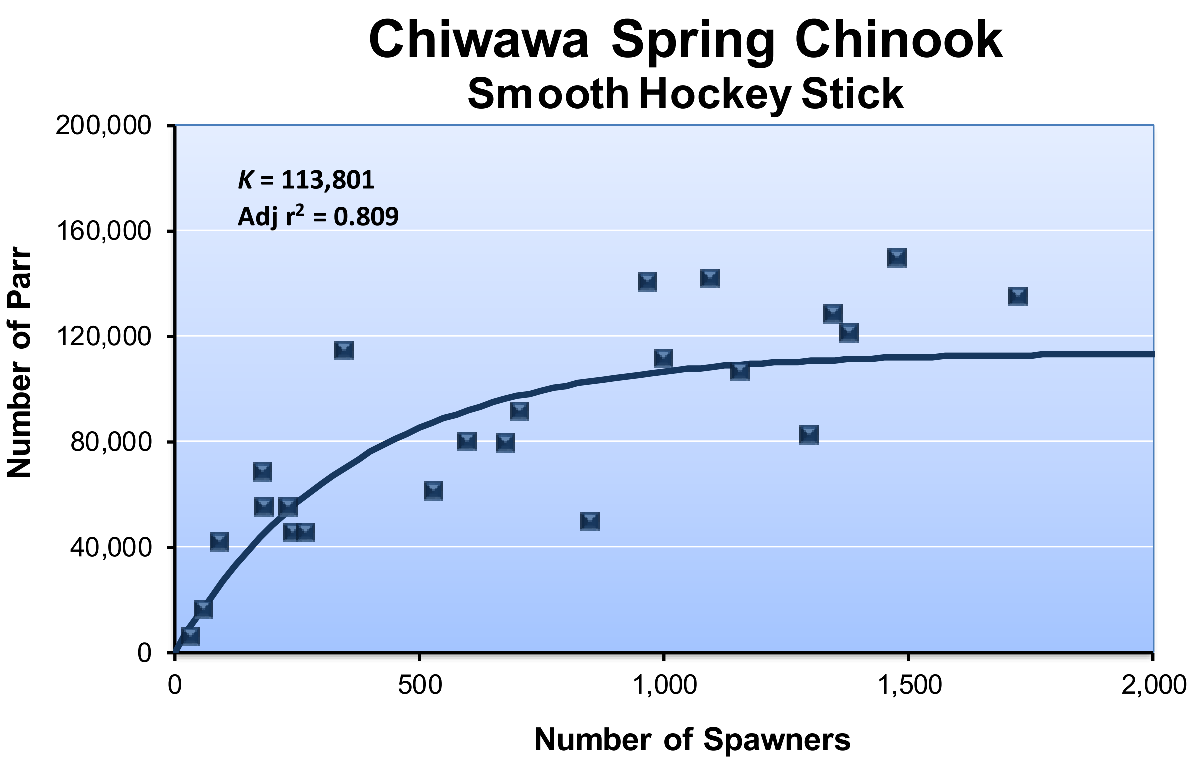


Figure 5.5. Relationship between spawners and number of parr produced in the Chiwawa River basin. Population carrying capacity (*K*) was estimated using the smooth hockey stick model, which explained most of the information in the data.

[11] Population carrying capacity (*K*) should not be confused with habitat carrying capacity (*C*), which is defined as the maximum population of a given species that a particular environment can sustain.

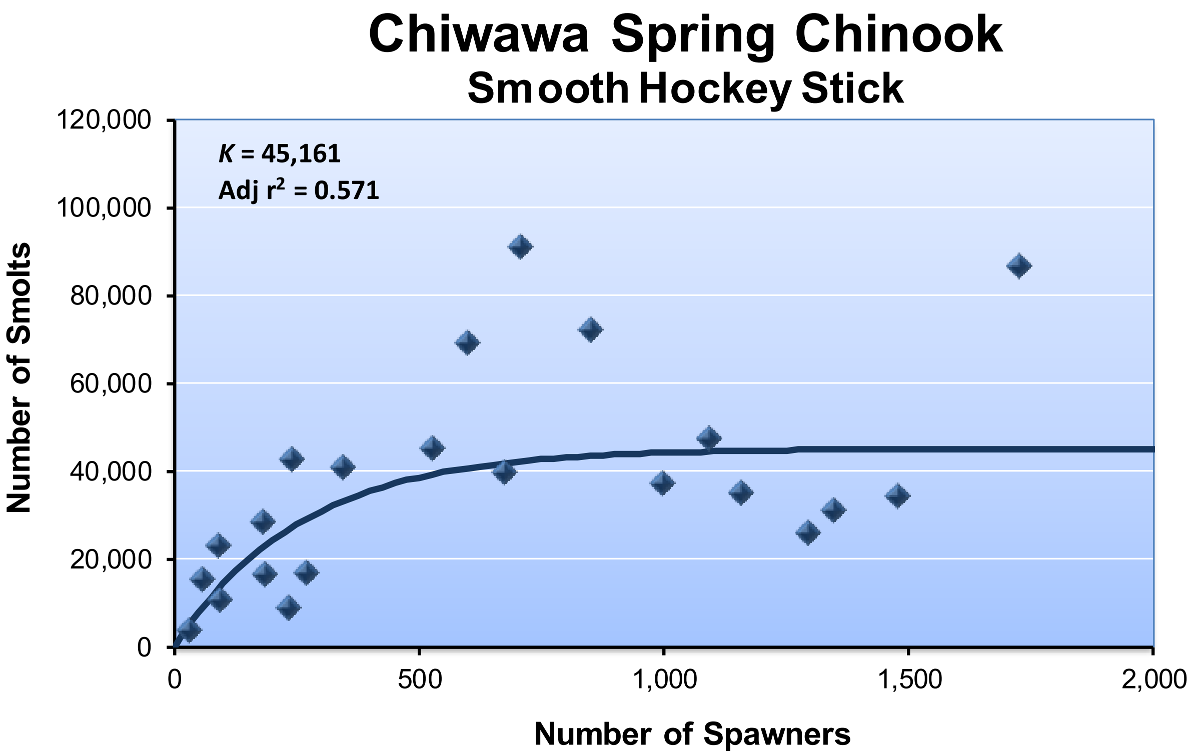


Figure 5.6. Relationship between spawners and number of yearling smolts produced in the Chiwawa River basin. Population carrying capacity (*K*) was estimated using the smooth hockey stick model, which explained most of the information in the data.

We tracked the precision of the smooth hockey stick parameters for Chiwawa spring Chinook smolts over time to see if precision improves with additional years of data, and the parameters and statistics stabilize over time. Examination of variation in the alpha (*A*) and beta (*B*) parameters of the smooth hockey stick model and their associated standard errors and confidence intervals indicates that the parameters appear to stabilize after 19 years of smolt and spawning escapement data (Table 5.21; Figure 5.7). This was also apparent in the estimates of population carrying capacity (Figure 5.8). That is, after 19 years of data, additional years of data had relatively little effect on the parameters of the smooth hockey stick model and its statistics. This observation will change if more extreme spawning escapements occur in the future or density independent factors overwhelm the influence of density dependent factors.

Table 5.21. Estimated parameters and statistics associated with fitting the smooth hockey stick model to spawning escapement and smolt data. Smolts represent numbers of smolts produced entirely within the Chiwawa River basin. *A* = alpha parameter; *B* = beta parameter; SE = standard error (estimated from 5,000 bootstrap samples); and r^2 = coefficient of determination. Spawners represent the stock size needed to achieve population capacity.

Years of data	Parameter				Population capacity	Intrinsic productivity	Spawners	r^2
	A	SE	*B*	SE				
5	10.80	11.51	110.23	942.46	49,257	110	1,339	0.706
6	10.43	30.61	163.03	28174.86	34,022	163	625	0.562
7	10.47	70.66	173.00	1918.57	35,362	173	613	0.567
8	10.40	13.26	206.97	41705.63	32,750	207	474	0.513
9	10.43	16.70	190.98	96463.71	33,727	191	529	0.518
10	10.56	41.60	184.83	719.39	38,590	185	625	0.564
11	11.10	8.98	154.07	246309.06	66,371	154	1,291	0.653
12	11.31	71.48	150.98	2254.06	81,605	151	1,620	0.701
13	11.28	43.85	142.41	236.06	79,572	142	1,674	0.664
14	11.34	5.26	141.43	118.39	84,292	141	1,786	0.699
15	11.40	15.61	141.76	35.71	89,256	142	1,887	0.718
16	11.38	2.77	141.35	37.66	87,522	141	1,856	0.723
17	11.02	3.10	155.71	38.89	60,965	156	1,173	0.651
18	10.92	0.79	160.92	38.85	55,020	161	1,023	0.635
19	10.82	0.25	166.78	39.68	50,150	167	901	0.614
20	10.82	0.20	166.99	39.58	49,972	167	897	0.622
21	10.78	0.17	169.82	38.50	48,142	170	849	0.618
22	10.75	0.15	172.32	39.35	46,494	172	809	0.611
23	10.73	0.13	173.36	40.07	45,815	173	792	0.612
24	10.73	0.13	173.36	39.82	45,815	173	792	0.612
25	10.72	0.12	174.08	41.00	45,161	174	777	0.610

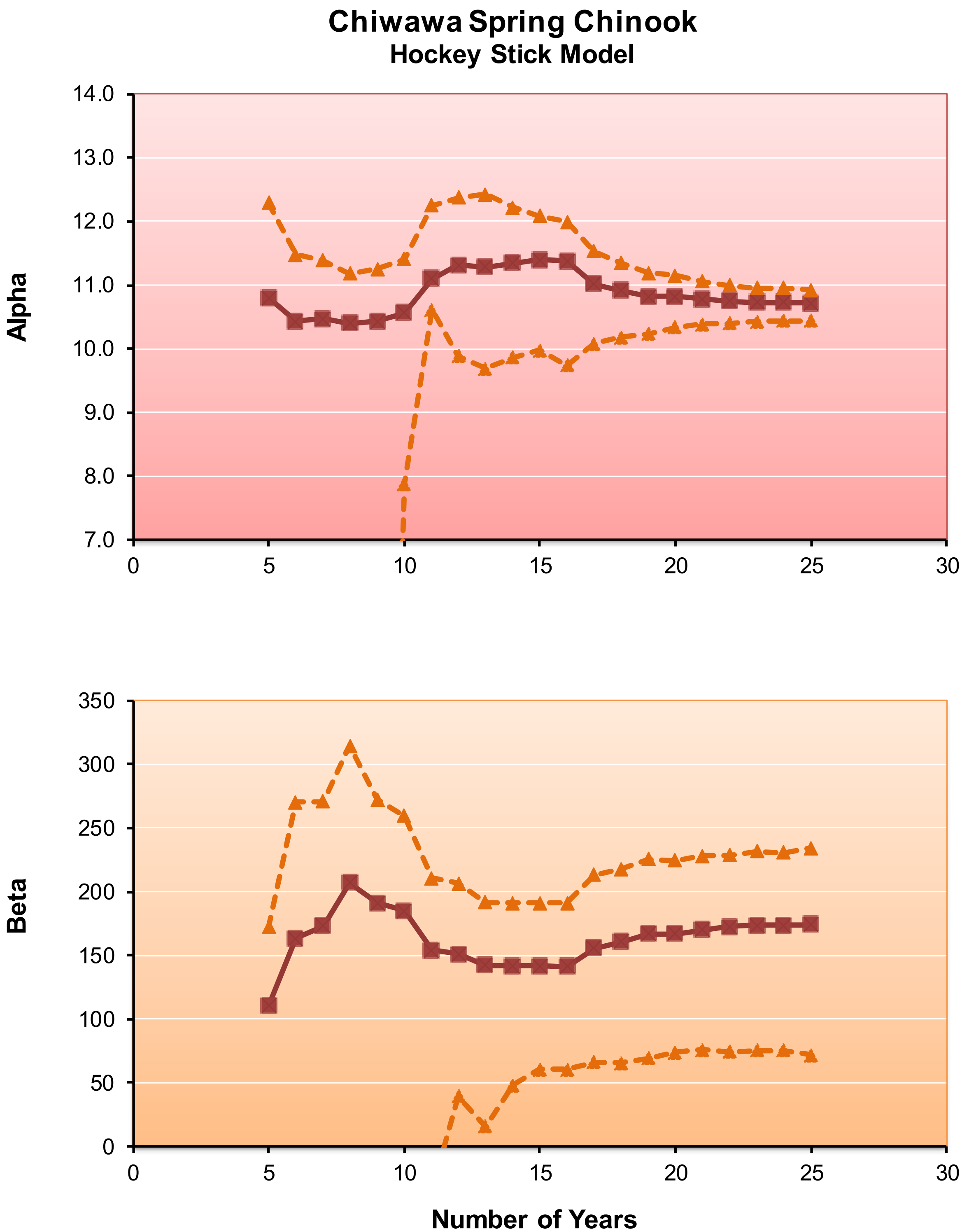


Figure 5.7. Time series of alpha and beta parameters and 95% confidence intervals for the smooth hockey stick model that was fit to Chiwawa spring Chinook smolt and spawning escapement data. Confidence intervals were estimated from 5,000 bootstrap samples.

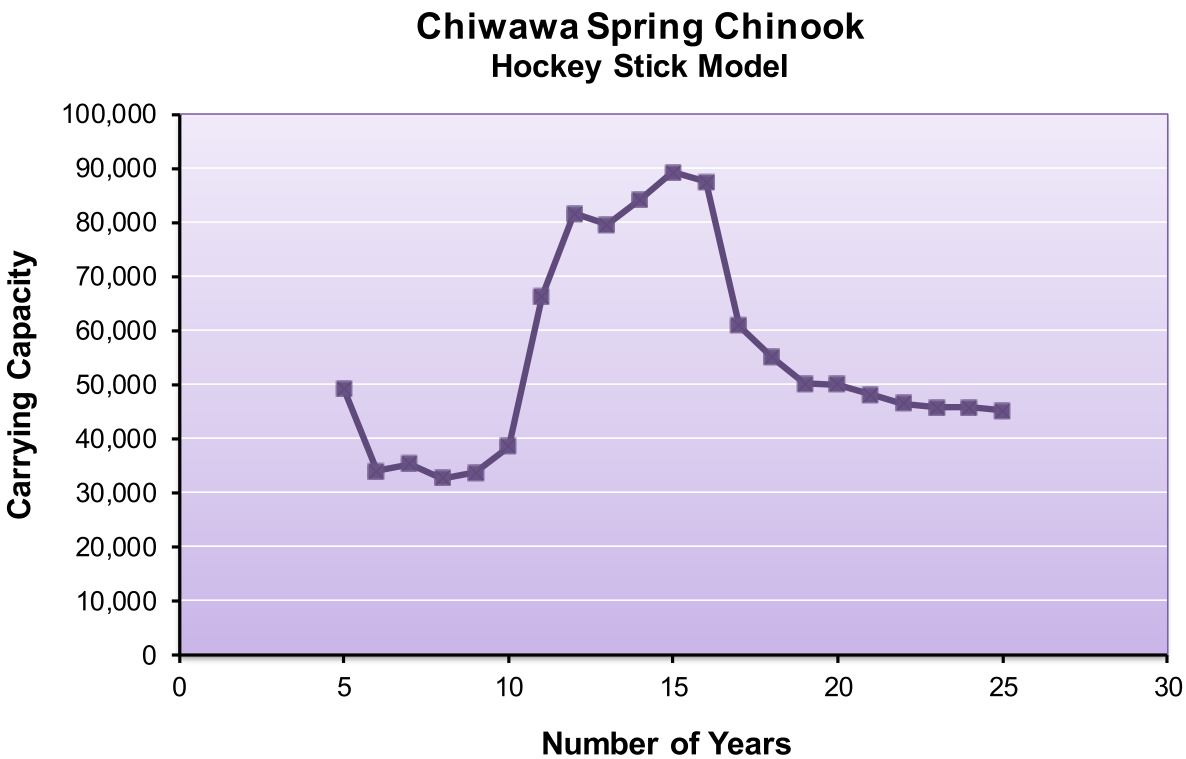


Figure 5.8. Time series of population carrying capacity estimates derived from fitting the smooth hockey stick model to Chiwawa spring Chinook smolt and spawning escapement data.

5.5 Spawning Surveys

Surveys for spring Chinook redds were conducted during the last week of July through September 2016 in the Chiwawa River (including Rock, Chikamin, and Phelps creeks), Nason Creek, Icicle Creek, Peshastin Creek (including Ingalls Creek), Upper Wenatchee River (including Chiwaukum Creek), Little Wenatchee River, and the White River (including the Napeequa River and Panther Creek).

Spawning escapement for spring Chinook was calculated as the total number of redds times the male-to-female ratio (i.e., fish per redd expansion factor) estimated from broodstock and fish sampled at adult trapping sites.[12] Beginning with return year 2015, WDFW used the Gaussian area-under-the-curve (AUC) method (Millar et al. 2012) to estimate the number of redds within survey reaches (see Appendix J). The number of redds within each reach were then divided by the mean net error (ratio of observed redds to true number of redds) to estimate the "true" number of redds within each reach. The Mean net error was modeled based on covariates such as surveyor experience, channel complexity (mean thalweg CV), and observed redd density (number of redds per km).

[12] Expansion factor = (1 + (number of males/number of females)).

Redd Counts

A total of 554 spring Chinook redds were counted in the Wenatchee River basin in 2016 (Table 5.22). This is lower than the average of 674 redds counted during the period 1989-2015 in the Wenatchee River basin. Most spawning occurred in the Chiwawa River (56.3% or 312 redds) (Table 5.22; Figure 5.9). Nason Creek contained 15.3% (85 redds), Icicle Creek contained 13.0% (72 redds), White River contained 7.9% (44 redds), Little Wenatchee contained 4.0% (22 redds), the Upper Wenatchee River 3.1% (17 redds), and Peshastin Creek contained 0.4% (2 redds).

Table 5.22. Numbers of spring Chinook redds counted (not "true" estimates) within different streams or watersheds within the Wenatchee River basin, 1989-2016. WDFW began full implementation of adult management in 2014.

Sample year	Number of spring Chinook redds							
	Chiwawa	Nason	Little Wenatchee	White	Wenatchee River	Icicle	Peshastin	Total
1989	314	98	45	64	94	24	NS	**639**
1990	255	103	30	22	36	50	4	**500**
1991	104	67	18	21	41	40	1	**292**
1992	302	81	35	35	38	37	0	**528**
1993	106	223	61	66	86	53	5	**600**
1994	82	27	7	3	6	15	0	**140**
1995	13	7	0	2	1	9	0	**32**
1996	23	33	3	12	1	12	1	**85**
1997	82	55	8	15	15	33	1	**209**
1998	41	29	8	5	0	11	0	**94**
1999	34	8	3	1	2	6	0	**54**
2000	128	100	9	8	37	68	0	**350**
2001	1,078	374	74	104	218	88	173*	**2,109**
2002	345	294	42	42	64	245	107*	**1,139**
2003	111	83	12	15	24	18	60	**323**
2004	239	169	13	22	46	30	55	**574**
2005	333	193	64	86	143	8	3	**830**
2006	297	152	21	31	27	50	10	**588**
2007	283	101	22	20	12	17	11	**466**
2008	689	336	38	31	180	116	21	**1,411**
2009	421	167	39	54	5	32	15	**733**
2010	502	188	38	33	47	155	5	**968**
2011	492	170	30	20	12	122	26	**872**
2012	880	413	43	86	73	199	10	**1,704**
2013	714	212	51	54	17	107	4	**1,159**
2014	485	115	25	26	23	211	0	**885**
2015	543	85	28	70	55	132	10	**923**
2016	312	85	22	44	17	72	2	**554**

Sample year	Number of spring Chinook redds							
	Chiwawa	Nason	Little Wenatchee	White	Wenatchee River	Icicle	Peshastin	Total
Average	*329*	*142*	*28*	*35*	*47*	*70*	*10*	*670*
Median	*300*	*102*	*27*	*29*	*32*	*45*	*4*	*581*

* Redd counts in Peshastin Creek in 2001 and 2002 were elevated because the U.S. Fish and Wildlife Service planted 487 and 350 spring Chinook adults, respectively, into the stream. These counts were not included in the total or average calculations.

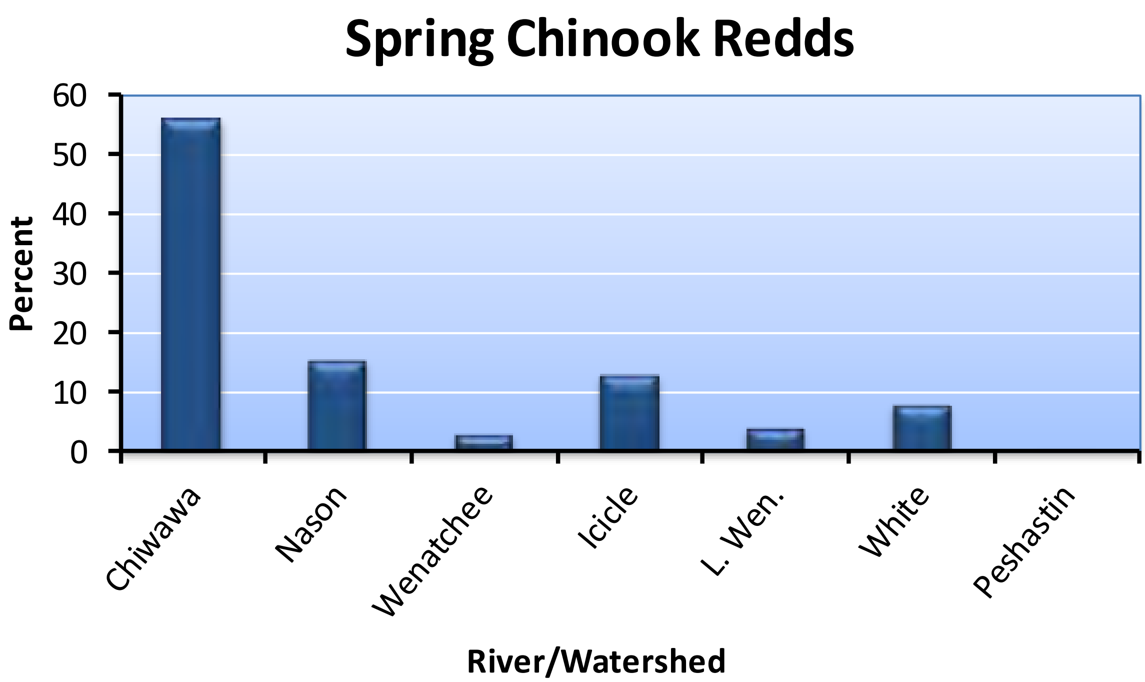


Figure 5.9. Percent of the total number of spring Chinook redds counted in different streams/watersheds within the Wenatchee River basin during August through September 2016.

As noted above, since 2015, WDFW has estimated the "true" number of redds within survey areas in the Wenatchee River basin using the Gaussian area-under-the-curve method. Based on two years of data, the average difference between the observed (counted) and true estimate is about 105 redds (Table 5.23).

Table 5.23. Comparison of the observed number and estimated "true" number of spring Chinook redds within different streams/watersheds within the Wenatchee River basin, 2015-2016.

Survey stream	Survey year			
	2015		2016	
	Observed	Estimated	Observed	Estimated
Chiwawa	542	607	312	354
Nason	85	103	85	100
Little Wenatchee	28	38	22	35
White	70	91	44	53

Survey stream	Survey year			
	2015		2016	
	Observed	Estimated	Observed	Estimated
Wenatchee	55	66	17	22
Peshastin	--	--	2	2
Icicle	--	--	72	72
Total	***780***	***905***	***554***	***638***

Redd Distribution

Spring Chinook redds were not evenly distributed among reaches within survey streams in 2016 (Table 5.24). Most of the spawning in the Chiwawa River basin occurred in Reaches 1 through 6. About 66% of the spawning in the Chiwawa River basin occurred in the lower two reaches (RKM 0.0-36.97; from the mouth to Rock Creek). Relatively few fish spawned in Rock and Chikamin creeks. The spatial distribution of redds in Nason Creek was weighted towards Reach 3, having 45% of the Nason Creek redds. In the Little Wenatchee River, about 89% of all spawning occurred in Reach 3 (RKM 9.2-14.0; Lost Creek to Falls). On the White River, 81% of the spawning occurred in Reach 3 (RKM 20.3-23.3; Napeequa River to Grasshopper Meadows). In the Wenatchee River about 50% of the fish spawned downstream from the mouth of the Chiwawa River, 41% spawned upstream from the mouth, and about 9% spawned in Chiwaukum Creek. In Icicle Creek, about 85% of spawning occurred in Reach 2 (RKM 4.9-6.7; Hatchery to Sleeping Lady). All the spawning in Peshastin Creek occurred upstream from the confluence with Camas Creek (RKM 9.0).

Table 5.24. Numbers (both observed and estimated) and proportions of spring Chinook redds estimated within different streams/watersheds within the Wenatchee River basin during August through September 2016. NS = not surveyed. See Table 2.8 for description of survey reaches.

Stream/watershed	Reach	Observed number of redds	Estimated number of redds	Proportion of estimated redds within stream/watershed
Chiwawa	Chiwawa 1 (C1)	56	64	0.18
	Chiwawa 2 (C2)	139	170	0.48
	Chiwawa 3 (C3)	21	21	0.06
	Chiwawa 4 (C4)	27	31	0.09
	Chiwawa 5 (C5)	33	34	0.10
	Chiwawa 6 (C6)	32	28	0.08
	Chiwawa 7 (C7)	3	5	0.01
	Phelps 1 (S1)	0	0	0.00
	Rock 1 (R1)	0	0	0.00
	Chikamin 1 (K1)	1	1	0.00
	Total	**312**	**354**	**1.00**
Nason	Nason 1 (N1)	14	14	0.14
	Nason 2 (N2)	20	23	0.23

Stream/watershed	Reach	Observed number of redds	Estimated number of redds	Proportion of estimated redds within stream/watershed
	Nason 3 (N3)	37	45	0.45
	Nason 4 (N4)	14	18	0.18
	Total	**85**	**100**	**1.00**
Little Wenatchee	Little Wen 1 (L1)	NS	--	--
	Little Wen 2 (L2)	3	4	0.11
	Little Wen 3 (L3)	19	31	0.89
	Total	**22**	**35**	**1.00**
White	White 1 (H1)[a]	0	--	--
	White 2 (H2)	4	6	0.11
	White 3 (H3)	37	43	0.81
	White 4 (H4)	2	3	0.06
	Napeequa 1 (Q1)	1	1	0.02
	Panther 1 (T1)	0	0	0.00
	Total	**44**	**53**	**1.00**
Wenatchee River	Wen 9 (W9)	7	11	0.50
	Wen 10 (W10)	8	9	0.41
	Chiwaukum (A1)	2	2	0.09
	Total	**17**	**22**	**1.00**
Icicle	Icicle 1 (I1)	2	2	0.03
	Icicle 2 (I2)	61	61	0.85
	Icicle 3 (I3)	9	9	0.13
	Total	**72**	**72**	**1.00**
Peshastin	Peshastin 1 (P1)	0	0	0.00
	Peshastin 2 (P2)	2	2	1.00
	Ingalls (D1)	0	0	0.00
	Total	**2**	**2**	**1.00**
Grand Total		***554***	***638***	***1.00***

[a] Reach H1 of the White River was surveyed once during the peak of the season to verify that no spawning was occurring in the lower portion of the river.

Spawn Timing

Spring Chinook began spawning during the last week of July in Nason Creek and the second week of August in the Chiwawa River. Spawning began the third week of August in the Little Wenatchee and White rivers, the fourth week of August in Icicle Creek, the fifth week of August in Peshastin Creek, and the first week of September in the Wenatchee River (Figure 5.10). Spawning peaked the last week of August in Icicle Creek and the Little Wenatchee River. The Chiwawa River and Nason Creek peaked during the first week of September. The White River peaked during the second week of September and the Wenatchee River peaked during the fourth week of September.

The 11 redds observed on the Wenatchee River during the fourth week of September may have been present the previous week when no survey occurred. Peshastin Creek had two redds, one occurring the last week of August and one during the second week of September. Chinook completed spawning by the end of September.

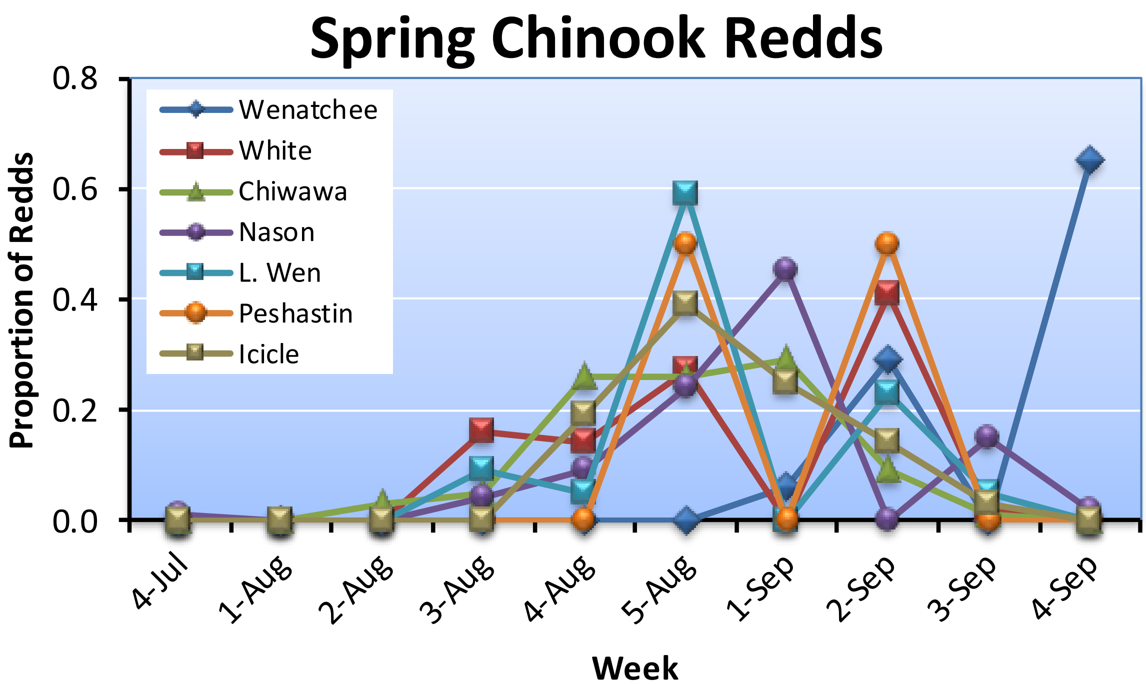


Figure 5.10. Proportion of spring Chinook redds counted during different weeks in different sampling streams within the Wenatchee River basin, August through September 2016.

Spawning Escapement

Spawning escapement for spring Chinook was calculated as the observed number of redds times the male-to-female ratio (i.e., fish per redd expansion factor) estimated from broodstock and fish sampled at adult trapping sites.[13] The estimated fish per redd ratio for spring Chinook upstream from Tumwater in 2016 was 1.83 (based on sex ratios estimated at Tumwater Dam). The estimated fish per redd ratio for spring Chinook downstream from Tumwater (Icicle and Peshastin creeks) was 1.81 (derived from broodstock collected at the Leavenworth National Fish Hatchery). Multiplying these ratios by the number of redds counted in the Wenatchee River basin resulted in a total spawning escapement of 1,012 spring Chinook (Table 5.25). The Chiwawa River basin had the highest spawning escapement (574 Chinook), while Peshastin Creek had the lowest (4 Chinook).

[13] Expansion factor = (1 + (number of males/number of females)).

Table 5.25. Number of observed redds, fish per redd ratios, and total spawning escapement for spring Chinook in the Wenatchee River basin, 2016. Spawning escapement was estimated as the product of redds times fish per redd.

Sampling area	Total number of redds	Fish/redd	Total spawning escapement*
Chiwawa	312	1.83	571
Nason	85	1.83	156
Upper Wenatchee River	17	1.83	31
Icicle	72	1.81	130
Little Wenatchee	22	1.83	40
White	44	1.83	81
Peshastin	2	1.81	4
Total	***554***	**--**	***1,012***

* Spawning escapement estimate is based on total number of observed redds by stream. If escapement is calculated at the reach scale, then the total escapement may vary from what is shown here because of rounding errors.

The estimated total spawning escapement of 1,012 spring Chinook in 2016 was less than the overall average of 1,367 spring Chinook (Table 5.26). The escapement in the Chiwawa River basin in 2016 was 3.7 times the escapement in Nason Creek, the second most abundant escapement in the Wenatchee River basin (Table 5.26).

Table 5.26. Spawning escapements for spring Chinook in the Wenatchee River basin for return years 1989-2016; NA = not available.

Return year	Upper basin spawning escapement						Lower basin spawning escapement			Total
	Fish/redd	Chiwawa	Nason	Little Wenatchee	White	Wenatchee River	Fish/redd	Icicle	Peshastin	
1989	2.27	713	222	102	145	213	1.56	37	NA	**1,419**
1990	2.24	571	231	67	49	81	1.71	86	7	**1,053**
1991	2.33	242	156	42	49	96	1.73	69	2	**626**
1992	2.24	676	181	78	78	85	1.65	61	0	**1,135**
1993	2.20	233	491	134	145	189	1.66	88	8	**1,250**
1994	2.24	184	60	16	7	13	2.11	32	0	**295**
1995	2.51	33	18	0	5	3	2.01	18	0	**68**
1996	2.53	58	83	8	30	3	2.09	25	2	**195**
1997	2.22	182	122	18	33	33	1.69	56	2	**422**
1998	2.21	91	64	18	11	0	1.81	20	0	**195**
1999	2.77	94	22	8	3	6	2.06	12	0	**139**
2000	2.70	346	270	24	22	100	1.68	114	0	**830**
2001	1.60	1,725	598	118	166	349	1.72	151	298	**3,217**
2002	2.05	707	603	86	86	131	1.55	380	166	**1,965**
2003	2.43	270	202	29	36	58	1.93	35	116	**673**
2004[a]	3.56/3.00	851	507	39	66	138	1.76	53	97	**1,686**
2005	1.80	599	347	115	155	257	1.67	13	5	**1,484**
2006	1.78	529	271	37	55	48	1.68	84	17	**1,000**
2007	4.58	1,296	463	101	92	55	1.91	32	21	**2,035**
2008	1.68	1,158	565	64	52	302	1.78	206	37	**2,278**

Return year	Upper basin spawning escapement						Lower basin spawning escapement			Total
	Fish/redd	Chiwawa	Nason	Little Wenatchee	White	Wenatchee River	Fish/redd	Icicle	Peshastin	
2009	3.20	1,347	534	125	173	16	2.22	71	33	**2,299**
2010	2.18	1,094	410	83	72	102	1.56	242	8	**1,921**
2011	4.13	2,032	702	124	83	50	2.60	317	68	**3,139**
2012	1.68	1,478	694	72	144	123	1.60	318	16	**2,720**
2013	1.93	1,378	409	98	104	33	1.98	212	8	**2,133**
2014	2.06	999	237	52	54	47	1.93	407	0	**1,600**
2015	1.78	967	151	50	125	98	1.87	247	19	**1,533**
2016	1.83	571	156	40	81	31	1.81	130	4	**953**
Average	***--***	***729***	***313***	***62***	***76***	***95***	***--***	***126***	***35***	***1,367***
Median	***--***	***638***	***254***	***58***	***69***	***70***	***--***	***78***	***8***	***1,335***

[a] In 2004, the fish/redd expansion estimate of 3.56 was applied to the Chiwawa River only and 3.00 fish/redd was applied to the rest of the upper basin.

5.6 Carcass Surveys

Surveys for spring Chinook carcasses were conducted during August through September 2016 in the Chiwawa River (including Rock, Chikamin, and Phelps creeks), Nason Creek, Icicle Creek, Peshastin Creek (including Ingalls Creek), Upper Wenatchee River (including Chiwaukum Creek), Little Wenatchee River, and White River (including the Napeequa River and Panther Creek).

Number sampled

A total of 362 spring Chinook carcasses were sampled during August through September in the Wenatchee River basin (Table 5.27). Most were sampled in the Chiwawa River basin (58% or 211 carcasses) and Nason Creek (26% or 95 carcasses) (Figure 5.11). A total of 25 carcasses were sampled in Icicle Creek, 13 in the Wenatchee River, 13 in the White River, and 5 in the Little Wenatchee River.

Table 5.27. Numbers of spring Chinook carcasses sampled within different streams/watersheds within the Wenatchee River basin, 1996-2016.

Survey year	Number of spring Chinook carcasses							
	Chiwawa	Nason	Little Wenatchee	White	Wenatchee River	Icicle	Peshastin	Total
1996	22	3	0	2	0	1	0	**28**
1997	17	42	3	8	1	28	1	**100**
1998	24	25	3	2	1	6	0	**61**
1999	15	5	0	0	2	1	0	**23**
2000	122	110	8	1	37	52	0	**330**
2001	763	388	68	81	213	163	63	**1,739**
2002	210	292	30	25	34	91	65	**747**
2003	70	100	8	8	11	37	64	**298**
2004	178	186	1	13	29	16	40	**463**
2005	391	217	48	52	120	2	0	**830**

Survey year	Number of spring Chinook carcasses							
	Chiwawa	Nason	Little Wenatchee	White	Wenatchee River	Icicle	Peshastin	Total
2006	241	190	13	25	15	7	0	**491**
2007	250	201	16	13	24	15	6	**525**
2008	386	243	15	13	94	67	5	**823**
2009	240	128	20	20	1	67	2	**478**
2010	192	141	7	11	29	39	2	**421**
2011	177	98	7	4	3	40	3	**332**
2012	390	332	24	21	23	61	3	**854**
2013	396	142	20	22	8	28	1	**671**
2014	320	68	15	8	19	44	0	**474**
2015	275	43	12	25	25	67	3	**450**
2016	211	95	5	13	13*	25	0	**362**
Average	***233***	***145***	***15***	***17***	***33***	***41***	***12***	***500***
Median	***211***	***128***	***12***	***13***	***19***	***37***	***2***	***463***

* The number of carcasses sampled in the Wenatchee River in 2016 include two recovered in reach (W6) just downstream from the mouth of Icicle Creek.

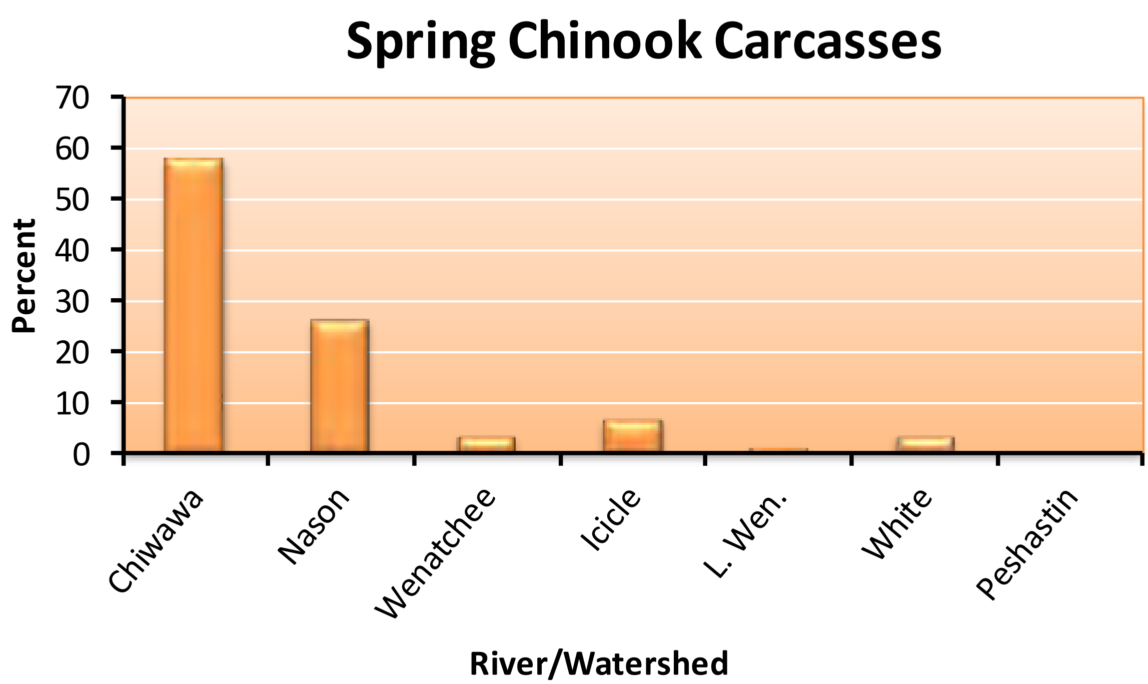


Figure 5.11. Percent of the total number of spring Chinook carcasses sampled in different streams/watersheds within the Wenatchee River basin during August through September 2016.

Carcass Distribution and Origin

Spring Chinook carcasses were not evenly distributed among reaches within survey streams in 2016 (Table 5.28). Most of the carcasses (71%) in the Chiwawa River basin occurred in Reaches

1 and 2 (downstream from Rock Creek). In Nason Creek, most carcasses (51%) were collected in Reach 3 and the fewest (8%) in Reach 4. Most carcasses in the Little Wenatchee River were sampled in Reach 3 (Lost Creek to Rainy Creek). On the White River, most (85%) occurred in Reach 3 (Napeequa River to Grasshopper Meadows). On the Wenatchee River, 62% of the carcasses were found upstream from the confluence of the Chiwawa River and 38% were found downstream from the confluence. Most of the carcasses in Icicle Creek (60%) were found in Reach 2 (Hatchery to Sleeping Lady). No carcasses were found in Peshastin Creek.

Table 5.28. Numbers and proportions of carcasses sampled within different streams/watersheds within the Wenatchee River basin during August through September 2016. See Table 2.8 for description of survey reaches.

Stream/watershed	Reach	Number of carcasses	Proportion of carcasses within stream/watershed
Chiwawa	Chiwawa 1 (C1)	38	0.18
	Chiwawa 2 (C2)	111	0.53
	Chiwawa 3 (C3)	9	0.04
	Chiwawa 4 (C4)	22	0.10
	Chiwawa 5 (C5)	17	0.08
	Chiwawa 6 (C6)	11	0.05
	Chiwawa 7 (C7)	1	0.00
	Phelps 1 (S1)	0	0.00
	Rock 1 (R1)	0	0.00
	Chikamin 1 (K1)	1	0.00
	Total	**211**	**1.00**
Nason	Nason 1 (N1)	21	0.22
	Nason 2 (N2)	8	0.08
	Nason 3 (N3)	48	0.51
	Nason 4 (N4)	18	0.19
	Total	**95**	**1.00**
Little Wenatchee	Little Wen 1 (L1)	NS	--
	Little Wen 2 (L2)	1	0.20
	Little Wen 3 (L3)	4	0.80
	Total	**5**	**1.00**
White	White 1 (H1)	0	0.00
	White 2 (H2)	1	0.08
	White 3 (H3)	11	0.85
	White 4 (H4)	1	0.08
	Napeequa 1 (Q1)	0	0.00
	Panther 1 (T1)	0	0.00
	Total	**13**	**1.00**
Wenatchee River	Wen 6 (W6)[a]	2	0.15
	Wen 9 (W9)	2	0.15
	Wen 10 (W10)	8	0.62

Stream/watershed	Reach	Number of carcasses	Proportion of carcasses within stream/watershed
	Chiwaukum 1 (U1)	1	0.08
	Total	**13**	**1.00**
Icicle	Icicle 1 (I1)	7	0.28
	Icicle 2 (I2)	15	0.60
	Icicle 3 (I3)	3	0.12
	Total	**25**	**1.00**
Peshastin	Peshastin 1 (P1)	0	0.00
	Peshastin 2 (P2)	0	0.00
	Ingalls (D1)	0	0.00
	Total	**0**	**0.00**
Grand Total		**362**	**1.00**

[a] Reach Wen 6 is not a survey reach for spring Chinook surveys; however, in 2016 two carcasses were sampled during a spring Chinook survey on the Icicle River. The carcasses were located downstream of the confluence of the Icicle River and Wenatchee River.

Final origin was determined for 208 of the 211 carcasses sampled in the Chiwawa River basin in 2016. Of those 208, 30% were hatchery fish (Table 5.29). In the Chiwawa River basin, the spatial distribution of hatchery and wild fish was not equal (Table 5.29). A larger percentage of hatchery fish were found in the lower reaches (C1 and C2; i.e., Mouth to Rock Creek). This general trend was also apparent in the pooled data (Figure 5.12).

Table 5.29. Numbers of wild and hatchery spring Chinook carcasses sampled within different reaches in the Chiwawa River basin, 1993-2016. Numbers represent recovered carcasses that had definitive origins. See Table 2.8 for description of survey reaches.

Survey year	Origin	Survey Reach									Total
		C-1	C-2	C-3	C-4	C-5	C-6	C-7	Chikamin	Rock	
1993	Wild	0	0	0	0	0	0	--	0	0	**0**
	Hatchery	1	0	0	0	0	0	--	0	0	**1**
1994	Wild	0	6	0	2	0	2	--	0	0	**10**
	Hatchery	1	1	0	2	0	0	--	0	0	**4**
1995	Wild	0	0	0	0	0	0	--	0	0	**0**
	Hatchery	2	3	0	1	0	0	--	0	0	**6**
1996	Wild	13	1	1	1	0	0	--	0	0	**16**
	Hatchery	6	0	0	0	0	0	--	0	0	**6**
1997	Wild	5	2	0	1	0	0	--	0	0	**8**
	Hatchery	3	1	0	0	0	1	--	1	3	**9**
1998	Wild	0	3	6	1	2	4	--	0	0	**16**
	Hatchery	1	3	2	0	1	1	--	0	0	**8**
1999	Wild	1	8	0	5	0	0	--	0	0	**14**
	Hatchery	0	0	0	0	1	0	--	0	0	**1**
2000	Wild	29	29	1	1	1	1	--	0	0	**62**

Survey year	Origin	Survey Reach									Total
		C-1	C-2	C-3	C-4	C-5	C-6	C-7	Chikamin	Rock	
	Hatchery	42	12	0	0	0	2	--	0	0	**56**
2001	Wild	27	60	15	43	16	21	--	1	3	**186**
	Hatchery	164	284	19	58	14	21	--	8	0	**568**
2002	Wild	22	15	10	6	9	7	--	1	0	**70**
	Hatchery	46	41	12	5	1	15	--	15	4	**139**
2003	Wild	7	13	0	12	4	2	--	0	0	**38**
	Hatchery	14	14	0	3	1	0	--	0	0	**32**
2004	Wild	25	50	2	12	7	2	--	0	1	**99**
	Hatchery	48	21	1	1	1	4	--	0	2	**78**
2005	Wild	18	36	3	5	3	2	--	0	0	**67**
	Hatchery	170	132	7	7	4	3	--	0	1	**324**
2006	Wild	10	17	2	8	4	3	--	1	0	**45**
	Hatchery	84	75	5	7	6	13	--	3	3	**196**
2007	Wild	3	15	3	4	2	2	--	0	0	**29**
	Hatchery	42	118	15	14	18	12	--	2	0	**221**
2008	Wild	4	23	0	4	4	8	--	0	0	**43**
	Hatchery	174	122	2	9	15	15	--	4	1	**342**
2009	Wild	3	21	4	8	4	1	--	0	3	**44**
	Hatchery	89	70	6	14	7	5	--	0	5	**196**
2010	Wild	4	30	7	8	10	3	--	0	0	**62**
	Hatchery	64	35	2	10	7	5	--	0	5	**128**
2011	Wild	8	26	10	6	8	6	--	0	1	**65**
	Hatchery	43	40	4	5	5	10	--	1	4	**112**
2012	Wild	11	74	6	21	13	18	0	0	3	**146**
	Hatchery	94	91	9	13	16	16	0	0	6	**245**
2013	Wild	8	38	7	21	16	14	1	0	3	**108**
	Hatchery	101	112	19	23	13	15	0	5	3	**291**
2014	Wild	18	77	9	28	19	21	0	0	0	**172**
	Hatchery	64	48	6	10	6	9	1	2	2	**148**
2015	Wild	14	37	6	12	12	13	0	0	0	**94**
	Hatchery	65	89	7	9	6	5	0	0	0	**181**
2016	Wild	15	77	8	18	15	10	0	2	0	**145**
	Hatchery	22	33	1	4	1	1	1	0	0	**63**
Average	***Wild***	***10***	***27***	***4***	***9***	***6***	***6***	***0***	***0***	***1***	***64***
	Hatchery	***56***	***56***	***5***	***8***	***5***	***6***	***0***	***2***	***2***	***140***
Median	***Wild***	***8***	***22***	***3***	***6***	***4***	***3***	***0***	***0***	***0***	***54***
	Hatchery	***45***	***38***	***2***	***5***	***3***	***5***	***0***	***0***	***1***	***120***

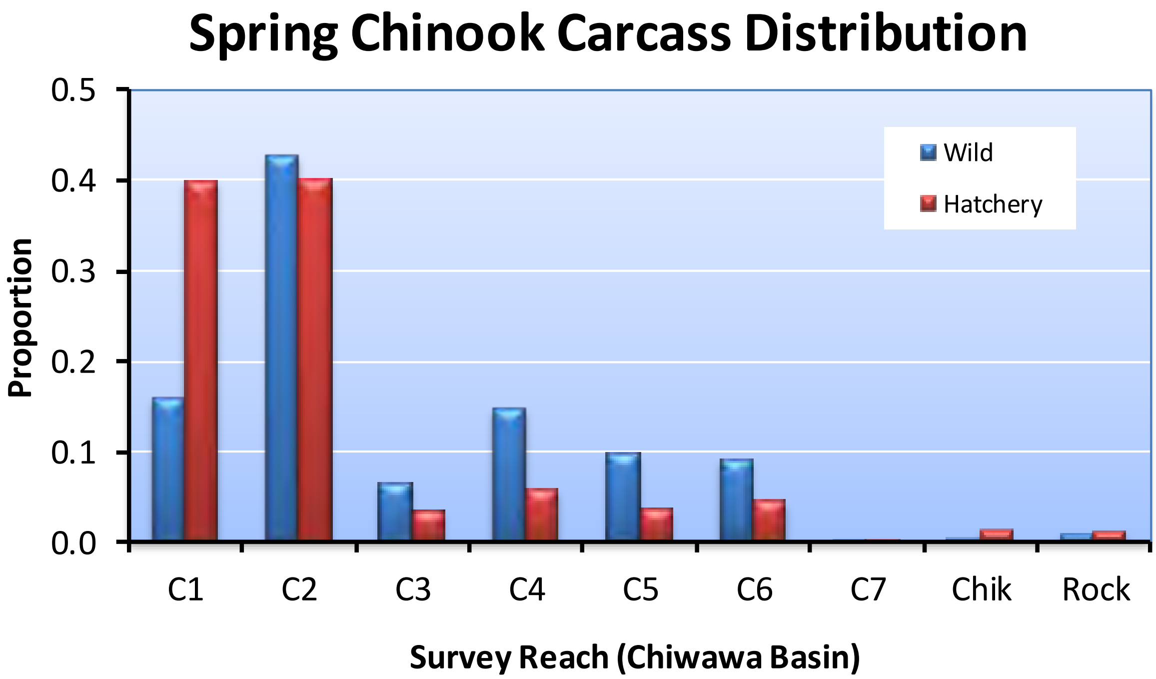


Figure 5.12. Distribution of wild and hatchery produced carcasses in different reaches in the Chiwawa River basin, 1993-2016; Chik = Chikamin Creek and Rock = Rock Creek. Reach codes are described in Table 2.8.

Sampling Rate

Overall, 36% of the estimated total spawning escapement of spring Chinook in the Wenatchee River basin was sampled in 2016 (Table 5.30). Sampling rates among streams/watershed varied from 0 to 61%.

Table 5.30. Number of redds and carcasses, total spawning escapement, and sampling rates for spring Chinook salmon in the Wenatchee River basin, 2016.

Sampling area	Total number of observed redds	Total number of carcasses	Total spawning escapement	Sampling rate
Chiwawa	312	211	571	0.37
Nason	85	95	156	0.61
Upper Wenatchee	17	13	31	0.42
Icicle	72	25	130	0.19
Little Wenatchee	22	5	40	0.13
White	44	13	81	0.16
Peshastin	2	0	4	0.00
Total	***554***	***362***	***1,012***	***0.36***

Length Data

Mean lengths (POH, cm) of male and female spring Chinook carcasses sampled during surveys in the Wenatchee River basin in 2016 are provided in Table 5.31. The average size of males and females sampled in the Wenatchee River basin was 63 cm.

Table 5.31. Mean lengths (postorbital-to-hypural length; cm) and standard deviations (in parentheses) of male and female spring Chinook carcasses sampled in different streams/watersheds in the Wenatchee River basin, 2016.

Stream/watershed	Mean lengths (cm)	
	Male	Female
Chiwawa	64 (12.0)	65 (6.5)
Nason	59 (10.1)	64 (6.2)
Upper Wenatchee	63 (13.2)	63 (6.8)
Icicle	61 (11.4)	60 (4.2)
Little Wenatchee	82 (4.2)	64 (5.7)
White	69 (4.0)	66 (6.2)
Peshastin	--	--
Total	***62 (11.5)***	***64 (6.3)***

5.7 Life History Monitoring

Life history characteristics of spring Chinook were assessed by examining carcasses on spawning grounds and fish collected at broodstock collection sites, and by reviewing tagging data and fisheries statistics.

Migration Timing

In 2016, there was a small difference in migration timing of hatchery and wild spring Chinook past Tumwater Dam (Table 5.32a and b; Figure 5.13). Hatchery fish arrived at the dam later than did wild fish, but ended their migration earlier than did wild fish. This same pattern was also observed in the overall average. Most hatchery and wild spring Chinook migrated upstream past Tumwater Dam during June and July (Figure 5.13).

Table 5.32a. The Julian day and date that 10%, 50% (median), and 90% of the wild and hatchery spring Chinook salmon passed Tumwater Dam, 1998-2016. The average Julian day and date are also provided. Migration timing is based on video sampling at Tumwater. Data for 1998 through 2003 were based on videotapes and broodstock trapping and may not reflect the actual number of hatchery spring Chinook. All spring Chinook were visually examined during trapping from 2004 to present.

Survey year	Origin	Spring Chinook Migration Time (days)								Sample size
		10 Percentile		50 Percentile		90 Percentile		Mean		
		Julian	Date	Julian	Date	Julian	Date	Julian	Date	
1998	Wild	156	5-Jun	156	5-Jun	156	5-Jun	156	5-Jun	49
	Hatchery	156	5-Jun	156	5-Jun	156	5-Jun	156	5-Jun	25
1999	Wild	192	11-Jul	207	26-Jul	224	12-Aug	207	26-Jul	173
	Hatchery	200	19-Jul	211	30-Jul	229	17-Aug	213	1-Aug	25
2000	Wild	171	19-Jun	186	4-Jul	194	12-Jul	184	2-Jul	651

Survey year	Origin	Spring Chinook Migration Time (days)								Sample size
		10 Percentile		50 Percentile		90 Percentile		Mean		
		Julian	Date	Julian	Date	Julian	Date	Julian	Date	
	Hatchery	179	27-Jun	189	7-Jul	201	19-Jul	190	8-Jul	357
2001	Wild	154	3-Jun	166	15-Jun	185	4-Jul	167	16-Jun	2,073
	Hatchery	157	6-Jun	169	18-Jun	185	4-Jul	170	19-Jun	4,244
2002	Wild	174	23-Jun	189	8-Jul	204	23-Jul	189	8-Jul	1,033
	Hatchery	178	27-Jun	189	8-Jul	199	18-Jul	189	8-Jul	1,363
2003	Wild	162	11-Jun	181	30-Jun	200	19-Jul	181	30-Jun	919
	Hatchery	157	6-Jun	179	28-Jun	192	11-Jul	178	27-Jun	423
2004	Wild	156	4-Jun	172	20-Jun	189	7-Jul	172	20-Jun	969
	Hatchery	161	9-Jun	177	25-Jun	189	7-Jul	177	25-Jun	1,295
2005	Wild	153	2-Jun	172	21-Jun	193	12-Jul	173	22-Jun	1,038
	Hatchery	153	2-Jun	173	22-Jun	187	6-Jul	172	21-Jun	2,808
2006	Wild	177	26-Jun	184	3-Jul	193	12-Jul	185	4-Jul	577
	Hatchery	178	27-Jun	185	4-Jul	194	13-Jul	186	5-Jul	1601
2007	Wild	169	18-Jun	185	4-Jul	203	22-Jul	185	4-Jul	351
	Hatchery	174	23-Jun	192	11-Jul	209	28-Jul	192	11-Jul	3,232
2008	Wild	173	21-Jun	188	6-Jul	209	27-Jul	189	7-Jul	634
	Hatchery	177	25-Jun	193	11-Jul	210	28-Jul	193	11-Jul	5,368
2009	Wild	174	23-Jun	186	5-Jul	201	20-Jul	187	6-Jul	1,008
	Hatchery	175	24-Jun	187	6-Jul	202	21-Jul	188	7-Jul	4,106
2010	Wild	173	22-Jun	190	9-Jul	214	2-Aug	191	10-Jul	977
	Hatchery	180	29-Jun	194	13-Jul	213	1-Aug	195	14-Jul	4,450
2011	Wild	183	2-Jul	198	17-Jul	213	1-Aug	198	17-Jul	1,433
	Hatchery	187	6-Jul	200	19-Jul	210	29-Jul	199	18-Jul	4,707
2012	Wild	180	28-Jun	191	9-Jul	205	23-Jul	192	10-Jul	1,482
	Hatchery	182	30-Jun	194	12-Jul	206	24-Jul	194	12-Jul	4,449
2013	Wild	163	12-Jun	182	1-Jul	199	18-Jul	183	2-Jul	1,106
	Hatchery	164	13-Jun	181	30-Jun	195	14-Jul	181	30-Jun	3,681
2014	Wild	171	20-Jun	188	7-Jul	202	21-Jul	187	6-Jul	1,329
	Hatchery	167	16-Jun	182	1-Jul	195	14-Jul	181	30-Jun	2,510
2015	Wild	150	30-May	170	19-Jun	184	3-Jul	170	19-Jun	1,370
	Hatchery	148	28-May	168	17-Jun	180	29-Jun	167	16-Jun	1,773
2016	Wild	158	6-Jun	180	28-Jun	200	18-Jul	181	29-Jun	1,252
	Hatchery	160	8-Jun	179	27-Jun	191	9-Jul	178	26-Jun	1,284
Average	Wild	***168***		***183***		***198***		***183***		***970***
	Hatchery	***170***		***184***		***197***		***184***		***2,511***
Median	Wild	***171***		***185***		***200***		***185***		***1,008***
	Hatchery	***174***		***185***		***195***		***186***		***2,510***

Table 5.32b. The week that 10%, 50% (median), and 90% of the wild and hatchery spring Chinook salmon passed Tumwater Dam, 1998-2016. The average week is also provided. Migration timing is based on video sampling at Tumwater. Data for 1998 through 2003 were based on videotapes and broodstock trapping and may not reflect the actual number of hatchery spring Chinook. All spring Chinook were visually examined during trapping from 2004 to present.

Survey year	Origin	Spring Chinook Migration Time (week)				Sample size
		10 Percentile	50 Percentile	90 Percentile	Mean	
1998	Wild	23	23	23	23	49
	Hatchery	23	23	23	23	25
1999	Wild	28	30	32	30	173
	Hatchery	29	31	34	31	25
2000	Wild	24	27	27	27	651
	Hatchery	26	27	29	28	357
2001	Wild	22	24	27	24	2,073
	Hatchery	23	25	27	25	4,244
2002	Wild	25	27	30	27	1,033
	Hatchery	26	27	29	27	1,363
2003	Wild	24	26	29	26	919
	Hatchery	23	26	28	26	423
2004	Wild	23	25	27	25	969
	Hatchery	23	26	27	26	1,295
2005	Wild	22	25	28	25	1,038
	Hatchery	22	25	27	25	2,808
2006	Wild	26	27	28	27	577
	Hatchery	26	27	28	27	1,601
2007	Wild	25	27	29	27	351
	Hatchery	25	28	30	28	3,232
2008	Wild	25	27	30	27	634
	Hatchery	26	28	30	28	5,368
2009	Wild	25	27	29	27	1,008
	Hatchery	25	27	29	27	4,106
2010	Wild	25	28	31	28	977
	Hatchery	26	28	31	28	4,450
2011	Wild	27	29	31	29	1,433
	Hatchery	27	29	30	29	4,707
2012	Wild	26	28	30	28	1,482
	Hatchery	26	28	30	28	4,449
2013	Wild	24	26	29	27	1,106
	Hatchery	24	26	28	26	3,681
2014	Wild	25	27	29	27	1,329
	Hatchery	24	26	28	26	2,510

Survey year	Origin	Spring Chinook Migration Time (week)				Sample size
		10 Percentile	50 Percentile	90 Percentile	Mean	
2015	Wild	22	25	27	25	1,370
	Hatchery	22	24	26	24	1,773
2016	Wild	23	26	29	26	1,252
	Hatchery	23	26	28	26	1,284
Average	Wild	***24***	***27***	***29***	***27***	***970***
	Hatchery	***25***	***27***	***29***	***27***	***2,511***
Median	Wild	***25***	***27***	***29***	***27***	***1,008***
	Hatchery	***25***	***27***	***28***	***27***	***2,510***

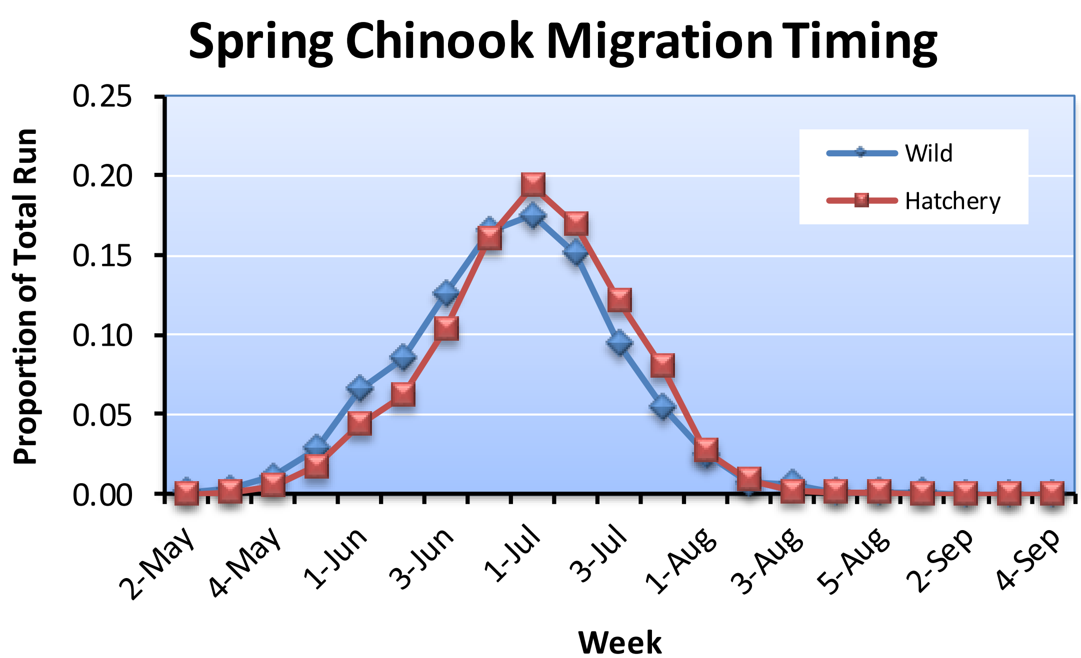


Figure 5.13. Proportion of wild and hatchery spring Chinook observed (using video) passing Tumwater Dam each week during their migration period May through September; data were pooled over survey years 1998-2016.

Age at Maturity

Most of the wild and hatchery spring Chinook sampled during the period 1994-2016 in the Chiwawa River basin were age-4 fish (total age) (Table 5.33; Figure 5.14). On average, hatchery fish made up a higher percentage of age-3 Chinook than did wild fish. In contrast, a higher proportion of age-5 wild fish returned than did age-5 hatchery fish. Thus, wild fish tended to return at an older age than hatchery fish.

Table 5.33. Proportions of wild and hatchery spring Chinook of different ages (total age) sampled on spawning grounds in the Chiwawa River basin, 1994-2016.

Sample year	Origin	Total age					Sample size
		2	3	4	5	6	
1994	Wild	0.00	0.00	0.33	0.67	0.00	9
	Hatchery	0.00	0.20	0.00	0.80	0.00	5
1995	Wild	0.00	0.00	0.00	0.00	0.00	0
	Hatchery	0.00	0.00	1.00	0.00	0.00	5
1996	Wild	0.00	0.36	0.64	0.00	0.00	14
	Hatchery	0.00	0.83	0.17	0.00	0.00	6
1997	Wild	0.00	0.00	0.75	0.25	0.00	8
	Hatchery	0.00	0.00	1.00	0.00	0.00	9
1998	Wild	0.00	0.00	0.00	1.00	0.00	15
	Hatchery	0.00	0.00	0.13	0.88	0.00	8
1999	Wild	0.00	0.07	0.50	0.43	0.00	14
	Hatchery	0.00	0.00	0.00	1.00	0.00	1
2000	Wild	0.00	0.02	0.95	0.04	0.00	56
	Hatchery	0.00	0.50	0.50	0.00	0.00	52
2001	Wild	0.00	0.01	0.95	0.04	0.00	176
	Hatchery	0.00	0.02	0.98	0.00	0.00	571
2002	Wild	0.00	0.00	0.56	0.44	0.00	54
	Hatchery	0.00	0.00	0.91	0.09	0.00	129
2003	Wild	0.00	0.08	0.00	0.92	0.00	36
	Hatchery	0.00	0.19	0.03	0.78	0.00	32
2004	Wild	0.00	0.05	0.94	0.01	0.00	99
	Hatchery	0.00	0.42	0.58	0.00	0.00	78
2005	Wild	0.00	0.02	0.78	0.21	0.00	67
	Hatchery	0.00	0.04	0.96	0.00	0.00	324
2006	Wild	0.02	0.02	0.51	0.44	0.00	45
	Hatchery	0.01	0.04	0.78	0.18	0.00	196
2007	Wild	0.00	0.10	0.24	0.67	0.00	29
	Hatchery	0.00	0.35	0.59	0.06	0.00	221
2008	Wild	0.02	0.02	0.81	0.14	0.00	43
	Hatchery	0.00	0.07	0.89	0.05	0.00	340
2009	Wild	0.00	0.09	0.86	0.05	0.00	44
	Hatchery	0.00	0.24	0.75	0.02	0.00	196
2010	Wild	0.00	0.00	0.90	0.10	0.00	63
	Hatchery	0.00	0.07	0.91	0.02	0.00	127
2011	Wild	0.00	0.08	0.38	0.54	0.00	65
	Hatchery	0.00	0.26	0.45	0.30	0.00	112

Sample year	Origin	Total age					Sample size
		2	3	4	5	6	
2012	Wild	0.00	0.01	0.80	0.19	0.00	141
	Hatchery	0.00	0.03	0.96	0.02	0.00	243
2013	Wild	0.00	0.09	0.60	0.31	0.00	105
	Hatchery	0.00	0.13	0.78	0.09	0.00	275
2014	Wild	0.00	0.04	0.89	0.07	0.00	169
	Hatchery	0.00	0.08	0.90	0.02	0.00	148
2015	Wild	0.00	0.01	0.83	0.16	0.00	96
	Hatchery	0.00	0.06	0.93	0.01	0.00	185
2016	Wild	0.00	0.04	0.67	0.29	0.00	138
	Hatchery	0.00	0.04	0.80	0.16	0.00	71
Average	***Wild***	***0.00***	***0.04***	***0.74***	***0.22***	***0.00***	***65***
	Hatchery	***0.00***	***0.11***	***0.83***	***0.06***	***0.00***	***145***
Median	***Wild***	***0.00***	***0.03***	***0.73***	***0.25***	***0.00***	***54***
	Hatchery	***0.00***	***0.07***	***0.90***	***0.03***	***0.00***	***127***

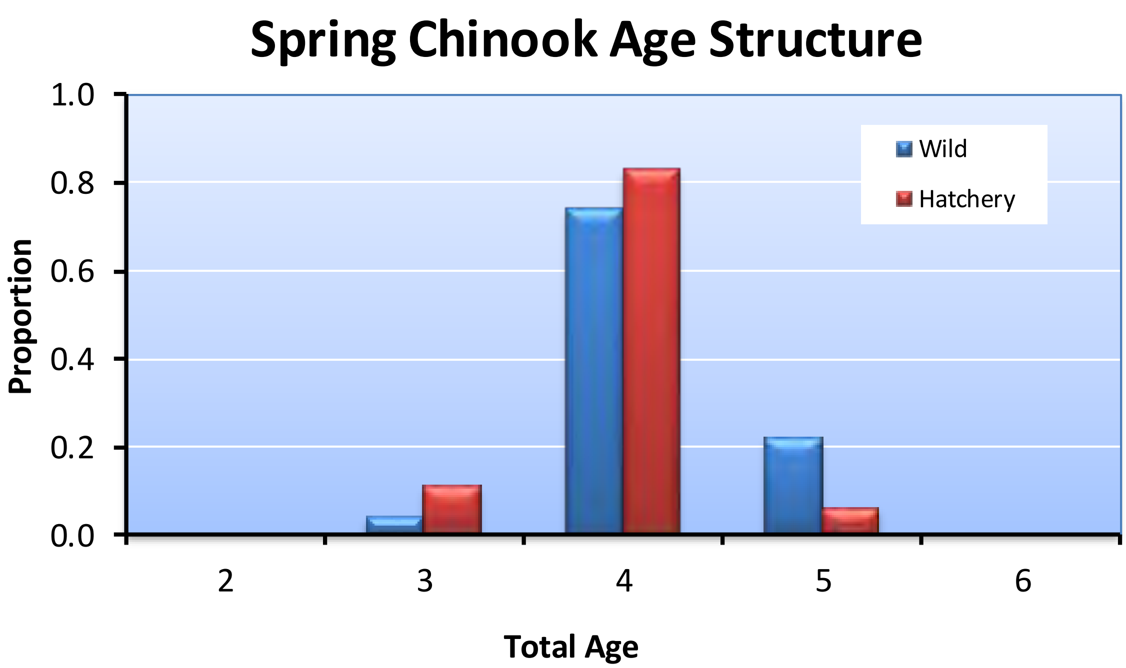


Figure 5.14. Proportions of wild and hatchery spring Chinook of different total ages sampled at the Chiwawa Weir and on spawning grounds in the Chiwawa River basin for the combined years 1994-2016.

Size at Maturity

On average, hatchery and wild spring Chinook of a given age differed slightly in length (Table 5.34). Differences were usually no more than 4 cm between hatchery and wild fish of the same age.

Table 5.34. Mean lengths (POH in cm; ±1SD) and sample sizes (in parentheses) of different ages (total age) of male and female spring Chinook of wild and hatchery-origin sampled in the Chiwawa River basin, 1994-2016. Return years 2004-2016 include carcasses and live fish PIT-tag detections. In addition, 2005 and 2006 include fish released at the weir.

Return year	Total age	Mean length (cm)			
		Male		Female	
		Wild	Hatchery	Wild	Hatchery
1994	3				43 ±0 (1)
	4			62 ±3 (3)	
	5	76 ±0 (1)		73 ±2 (5)	
	6				
1995	3				
	4		61 ±5 (5)		
	5				
	6				
1996	3	45 ±3 (5)	49 ±7 (10)		
	4	69 ±4 (6)	69 ±0 (1)	67 ±8 (2)	
	5				
	6				
1997	3				
	4	61 ±1 (2)	68 ±0 (1)	67 ±5 (3)	63 ±3 (8)
	5	67 ±5 (2)			
	6				
1998	3				
	4				54 ±0 (1)
	5	77 ±7 (8)	75 ±4 (4)	74 ±4 (7)	76 ±4 (3)
	6				
1999	3	44 ±0 (1)			
	4	61 ±0 (1)		64 ±3 (6)	
	5	76 ±5 (3)		72 ±5 (3)	66 ±0 (1)
	6				
2000	3		46 ±3 (17)		50 ±7 (3)
	4	60 ±8 (23)	62 ±5 (5)	61 ±5 (26)	62 ±3 (20)
	5	77 ±1 (2)			
	6				
2001	3	37 ±0 (1)	42 ±4 (11)	41 ±0 (1)	60 ±0 (1)
	4	63 ±5 (57)	65 ±5 (151)	62 ±4 (110)	63 ±4 (407)
	5	75 ±5 (2)	83 ±0 (1)	76 ±1 (5)	
	6				
2002	3				
	4	64 ±4 (14)	66 ±5 (46)	60 ±4 (15)	63 ±4 (71)
	5	80 ±6 (13)	75 ±5 (4)	72 ±3 (12)	73 ±6 (6)
	6				
2003	3	45 ±2 (3)	45 ±1 (6)		

Return year	Total age	Mean length (cm)			
		Male		Female	
		Wild	Hatchery	Wild	Hatchery
	4		63 ±0 (1)		
	5	78 ±5 (12)	74 ±8 (11)	75 ±3 (19)	72 ±5 (14)
	6				
2004	3	42 ±3 (3)	44 ±5 (33)		
	4	63 ±7 (60)	66 ±5 (9)	63 ±4 (59)	63 ±6 (36)
	5			74 ±0 (1)	
	6				
2005	3		43 ±5 (48)		
	4	61 ±5 (32)	65 ±5 (224)	62 ±4 (61)	62 ±4 (382)
	5	74 ±5 (6)	54±0 (1)	71 ±3 (11)	
	6				
2006	3	45 ±3 (3)	43 ±3 (73)		
	4	64 ±3 (7)	62 ±6 (91)	63 ±5 (41)	60 ±4 (227)
	5	74 ±6 (8)	75 ±6 (17)	71 ±4 (26)	71± 4 (37)
	6				
2007	3	39 ±3 (5)	45 ±6 (90)		50 ±3 (7)
	4	60 ±4 (4)	66 ±5 (45)	61 ±4 (10)	63 ±3 (142)
	5	78 ±6 (15)	76 ±5 (8)	74 ±3 (20)	73 ±5 (12)
	6				
2008	3	43 ±0 (1)	44 ±5 (22)		
	4	65 ±4 (9)	64 ±6 (73)	62 ±4 (26)	64 ±4 (229)
	5	65 ±5 (3)	79 ±5 (10)	73 ±3 (4)	72 ±3 (5)
	6				
2009	3	45 ±3 (8)	46 ±6 (68)		65 ±0 (1)
	4	64 ±4 (38)	65 ±5 (136)	63 ±3 (67)	64 ±4 (202)
	5	79 ±0 (1)		72 ±2 (4)	71 ±4 (10)
	6				
2010	3		46 ±4 (11)		65 ±3 (3)
	4	64 ±5 (31)	66 ±5 (74)	64 ±4 (82)	65 ±3 (196)
	5	77 ±4 (6)		73 ±5 (9)	73 ±6 (4)
	6				
2011	3	43 ±4 (133)	44 ±4 (1374)		53 ±4 (17)
	4	62 ±5 (137)	64 ±5 (169)	64 ±3 (94)	64 ±3 (258)
	5	80 ±5 (78)	79 ±4 (85)	75 ±3 (116)	75 ±3 (63)
	6				
2012	3	56 ±0 (1)	52 ±7 (7)		
	4	79 ± 6 (37)	80 ±6 (49)	79 ±3 (76)	78 ±4 (180)
	5	97 ±7 (11)	96 ±3 (4)	93 ±4 (16)	87 ±0 (1)
	6				
2013	3	45 ±4 (8)	43 ±4 (32)	35 ±0 (1)	49 ±12 (3)
	4	60 ±6 (29)	63 ±7 (41)	61 ±6 (34)	61 ±4 (171)

Return year	Total age	Mean length (cm)			
		Male		Female	
		Wild	Hatchery	Wild	Hatchery
	5	75 ±5 (9)	71 ±2 (7)	71 ±3 (24)	69 ±4 (18)
	6				
2014	3	45 ±7 (5)	45±4 (11)	50±0 (1)	47±0 (1)
	4	64 ±7 (60)	62 ±7 (30)	63 ±4 (91)	61 ±4 (99)
	5	81 ±4 (4)		72 ±6 (8)	69 ±4 (3)
	6				
2015	3	56±0 (1)	48±4 (11)		52±0 (1)
	4	65±5 (23)	65±6 (42)	63±5 (57)	63±4 (126)
	5	75±7 (6)	71±0 (1)	69±6 (9)	73±0 (1)
	6				
2016	3	41±5 (5)	43±4 (3)		
	4	63±7 (30)	64±7 (12)	63±5 (62)	61±5 (45)
	5	76±7 (13)	75±0 (1)	73±5 (27)	67±4 (10)
	6				

Contribution to Fisheries

Nearly all the harvest on hatchery-origin Chiwawa spring Chinook occurs within the Columbia River basin. Ocean catch records (Pacific Fishery Management Council) indicate that very few Upper Columbia spring Chinook are taken in ocean fisheries. Most of the harvest on hatchery-origin Chiwawa spring Chinook occurs in the Lower Columbia River fisheries, which are managed by the states and tribes pursuant to management plans developed in *U.S. v Oregon*. The Lower Columbia River fisheries occur during what is referred to in *U.S. v Oregon* as the winter, spring, and summer seasons, which begin in February and ends 31 July of each year. The Tribal fishery occurs upstream from Bonneville Dam, but primarily in Zone 6, the area between Bonneville and McNary dams; the non-treaty commercial fisheries occur in Zones 1-5, which are downstream from Bonneville Dam. The non-treaty recreational (sport) fishery occurs in the lower mainstem.

The total number of hatchery-origin spring Chinook captured in different fisheries has been relatively low (Table 5.35). The largest harvest occurred on the 2008 brood year.

Table 5.35. Estimated number and percent (in parentheses) of hatchery-origin Chiwawa spring Chinook captured in different fisheries, brood years 1989-2011; NP = no hatchery program.

Brood year	Ocean fisheries	Columbia River Fisheries			Total
		Tribal	Commercial (Zones 1-5)	Recreational[a] (sport)	
1989	3 (13)	5 (21)	0 (0)	16 (67)	24
1990	0 (0)	0 (0)	0 (0)	18 (100)	18
1991	0 (0)	3 (100)	0 (0)	0 (0)	3
1992	0 (0)	1 (100)	0 (0)	0 (0)	1
1993	3 (75)	1 (25)	0 (0)	0 (0)	4
1994	0 (0)	0 (0)	0 (0)	0 (0)	0

Brood year	Ocean fisheries	Columbia River Fisheries			Total
		Tribal	Commercial (Zones 1-5)	Recreational[a] (sport)	
1995	NP	NP	NP	NP	NP
1996	0 (0)	2 (100)	0 (0)	0 (0)	2
1997	1 (0)	193 (51)	68 (18)	115 (31)	377
1998	10 (5)	47 (24)	12 (6)	126 (65)	195
1999	NP	NP	NP	NP	NP
2000	0 (0)	17 (74)	0 (0)	6 (26)	23
2001	36 (64)	8 (14)	1 (2)	11 (20)	56
2002	12 (17)	11 (15)	22 (31)	26 (37)	71
2003	18 (21)	29 (35)	11 (13)	26 (31)	84
2004	3 (1)	188 (40)	31 (7)	253 (53)	475
2005	6 (5)	31 (24)	18 (14)	74 (57)	129
2006	25 (3)	469 (60)	84 (11)	201 (26)	779
2007	14 (3)	180 (43)	75 (18)	151 (36)	420
2008	8 (1)	298 (21)	41 (3)	1,047 (75)	1,394
2009	6 (2)	85 (22)	73 (19)	228 (58)	392
2010	0 (0)	372 (57)	45 (7)	236 (28)	653
2011	3 (0)	393 (53)	138 (19)	206 (28)	740
Average	***7 (10)***	***111 (42)***	***29 (8)***	***130 (35)***	***278***
Median	***3 (1)***	***29 (35)***	***12 (6)***	***26 (31)***	***84***

[a] Includes the Wanapum fishery and the Icicle and Wenatchee fisheries when they occurred.

Straying

Stray rates were determined by examining CWTs recovered on spawning grounds within and outside the Wenatchee River basin. Targets for strays based on return year (recovery year) within the Wenatchee River basin should be less than 10% and targets for strays outside the Wenatchee River basin should be less than 5%. The target for brood year stray rates should be less than 5%.

The percentage of the spawning escapement made up of hatchery-origin Chiwawa spring Chinook in non-target spawning areas within the Wenatchee River basin has been high in some years and exceeded the target of 10% (Table 5.36). Over the years of sampling, Chiwawa spring Chinook have strayed into all non-target spawning areas, but, on average, have contributed most to the Nason Creek and Upper Wenatchee spawning escapements.

Table 5.36. Number (No.) and percent (%) of the spawning escapement in other non-target spawning streams within the Wenatchee River basin that consisted of hatchery-origin Chiwawa spring Chinook, return years 1992-2015. For example, for return year 2001, 35.3% of the spring Chinook spawning escapement in Nason Creek consisted of hatchery-origin Chiwawa spring Chinook. Percent strays should be less than 10%.

Return year	Nason Creek		Icicle Creek		Peshastin Creek		Upper Wenatchee		White River		Little Wenatchee	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
1992	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
1993	61	12.4	0	0.0	0	0.0	34	18.0	7	4.8	0	0.0
1994	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
1995	0	0.0	0	0.0	0	0.0	2	66.7	0	0.0	0	0.0
1996	25	30.1	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
1997	55	45.1	8	11.0	0	0.0	0	0.0	0	0.0	0	0.0
1998	3	4.7	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
1999	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
2000	45	16.7	0	0.0	0	0.0	31	31.0	0	0.0	6	25.0
2001	211	35.3	0	0.0	0	0.0	271	77.7	46	27.7	52	44.1
2002	188	31.2	10	2.6	0	0.0	60	45.8	14	16.3	21	24.4
2003	14	6.9	0	0.0	0	0.0	30	51.7	0	0.0	0	0.0
2004	139	27.4	0	0.0	0	0.0	54	39.1	6	9.1	0	0.0
2005	252	72.6	7	53.8	0	0.0	256	99.6	106	68.4	65	56.5
2006	131	48.3	13	15.5	0	0.0	28	58.3	9	16.4	12	32.4
2007	303	65.4	0	0.0	0	0.0	37	67.3	7	7.6	6	5.9
2008	381	67.4	48	23.3	29	78.4	258	85.4	30	57.7	52	81.3
2009	289	54.1	8	11.3	0	0.0	16	100.0	63	36.4	56	44.8
2010	272	66.3	58	24.0	11	100.0	86	84.3	23	31.9	59	71.1
2011	397	56.6	61	19.2	0	0.0	41	82.0	0	0.0	53	42.7
2012	398	57.3	49	15.4	7	43.8	98	79.7	45	31.3	15	20.8
2013	281	68.7	15	7.1	0	0.0	24	72.7	5	4.8	10	10.2
2014	204	86.1	19	4.7	0	0.0	41	87.2	0	0.0	1	1.9
2015	11	7.3	12	4.9	0	0.0	50	51.0	8	6.4	0	0.0
Average	***153***	***35.8***	***13***	***8.0***	***2***	***9.3***	***59***	***49.9***	***15***	***13.3***	***17***	***19.2***
Median	***135***	***33.3***	***4***	***1.3***	***0***	***0.0***	***33***	***55.0***	***6***	***4.8***	***4***	***3.9***

Hatchery-origin Chiwawa spring Chinook have strayed into the Methow and Entiat basins (Table 5.37). Based on return year analyses, rates of hatchery-origin Chiwawa spring Chinook straying into these populations have been low in most years; in 2015, Chiwawa spring Chinook made up 4.7% of the spawning escapement in the Entiat River and 0.5% in the Methow River. However, during return years 2002, 2006, 2008-2009, and 2011-2013, Chiwawa spring Chinook made up more than 5% of the spawning escapement in the Entiat River basin. In three years, Chiwawa spring Chinook hatchery fish made up more than 20% of the spawning escapement in the Entiat River basin; however, in return year 2014, no strays were detected in the Entiat or Methow River basins.

Table 5.37. Number and percent of spawning escapements within other non-target basins that consisted of hatchery-origin Chiwawa spring Chinook, return years 1992-2015. For example, for return year 2002, 9.2% of the spring Chinook spawning escapement in the Entiat River basin consisted of hatchery-origin Chiwawa spring Chinook. Percent strays should be less than 5%. NS = not sampled.

Return year	Methow River basin		Entiat River basin	
	Number	%	Number	%
1992	0	0.0	0	0.0
1993	0	0.0	0	0.0
1994	0	0.0	0	0.0
1995	0	0.0	0	0.0
1996	NS	NS	0	0.0
1997	0	0.0	0	0.0
1998	NS	NS	0	0.0
1999	0	0.0	0	0.0
2000	0	0.0	1	0.6
2001	0	0.0	1	0.2
2002	0	0.0	34	9.2
2003	0	0.0	6	2.3
2004	0	0.0	0	0.0
2005	10	0.7	15	4.2
2006	8	0.5	30	9.3
2007	9	0.8	24	1.6
2008	12	1.2	61	21.9
2009	7	0.3	15	5.4
2010	10	0.4	18	3.7
2011	51	1.7	190	31.9
2012	13	1.0	133	23.5
2013	9	0.8	24	10.1
2014	0	0.0	0	0.0
2015	7	0.5	24	4.7
Average	***6***	***0.4***	***24***	***5.4***
Median	***0***	***0.0***	***4***	***1.1***

Based on brood year analyses, on average, about 30% of the hatchery returns have strayed into non-target spawning areas, exceeding the target of 5% (Table 5.38). Depending on brood year, percent strays into non-target spawning areas have ranged from 0-81%. In most years, few (<1%) have strayed into non-target hatchery programs.

Table 5.38. Number and percent of hatchery-origin Chiwawa spring Chinook that homed to target spawning areas and the target hatchery program, and number and percent that strayed to non-target spawning areas and non-target hatchery programs, by brood years 1989-2011. Percent strays should be less than 5%.

Brood year	Homing				Straying			
	Target stream		Target hatchery*		Non-target streams		Non-target hatcheries	
	Number	%	Number	%	Number	%	Number	%
1989	74	41.1	1	0.6	102	56.7	3	1.7
1990	0	0.0	1	100.0	0	0.0	0	0.0
1991	29	90.6	0	0.0	2	6.3	1	3.1
1992	2	6.5	4	12.9	25	80.6	0	0.0
1993	134	47.5	82	29.1	63	22.3	3	1.1
1994	4	19.0	14	66.7	3	14.3	0	0.0
1995	No program							
1996	58	75.3	7	9.1	12	15.6	0	0.0
1997	1,242	55.6	298	13.4	687	30.8	5	0.2
1998	553	55.8	109	11.0	329	33.2	0	0.0
1999	No program							
2000	149	42.1	115	32.5	90	25.4	0	0.0
2001	647	35.8	276	15.3	881	48.7	4	0.2
2002	314	44.3	238	33.6	156	22	1	0.1
2003	556	78.6	11	1.6	133	18.8	7	1.0
2004	1,198	47.4	203	8.0	1,104	43.7	23	0.9
2005	822	59.3	139	10.0	415	29.9	10	0.7
2006	1,007	54.8	147	8.0	669	36.4	14	0.8
2007	510	57.8	60	6.8	294	33.3	19	2.2
2008	1,160	47.1	62	2.5	1,144	46.4	99	4.0
2009	746	63.1	53	4.5	356	30.1	27	2.3
2010	799	54.5	366	25.0	275	18.8	25	1.7
2011	560	57.7	258	26.6	150	15.5	2	0.2
Average	***503***	***49.2***	***116***	***19.9***	***328***	***29.9***	***12***	***1.0***
Median	***553***	***54.5***	***82***	***11.0***	***156***	***29.9***	***3***	***0.7***

* Homing to the target hatchery includes Chiwawa hatchery spring Chinook that are captured and included as broodstock in the Chiwawa Hatchery program. These hatchery fish are typically collected at the Chiwawa weir and Tumwater Dam.

Ford et al. (2015) used parentage analysis to estimate rates of straying and homing of spring Chinook within the Wenatchee River basin. They found that stray rates of hatchery spring Chinook based on parentage analysis were consistent with rates estimated using physical tag recoveries (the latter estimates are shown in the tables above). They also found that stray rates among the major spawning tributaries were higher than stray rates of tagged fish to areas outside of the Wenatchee River basin (e.g., Entiat and Methow basins), which is consistent with the results shown in the tables above. Finally, the researchers noted that hatchery spring Chinook homed at a far lower rate than natural-origin fish and stray rates of natural-origin fish ranged from about 0-100%. Rates of straying of natural-origin spring Chinook were affected by spawning tributary and by parental origin (i.e., progeny of naturally spawning hatchery-produced fish strayed at higher rates than progeny whose parents were of natural origin).

Genetics

Genetic studies were conducted in 2007 to determine the potential effects of the Chiwawa Supplementation Program on natural-origin spring Chinook in the upper Wenatchee River basin (Blankenship et al. 2007; the entire report is appended as Appendix K). A total of 32 population collections of adult spring Chinook were obtained from the Wenatchee River basin between 1989 and 2006. This included nine collections of natural-origin Chinook adults from the Chiwawa River (N = 501) and nine collections of Chiwawa hatchery-origin Chinook (N = 595) at the Chiwawa weir. Collections in 1993 and 1994 included hatchery-origin smolts. Additional samples were collected from the White River, Little Wenatchee River, and Nason Creek; six collections of natural-origin Chinook from the White River (N = 179), one collection from the Little Wenatchee (N = 19), and six collections from Nason Creek (N = 268). A single collection was obtained for Chinook spawning in the mainstem Wenatchee River and from the Leavenworth National Fish Hatchery. Finally, an out-of-basin collection from the Entiat River was included in the analysis. Scale, fin clips, or operculum punches were collected from each sample. Microsatellite DNA allele frequencies were used to statistically assign individual fish to specific demes (locations) within the Wenatchee population. In addition, genetic effects of the hatchery program were assessed by examining relationships between census and effective population sizes (N_e) from samples collected before and after supplementation.

Overall, this work showed that although allele frequencies within and between natural and hatchery-origin spring Chinook were significantly different, there was no evidence (i.e., robust signal) that the difference was the result of the hatchery program. Rather, the differences were more likely the result of life history characteristics. However, there was an increasing trend toward homogenization of the allele frequencies of the natural and hatchery-origin fish that comprised the broodstock, even though there was consistent year-to-year variation in allele frequencies among hatchery and natural-origin fish. In addition, there were no robust signals indicating that hatchery-origin hatchery broodstock, hatchery-origin natural spawners, natural-origin hatchery broodstock, and natural-origin natural spawners were substantially different from each other. Finally, the N_e estimate of 387 was only slightly larger than the pre-hatchery N_e (based on demographic data from 1989-1992), which means that the Chiwawa hatchery program has not reduced the N_e of the Wenatchee spring Chinook population.

Significant differences in allele frequencies were observed within and among major spawning areas in the Upper Wenatchee River basin. However, these differences made up only a very small portion of the overall variation, indicating genetic similarity among the major spawning areas. There was no evidence that the Chiwawa program has changed the genetic structure (allele frequency) of spring Chinook in Nason Creek and the White River, despite the presence of hatchery-origin spawners in both systems.

It is important to note that no new information will be reported on genetics until the next five-year report (2018).

Proportionate Natural Influence

Another method for assessing the genetic risk of a supplementation program is to determine the influence of the hatchery and natural environments on the adaptation of the composite population. This is estimated by the proportion of natural-origin fish in the hatchery broodstock (pNOB) and the proportion of hatchery-origin fish in the natural spawning escapement (pHOS). We calculated Proportionate Natural Influence (PNI) by iterating Ford's (2002) equations 5 and 6 to equilibrium, using a heritability of 0.3 and a selection strength of three standard deviations.[14] The larger the PNI value, the greater the strength of selection in the natural environment relative to that of the hatchery environment. For the natural environment to dominate selection, PNI should be greater than 0.50, and important integrated populations should have a PNI of at least 0.67 (HSRG/WDFW/NWIFC 2004).

For brood years 1989-1994, PNI values were greater than or equal to 0.67 (Table 5.39). Since brood year 1994, PNI has been less than 0.67, except for brood year 2016, which was 0.70.

Table 5.39. Proportionate Natural Influence (PNI) values for the Chiwawa spring Chinook supplementation program for brood years 1989-2016. NOS = number of natural-origin Chinook on the spawning grounds; HOS = number of hatchery-origin Chinook on the spawning grounds; NOB = number of natural-origin Chinook collected for broodstock; and HOB = number of hatchery-origin Chinook included in hatchery broodstock.

Brood year	Spawners			Broodstock			PNI[a]
	NOS	HOS	pHOS	NOB	HOB	pNOB	
1989	713	0	0.00	28	0	1.00	1.00
1990	571	0	0.00	18	0	1.00	1.00
1991	242	0	0.00	27	0	1.00	1.00
1992	676	0	0.00	78	0	1.00	1.00
1993	231	2	0.01	94	0	1.00	0.99
1994	123	61	0.33	8	4	0.67	0.68
1995	0	33	1.00	No Program			
1996	41	17	0.29	8	10	0.44	0.62
1997	60	122	0.67	32	79	0.29	0.32
1998	59	32	0.35	13	34	0.28	0.47
1999	87	7	0.07	No Program			
2000	233	113	0.33	9	21	0.30	0.50
2001	506	1219	0.71	113	259	0.30	0.32
2002	254	453	0.64	20	51	0.28	0.33
2003	168	102	0.38	41	53	0.44	0.55
2004	575	276	0.32	83	132	0.39	0.57
2005	139	460	0.77	91	181	0.33	0.32
2006	114	415	0.78	91	224	0.29	0.29

14 According to authorized annual take permits, PNI is calculated using the PNI approximate equation 11 (HSRG 2009; Appendix A). However, in this report, we used Ford's (2002) equations 5 and 6 with a heritability of 0.3 and a selection strength of three standard deviations to calculate PNI (C. Busack, NOAA Fisheries, 21 March 2016, provided the model for calculating PNI). This approach is more accurate than using the PNI approximate equation.

Brood year	Spawners			Broodstock			PNI[a]
	NOS	HOS	pHOS	NOB	HOB	pNOB	
2007	155	1141	0.88	43	104	0.29	0.27
2008	190	968	0.84	83	220	0.27	0.26
2009	297	1050	0.78	96	111	0.46	0.39
2010	419	675	0.62	77	98	0.44	0.43
2011	801	1231	0.61	80	93	0.46	0.45
2012	574	904	0.61	73	38	0.66	0.53
2013	422	956	0.69	70	0	1.00	0.60
2014	538	461	0.46	61	12	083	0.65
2015	337	630	0.65	72	0	1.00	0.61
2016	407	164	0.29	62	37	0.63	0.70
Average	***319***	***410***	***0.47***	***57***	***74***	***0.55***	***0.56***
Median	***248***	***220***	***0.54***	***66***	***45***	***0.44***	***0.50***

[a] PNI was calculated previously using PNI approximate equation 11 (HSRG 2009; their Appendix A). All PNI values presented here were recalculated by iterating Ford's (2002) equations 5 and 6 to equilibrium using a heritability of 0.3 and a selection strength of three standard deviations. C. Busack, NOAA Fisheries, 21 March 2016, provided the model for calculating PNI.

Post-Release Survival and Travel Time

We used PIT-tagged fish to estimate survival rates and travel time (arithmetic mean days) of hatchery spring Chinook from the Chiwawa River release site to McNary Dam, and smolt to adult ratios (SARs) from release to detection at Bonneville Dam (Table 5.40).[15] Over the ten brood years for which PIT-tagged hatchery fish were released, survival rates from the Chiwawa River to McNary Dam ranged from 0.435 to 0.662; SARs from release to detection at Bonneville Dam ranged from 0.003 to 0.018. Average travel time from the Chiwawa River to McNary Dam ranged from 14 to 44 days. Although there is only one year in which a forced release was compared to a volitional release (brood year 2005), hatchery spring Chinook that were forced out of the Chiwawa Acclimation Facility had slightly higher survival rates and SARs, and a faster travel time to McNary Dam, than did the volitional release.

Table 5.40. Total number of Chiwawa hatchery spring Chinook released with PIT tags, their survival and travel times (mean days) to McNary Dam, and smolt-to-adult (SAR) ratios for brood years 2005-2014. Standard errors are shown in parentheses. NA = not available (i.e., not all the adults from the release groups have returned to the Columbia River).

Brood year	Number of tagged fish released	Survival to McNary Dam	Travel time to McNary Dam (d)	SAR to Bonneville Dam
2005	4,993 (forced)	0.662 (0.027)	22.9 (6.6)	0.008 (0.001)
2005	4,988 (volitional)	0.638 (0.027)	43.6 (6.9)	0.003 (0.001)
2006	9,894	0.619 (0.038)	30.6 (7.6)	0.011 (0.001)
2007	10,031	0.435 (0.019)	32.9 (7.7)	0.007 (0.001)
2008	10,006	0.631 (0.038)	39.9 (10.3)	0.018 (0.001)

[15] It is important to point out that because of fish size differences among rearing tanks or raceways, fish PIT tagged in one tank or raceway may not represent untagged fish rearing in other tanks or raceways.

Brood year	Number of tagged fish released	Survival to McNary Dam	Travel time to McNary Dam (d)	SAR to Bonneville Dam
2009	9,412	0.547 (0.044)	30.2 (6.7)	0.006 (0.001)
2010	5,020	0.548 (0.038)	18.9 (7.3)	0.008 (0.001)
2011	9,987	0.458 (0.029)	14.2 (7.5)	0.009 (0.001)
2012	5,061	0.478 (0.043)	30.9 (6.5)	NA
2013	10,021	0.438 (0.041)	29.5 (5.9)	NA
2014	10,179	0.628 (0.029)	24.9 (6.2)	NA

Natural and Hatchery Replacement Rates

Natural replacement rates (NRR) were calculated as the ratio of natural-origin recruits (NOR) to the parent spawning population (spawning escapement). Natural-origin recruits are naturally produced (wild) fish that survive to contribute to harvest (directly or indirectly), to broodstock, and to spawning grounds. We do not account for fish that died in route to the spawning grounds (migration mortality) or died just before spawning (pre-spawn mortality) (see Appendix B in Hillman et al. 2012). We calculated NORs with and without harvest. NORs without harvest include all returning fish that either returned to the basin or were collected as wild broodstock. NORs with harvest include all fish harvested and are based on a brood year harvest rates from the hatchery program. For brood years 1989-2010, NRR for spring Chinook in the Chiwawa averaged 1.05 (range, 0.01-4.40) if harvested fish were not included in the estimate and 1.16 (range, 0.01-4.81) if harvested fish were included in the estimate (Table 5.41). NRRs for more recent brood years will be calculated as soon as all tag recoveries and sampling rates have been loaded into the database.

Hatchery replacement rates (HRR) are the hatchery adult-to-adult returns and were calculated as the ratio of hatchery-origin recruits (HOR) to the parent broodstock collected. These rates should be greater than the NRRs and greater than or equal to 6.7 (the calculated target value in Hillman et al. 2013). The target value of 6.7 includes harvest. In nearly all years, HRRs were greater than NRRs, regardless if harvest was or was not included (Table 5.41). HRRs exceeded the estimated target value of 6.7 in 9 of the 20 years.

Table 5.41. Broodstock collected, spawning escapements, natural and hatchery-origin recruits (NOR and HOR), and natural and hatchery replacement rates (NRR and HRR; with and without harvest) for spring Chinook in the Chiwawa River basin, brood years 1989-2010; NP = no hatchery program.

Brood year	Broodstock Collected	Spawning Escapement	Harvest not included				Harvest included			
			HOR	NOR	HRR	NRR	HOR	NOR	HRR	NRR
1989	28	713	180	194	6.43	0.27	204	282	7.29	0.40
1990	19	571	1	34	0.05	0.06	19	40	1.00	0.07
1991	32	242	32	2	1.00	0.01	35	2	1.09	0.01
1992	78	676	31	46	0.40	0.07	32	48	0.41	0.07
1993	100	233	282	159	2.82	0.68	286	163	2.86	0.70
1994	13	184	21	37	1.62	0.20	21	38	1.62	0.21
1995	NP	33	--	66	--	2.00	--	69	--	2.09

Brood year	Broodstock Collected	Spawning Escapement	Harvest not included				Harvest included			
			HOR	NOR	HRR	NRR	HOR	NOR	HRR	NRR
1996	18	58	77	255	4.28	4.40	79	279	4.39	4.81
1997	120	182	2,232	714	18.60	3.92	2,609	792	21.74	4.35
1998	48	91	991	349	20.65	3.84	1,186	373	24.71	4.10
1999	NP	94	--	10	--	0.11	--	11	--	0.12
2000	48	346	354	695	7.38	2.01	377	729	7.85	2.11
2001	382	1,725	1,808	309	4.73	0.18	1,864	317	4.88	0.18
2002	84	707	709	244	8.44	0.35	780	254	9.29	0.36
2003	119	270	707	107	5.94	0.40	791	115	6.65	0.43
2004	296	851	2,528	276	8.54	0.32	3,003	298	10.15	0.35
2005	283	599	1,386	396	4.90	0.66	1,515	409	5.35	0.68
2006	398	529	1,837	967	4.62	1.83	2,616	1,215	6.57	2.30
2007	169	1,296	883	478	5.22	0.37	1,303	571	7.71	0.44
2008	329	1,158	2,465	740	7.49	0.64	3,859	830	11.73	0.72
2009	264	1,347	1,182	349	4.48	0.26	1,574	379	5.96	0.28
2010	186	1,094	1,465	633	7.88	0.58	2,118	834	11.39	0.76
Average	***151***	***591***	***959***	***321***	***6.27***	***1.05***	***1,214***	***366***	***7.63***	***1.16***
Median	***110***	***550***	***796***	***266***	***5.06***	***0.38***	***989***	***290***	***6.61***	***0.43***

Smolt-to-Adult Survivals

Smolt-to-adult survival ratios (SARs) were calculated as the number of hatchery adult recaptures divided by the number of tagged hatchery smolts released. Here, SARs were based on CWT returns. For the available brood years, SARs have ranged from 0.00036 to 0.01563 for hatchery spring Chinook (Table 5.42).

Table 5.42. Smolt-to-adult ratios (SARs) for Chiwawa hatchery spring Chinook, brood years 1989-2011.

Brood year	Number of tagged smolts released[a]	Estimated adult captures[b]	SAR
1989	42,707	204	0.00478
1990	52,798	19	0.00036
1991	61,088	35	0.00057
1992	82,976	31	0.00037
1993	221,316	284	0.00128
1994	27,135	21	0.00077
1995	No hatchery program		
1996	12,767	67	0.00525
1997	259,585	2,549	0.00982
1998	71,571	1,119	0.01563
1999	No hatchery program		

Brood year	Number of tagged smolts released[a]	Estimated adult captures[b]	SAR
2000	46,726	375	0.00803
2001	374,129	1,849	0.00494
2002	145,074	760	0.00524
2003	216,702	775	0.00358
2004	491,987	2,992	0.00608
2005	489,664	1,506	0.00308
2006	548,777	2,604	0.00475
2007	292,682	1,301	0.00445
2008	609,286	3,859	0.00633
2009	433,608	1,560	0.00360
2010	342,778	2,104	0.00614
2011	278,801	1,697	0.00609
Average	***242,960***	***1,224***	***0.00482***
Median	***221,316***	***1,119***	***0.00478***

[a] Includes all tag codes and CWT released fish (CWT + Ad Clip fish and CWT-only fish).

[b] Includes estimated recoveries (spawning ground, hatcheries, harvest, etc.) and observed recoveries if estimated recoveries were unavailable.

5.8 ESA/HCP Compliance

Broodstock Collection

The collection of 2014 Brood Chiwawa River spring Chinook broodstock was consistent with the 2014 Upper Columbia River salmon and steelhead broodstock objectives and site-based broodstock collection protocols. Specifically, broodstock collection targeted previously PIT-tagged natural-origin fish at Tumwater Dam and operation of the Chiwawa Weir. In-season adjustments were made to the natural-origin spring Chinook collected for broodstock as needed and were based on in-season escapement monitoring at Tumwater Dam and estimated Chiwawa run-escapement.

Trapping at Tumwater Dam began on 8 June 2014 and concluded on 14 July 2014. Operation of the Chiwawa Weir was limited to 15 days between 1 June and 15 August and was further constrained by flows and total available bull trout effects. Broodstock collection targeted natural-origin spring Chinook and hatchery-origin spring Chinook as needed to attain a 100% natural-origin broodstock and a maximum 33% extraction of the estimated natural-origin return to the Chiwawa River.

The 2014 brood collection retained a total of 61 natural-origin spring Chinook. All spring Chinook, steelhead, and bull trout that were captured were anesthetized with tricaine methanesulfonate (MS-222) and subject to water-to-water transfers during handling. All fish were allowed to fully recover before release.

The estimated broodstock extraction rate of natural-origin Chiwawa spring Chinook and overall extraction of spring Chinook upstream from Tumwater Dam comply with provisions of ESA Permit 18121.

Hatchery Rearing and Release

The rearing and release of 2014 brood Chiwawa spring Chinook was completed without incident. No mortality events occurred that exceeded 10% of the population. Fish were acclimated on Chiwawa River water with regulated amounts of Wenatchee River water to prevent frazzle ice formation during the winter months (see Section 5.2).

The release of 2014 brood Chiwawa spring Chinook smolts totaled 144,360 fish, representing 100% of the program objective of 144,023 smolts and complied with the ESA Section 10 Permit 18121 program not to exceed the level of 158,425 smolts.

Hatchery Effluent Monitoring

Per ESA Permits 1196 (expired), 1347 (expired), 1395 (expired), 18118, 18120, and 18121, permit holders shall monitor and report hatchery effluents in compliance with applicable National Pollution Discharge Elimination Systems (NPDES) (EPA 1999) permit limitations. There were no NPDES violations reported at the Chelan PUD Hatchery facilities during the period 1 January through 31 December 2016. NPDES monitoring and reporting for Chelan PUD Hatchery Programs during 2016 are provided in Appendix F.

Smolt and Emigrant Trapping

Per ESA Section 10 Permit Nos. 18118, 18120, and 18121, the permit holders are authorized a direct take of up to 20% of the emigrating spring Chinook population during juvenile emigration monitoring and a lethal take not to exceed 2% of the fish captured (NMFS 2013). Based on the estimated wild spring Chinook population (smolt trap expansion) and hatchery juvenile spring Chinook population estimate (hatchery release data) for the Wenatchee River basin, the reported spring Chinook encounters during 2016 emigration monitoring complied with take provisions in the Section 10 permit. Spring Chinook encounter and mortality rates for each trap site (including PIT tag mortalities) are detailed in Table 5.43. Additionally, juvenile fish captured at the trap locations were handled consistent with provisions in ESA Section 10 Permits 18118, 18120, and 18121, Section B.

Table 5.43. Estimated take of Upper Columbia River spring Chinook resulting from juvenile emigration monitoring in the Wenatchee River basin, 2016.

Trap location	Population estimate			Number trapped			Total	Take allowed under Permit
	Wild[a]	Hatchery[b]	Sub-yearling[c]	Wild	Hatchery	Sub-yearling		
Chiwawa Trap								
Population	37,170	341,226	145,971	2,807	2,525	16,393	21,725	
Encounter rate	NA	NA	NA	0.0755	0.0074	0.1123	0.0414	0.20
Mortality[e]	NA	NA	NA	4	0	82	86	
Mortality rate	NA	NA	NA	0.0014	0.0000	0.0050	0.0040	0.02
Lower Wenatchee Trap								
Population	36,752	373,441	4,023,310	610	7,702	27,407	35,719	

Trap location	Population estimate			Number trapped			Total	Take allowed under Permit
	Wild[a]	Hatchery[b]	Sub-yearling[c]	Wild	Hatchery	Sub-yearling		
Encounter rate	NA	NA	NA	0.0166	0.0206	0.0019	0.0024	0.20
Mortality[d]	NA	NA	NA	2	3	184	189	
Mortality rate	NA	NA	NA	0.0033	0.001	0.0067	0.0053	0.02
Wenatchee River Basin Total								
Population	73,922	373,441	4,169,281	3,417	10,227	43,800	57,444	
Encounter rate	NA	NA	NA	0.0462	0.0274	0.0030	0.0039	0.20
Mortality[d]	NA	NA	NA	6	3	266	275	
Mortality rate	NA	NA	NA	0.0018	0.0001	0.0061	0.0048	0.02

[a] Smolt population estimate derived from juvenile emigration trap data.

[b] 2016 BY smolt release data for the Wenatchee River basin.

[c] Based on size, date of capture and location of capture, subyearling Chinook encountered at the Lower Wenatchee Trap are categorized as summer Chinook salmon.

[d] Combined trapping and PIT tagging mortality.

Spawning Surveys

Spring Chinook spawning ground surveys were conducted in the Wenatchee River basin during 2016, as authorized by ESA Section 10 Permits 18118, 18120, and 18121. Because of the difficulty of quantifying the level of take associated with spawning ground surveys, the Permit does not specify a take level associated with these activities, even though it does authorize implementation of spawning ground surveys. Therefore, no take levels are reported. However, to minimize potential effects to established redds, wading was restricted to the extent practical, and extreme caution was used to avoid established redds when wading was required.

Spring Chinook Reproductive Success Study

ESA Section 10 Permits 18118, 18120, and 18121 specifically provide authorization to capture, anesthetize, biologically sample, PIT tag, and release adult spring Chinook at Tumwater Dam for reproductive success studies and general program monitoring. During 2010 through 2016, all spring Chinook passing Tumwater Dam were enumerated, anesthetize, biologically sampled, PIT tagged, and released (not including hatchery-origin Chinook retained for broodstock) as a component of the reproductive success study (BPA Project No. 2003-039-00). Please refer to Ford et al. (2010, 2011, 2012, 2013, 2014, 2015, and 2016) for complete details on the methods and results of the spring Chinook reproductive success study for the period 2010-2016.

SECTION 6: NASON CREEK SPRING CHINOOK

The goals of the Nason Creek spring Chinook salmon supplementation program are to conserve, aid in the recovery, and prevent the extinction of naturally spawning spring Chinook in Nason Creek, and to meet the mitigation responsibilities of Grant County PUD. In 1997, a spring Chinook captive-broodstock program was initiated for the Nason Creek population to reduce the risk of extinction. Improvements in adult escapement in Nason Creek have reduced the near-term risk of extinction and therefore the captive-broodstock program was discontinued. An adult-based supplementation program began with the collection of broodstock in 2013. The first releases of the program occurred from the Nason Creek Acclimation Facility in the spring of 2015.

In 2013, natural-origin adult spring Chinook were collected for broodstock at Tumwater Dam and from Nason Creek using tangle and dip nets. In 2014, all natural-origin broodstock were collected from Nason Creek using tangle and dip nets. While these brood collection methods were successful at collecting adults from the Nason Creek spawning aggregate, they were unable to collect the necessary number of adults to meet mitigation production goals in 2013 and 2014. The PRCC Hatchery Subcommittee decided to implement the Nason Creek conservation program using a composite of Nason and Chiwawa natural-origin broodstock beginning with brood year 2015 in order to be able to consistently meet program goals. The decision was also made to collect all the brood at Tumwater Dam.

The production goal for the Nason Creek program requires collection of 126 adult spring Chinook (64 natural-origin fish and 66 hatchery-origin fish). However, the Section 10 permit requirements restrict the number of natural-origin adults collected and cannot exceed 33% of the natural-origin spring Chinook estimates to Tumwater Dam.

Adult spring Chinook broodstock are spawned and reared at Eastbank Fish Hatchery. Juvenile spring Chinook are transferred from the hatchery to the Nason Creek Acclimation Facility in late September or early October. Fish are reared in 30-foot dual-drain circular tanks throughout winter at the Nason Creek Acclimation Facility. Yearling Chinook were released volitionally during April and May the following year up until 2015. Beginning in 2016, all fish are force released at night to improve survival.

The current production goal is to release 223,670 smolts (125,000 for conservation and 98,670 for safety net). Juveniles released from the Nason facility will be 100% marked with CWTs and a minimum of 5,000 fish will be PIT tagged annually.

The following information focuses on results from monitoring the Nason Creek spring Chinook program. Information on spring Chinook collected throughout the Wenatchee River basin is presented in Section 5.

6.1 Broodstock Sampling

This section focuses on results from sampling 2014-2016 Nason Creek spring Chinook broodstock, which were collected in Nason Creek in 2014 and at Tumwater Dam in 2015 and 2016.

Origin of Broodstock

Natural-origin adults made up between 48% and 100% of the Nason Creek spring Chinook broodstock for return years 2014-2016 (Table 6.1). Beginning with brood year 2015, natural-origin adults were targeted for collection at Tumwater Dam during trapping operations. Natural-origin fish collected at Tumwater Dam were used for broodstock if genotyping confirmed they were natural-origin fish from the Wenatchee population and they were not White River fish. Fish that were genotyped to the White River were returned to the upper Wenatchee River basin to spawn naturally.

Table 6.1. Numbers of wild and hatchery Nason Creek spring Chinook collected for broodstock, numbers that died before spawning, and numbers of Chinook spawned, 2013-2016. Unknown origin fish (i.e., undetermined by scale analysis, no CWT or fin clips, and no additional hatchery marks) were considered naturally produced. Mortality includes fish that died of natural causes typically near the end of spawning and were not needed for the program or were surplus fish killed at spawning.

Brood year	Wild spring Chinook					Hatchery spring Chinook					Total number spawned
	Number collected	Prespawn loss[a]	Mortality	Number spawned	Number released	Number collected	Prespawn loss[a]	Mortality	Number spawned	Number released	
2013	22	0	1	21	0	4	0	0	4	0	25
2014[b]	28	2	5	21	0	0	0	0	0	0	21
2015	78	1	6	59	12	63	0	0	63	0	122
2016	82	0	1	70	11	68	1	1	66	0	136
Average[c]	***53***	***1***	***3***	***43***	***6***	***34***	***0***	***0***	***33***	***0***	***76***
Median[c]	***53***	***1***	***3***	***40***	***6***	***34***	***0***	***0***	***34***	***0***	***74***

[a] Pre-spawn loss represents the number of fish that died during the holding period before spawning. Mortality is the number of fish that were surplused following spawning.
[b] Until sufficient Nason Creek Spring Chinook HOR's are collected to meet broodstock objectives, Chiwawa Spring Chinook HOR's are utilized to fulfill program goals (see table 5.1 and the 2014 Broodstock Protocols). About 12 Chiwawa HORs were used to fulfill the Chiwawa Program; about 122 Chiwawa HORs were used to fulfill the Nason Creek safety-net obligation.
[c] Origin determinations should be considered preliminary pending scale analyses.

Age/Length Data

Ages were determined from scales and/or coded wire tags (CWT) collected from broodstock. For both the 2015 and 2016 returns, most adults, regardless of origin, were age-4 Chinook (Table 6.2). A larger percentage of the age-3 and 5 Chinook were natural-origin fish.

Table 6.2. Percent of hatchery and wild spring Chinook of different ages (total age) collected from broodstock, 2013-2016.

Return year	Origin	Total age			
		2	3	4	5
2013	Wild	0.0	14.3	85.7	0.0
	Hatchery	0.0	0.0	100.0	0.0
2014	Wild	0.0	18.2	68.2	13.6
	Hatchery[a]	0.0	0.0	98.5	1.5
2015	Wild	0.0	0.0	92.0	8.0
	Hatchery	0.0	0.0	100.0	0.0
2016	Wild	0.0	0.0	69.6	30.4
	Hatchery	0.0	0.0	93.4	6.6

Return year	Origin	Total age			
		2	3	4	5
Average	***Wild***	0.0	8.1	78.9	13.0
	Hatchery	0.0	0.0	98.0	2.0
Median	***Wild***	0.0	7.2	77.7	10.8
	Hatchery	0.0	0.0	99.3	0.8

[a] Data from Table 5.2.

Age-4 natural-origin and hatchery-origin broodstock were similar in size in 2015; however, in 2016, age 4 hatchery-origin broodstock were larger than natural-origin broodstock (Table 6.3).

Table 6.3. Mean fork length (cm) at age (total age) of hatchery and wild spring Chinook collected from broodstock, 2013-2016; N = sample size and SD = 1 standard deviation.

Return year	Origin	Spring Chinook fork length (cm)											
		Age-2			Age-3			Age-4			Age-5		
		Mean	N	SD	Mean	N	SD	Mean	N	SD	Mean	N	SD
2013	Wild	-	0	-	56	3	2	75	16	6	-	0	-
	Hatchery	-	0	-	-	0	-	79	5	6	-	0	-
2014	Wild	-	0	-	57	4	6	82	15	7	86	3	8
	Hatchery[a]	-	0	-	-	0	-	81	192	6	85	3	2
2015	Wild	-	0	-	-	0	-	82	43	5	97	8	6
	Hatchery	-	0	-	-	0	-	82	55	5	-	0	-
2016	Wild	-	0	-	-	0	-	81	39	5	94	17	6
	Hatchery	-	0	-	-	0	-	84	57	6	89	4	9
Average	***Wild***	***-***	***0***	***-***	***57***	***4***	***4***	***80***	***28***	***6***	***92***	***7***	***7***
	Hatchery	***-***	***0***	***-***	***-***	***0***	***-***	***82***	***77***	***6***	***87***	***2***	***6***

[a] Data from Table 5.3.

Sex Ratios

Male spring Chinook in the 2014-2016 return years made up 60%, 50%, and 49%, respectively, of the adults collected. This resulted in overall male to female ratios of 1.50:1.00, 1.01:1.00, and 0.95:1.00, respectively (Table 6.4).

Table 6.4. Numbers of male and female wild and hatchery spring Chinook collected for broodstock, 2013-2016. Ratios of males to females are also provided.

Return year	Number of wild spring Chinook			Number of hatchery spring Chinook			Total M/F ratio
	Males (M)	Females (F)	M/F	Males (M)	Females (F)	M/F	
2013	12	10	1.20:1:00	1	3	0.33:1.00	1.00:1.00
2014[a]	18	12	1.50:1.00	0	0	-	1.50:1.00
2015	40	38	1.05:1.00	31	32	0.97:1.00	1.01:1.00
2016	40	42	0.95:1.00	33	35	0.94:1.00	0.95:1.00
Total	***110***	***102***	***1.08:1.00***	***65***	***70***	***0.93:1.00***	***1.02:1.00***

[a] Data for HOR brood are in Table 5.4.

Fecundity

The mean fecundities for the 2014-2016 returns of Nason Creek spring Chinook ranged from 3,787- 4,487 eggs per female (Table 6.5). Fecundities in the 2013 and 2015 natural-origin brood, and in the 2013, 2014, and 2016 hatchery-origin brood were less than the expected fecundity of 4,400 eggs per female assumed in the broodstock protocol.

Table 6.5. Mean fecundity of wild, hatchery, and all female spring Chinook collected for broodstock, 2013-2016.

Return year	Mean fecundity		
	Wild	Hatchery	Total
2013	4,047	4,069	4,052
2014[a]	4,484	3,834	3,787
2015	4,380	4,535	4,463
2016	4,688	4,274	4,487
Average	***4,400***	***4,178***	***4,197***

[a] Average fecundities are from Table 5.5.

6.2 Hatchery Rearing

Rearing History

Number of eggs taken

Based on the unfertilized egg-to-release survival standard of 85%, a total of 263,141 eggs are required to meet the program release goal of 223,670 smolts (Table 6.6). The green egg take for the 2014-2016 brood years was 102%, 102%, and 119% of program goal, respectively.

Table 6.6. Numbers of eggs taken from spring Chinook broodstock, 2013-2016.

Return year	Number of eggs taken
2013[a]	49,720
2014[b]	267,783
2015	268,247
2016	314,090
Average	***224,960***
Median	***268,015***

[a] Safety-net obligation met through the White River Program. Conservation egg take goal was 116,082.
[b] Includes surrogate Chiwawa HxH egg take calculated from tagging proportions.

Number of acclimation days

Fish from the 2014 brood were acclimated for 119-166 days on Nason Creek water and 12 days on well water with oxygen (Table 6.7).

Table 6.7. Number of days spring Chinook broods were acclimated on Nason Creek water and well water, brood years 2013-2014.

Brood year	Release year	Transfer date	Release date	Number of acclimation days
2013	2015	13 Oct	13 Apr – 1 May	182-200
2014[a]	2016	21-23 Oct	15-20 Apr	119-122 Nason, 12 Well

[a] Because of water-intake concerns at the Nason Creek Acclimation Facility, the HxH Chinook were transferred to the Chiwawa Acclimation Facility on 2-3 March for final acclimation and release. The WxW fish were on Nason Creek water for 166 days. The HxH fish were on Nason Creek water for 119-122 days and on Chiwawa River water for 43-49 days. WxW and HxH fish were on well water and oxygen for 12 days while rearing at the Nason Creek Acclimation Facility.

Release Information

Numbers released

The 2014 brood Nason Creek spring Chinook program achieved 25.8% of the 125,000 target goal with about 32,215 WxW smolts forced into Nason Creek in 2016 (Table 6.8). The remainder of the smolt obligation was fulfilled with HxH progeny. The HxH Nason program was transferred to the Chiwawa Acclimation Facility on 2-3 March 2016 for final acclimation because of water-intake concerns at the Nason Creek Acclimation Facility (see Table 5.8). A total of 196,866 HxH smolts were released from the Chiwawa Acclimation Facility for the Nason spring Chinook program.

Table 6.8. Numbers of spring Chinook smolts tagged and released from the hatchery, brood years 2013-2014. The release target for Nason Creek spring Chinook is 125,000 smolts.

Brood year	Release year	Type of release	CWT mark rate	Number released that were PIT tagged	Number of smolts released	Total number of smolts released
2013	2015	Volitional	0.9303	20,139	43,082	43,082
2014[a]	2016	Forced	0.9650	5,009	32,215	32,215

[a] Only the WxW Nason program was released from the Nason Creek Acclimation Facility because of water-intake concerns. The HxH Nason program was transferred to the Chiwawa Acclimation Facility on 2-3 March 2016 (see Table 5.8).

Numbers tagged

The 2014 brood Nason spring Chinook were 96% CWT and blank CWT adipose tagged (Table 6.8).

In 2017, a total of 10,104 Nason Creek spring Chinook from the 2015 brood were tagged at the Nason Creek Acclimation Facility on 6-9 March. Chinook in Ponds 1, 3, 5, and 7 were HxH fish, while Chinook in Ponds 2, 4, 6, and 8 were WxW fish. Fish were not fed during tagging or for two days before and after tagging. Fish averaged 110-115 mm in length and 17-19 g at time of tagging.

Table 6.9 summarizes the number of hatchery spring Chinook that have been PIT-tagged and released into Nason Creek.

Table 6.9. Summary of PIT-tagging activities for Nason Creek hatchery spring Chinook, brood years 2013-2014.

Brood year	Release year	Number of fish tagged	Number of tagged fish that died	Number of tags shed	Number of tagged fish released
2013	2015	20,234	94	1	20,139
2014	2016	5,010	1	0	5,009

Fish size and condition at release

The WxW spring Chinook from the 2014 brood were released as yearling smolts from 15-20 April 2016. Size at release (21 fpp) was larger than the approximate target of 24 fpp established for the program. The CV for fork length was just short of the target (Table 6.10).

The HxH spring Chinook were transferred to the Chiwawa Acclimation Facility for final rearing on 2-3 March 2016 because of water-intake concerns at the Nason Creek Acclimation Facility. These fish were volitionally released as yearling smolts from 15-20 April 2016 into the Chiwawa River. Size at release (16 fpp) was larger than the approximate target of 18 fpp established for the Chiwawa program. The CV for fork length was just short of the target (see Table 5.10).

Table 6.10. Mean lengths (FL, mm), weight (g and fish/pound), and coefficient of variation (CV) of spring Chinook smolts released from the hatchery, brood years 2013-2014. Size targets are provided in the last row of the table.

Brood year	Release year	Fork length (mm)		Mean weight	
		Mean	CV	Grams (g)	Fish/pound
2013	2015	129	8.3	27.6	16
2014[a]	2016	124	7.7	21.7	21
Average		***127***	***8***	***24.7***	***19***
Median		***127***	***8***	***24.7***	***19***
Targets		***155***	***9.0***	***37.8***	***18***

[a] This represents only the WxW Nason program released from the Nason Creek Acclimation Facility. The HxH program was transferred to the Chiwawa Acclimation Facility on 2-3 March 2016 for release because of water-intake concerns at the Nason Creek Acclimation Facility. Statistics on the 2014 brood HxH program pre-release sample at the Chiwawa Acclimation Facility were 134 mean length, 17.5 length CV, 28.6g mean wt., and 16 fpp.

Survival Estimates

Overall survival of Nason Creek spring Chinook from green (unfertilized) egg to release was above the standard set for the program (Table 6.11). There was higher than expected survivals throughout all stages contributing to increased program performance. Pre-spawn survival of adults was also above the standard set for the program.

Table 6.11. Hatchery life-stage survival rates (%) for spring Chinook, brood years 2013-2014. Survival standards or targets are provided in the last row of the table.

Brood year	Collection to spawning		Unfertilized egg-eyed	Eyed egg-ponding	30 d after ponding	100 d after ponding	Ponding to release	Transport to release	Unfertilized egg-release
	Female	Male							
2013	100.0	100.0	93.5	98.8	99.4	98.2	93.8	99.1	86.6
2014[a]	97.3	100.0	91.3	97.6	99.5	99.0	98.1	99.5	87.4
Average	***98.7***	***100.0***	***92.4***	***98.2***	***99.5***	***98.6***	***96.0***	***99.3***	***87.0***
Median	***98.7***	***100.0***	***92.4***	***98.2***	***99.5***	***98.6***	***96.0***	***99.3***	***87.0***
Standard	***90.0***	***85.0***	***92.0***	***98.0***	***97.0***	***93.0***	***90.0***	***95.0***	***81.0***

[a] The survival estimates are a combination of the WxW and HxH Nason programs. The WxW program was reared at the Nason Creek Acclimation Facility until release. The HxH Chinook that were reared at the Nason Creek Acclimation Facility until transferred to the Chiwawa Acclimation Facility on 2-3 March 2016 because of water-intake concerns at the Nason Creek Acclimation Facility. The HxH fish were released from the Chiwawa Acclimation Facility on 15-20 April 2016.

6.3 Disease Monitoring

Results of 2016 adult broodstock bacterial kidney disease (BKD) monitoring indicated that most females (90%) had ELISA values less than 0.199. Ten percent of the females had ELISA values greater than 0.120, resulting in no limitations to rearing densities (Table 6.12).

For the 2014 brood, a formalin drip treatment was used shortly after transfer to the Nason Creek Acclimation Facility to prevent infection associated with stress caused by the transfer. No significant health issues were encountered for the remainder of juvenile rearing.

Table 6.12. Proportion of bacterial kidney disease (BKD) titer groups for the Nason Creek spring Chinook broodstock by origin, brood years 2013-2016. Also included are the proportions to be reared at either 0.125 fish per pound or 0.060 fish per pound.

Brood year	Optical density values by titer group								Proportion at rearing densities (fish per pound, fpp)[b]			
	Very Low (≤ 0.099)		Low (0.1-0.199)		Moderate (0.2-0.449)		High (≥ 0.450)		≤ 0.125 fpp (<0.119)		≤ 0.060 fpp (>0.120)	
	Wild	Hatch	Wild	Hatch	Wild	Hatch	Wild	Hatch	Wild	Hatch	Wild	Hatch
2013	0.7000	0.3333	0.3000	0.6666	0.0000	0.0000	0.0000	0.0000	0.9231	0.1000	0.0769	0.0000
2014	0.5000	--	0.3000	--	0.0000	--	0.2000	--	0.8000	--	0.2000	--
2015[a]	1.0000	1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	1.000	0.0000	0.0000
2016	0.8888	0.9118	0.1111	0.0882	0.0000	0.0000	0.0000	0.0000	0.8888	0.9118	0.1111	0.0882
Average	0.7722	0.7484	0.1778	0.2516	0.0000	0.0000	0.0500	0.0000	0.9030	0.6706	0.0970	0.0294
Median	0.7944	0.9118	0.2056	0.0882	0.0000	0.0000	0.0000	0.0000	0.9060	0.9118	0.0940	0.0000

[a] Determination of origin should be considered preliminary pending scale analyses.
[b] ELISA values from broodstock BKD testing dictate what density the progeny of the broodstock are reared. Progeny of broodstock with high ELISA values are reared at lower density.

6.4 Natural Juvenile Productivity

During 2016, juvenile spring Chinook were sampled at the Nason Creek trap.

Smolt and Emigrant Estimates

Numbers of spring Chinook smolts and emigrants were estimated at the Nason Creek trap in 2016. A complete description of trapping operations on Nason Creek can be found in Appendix L.

Nason Creek Trap

The Nason Creek Trap operated between 1 March and 30 November 2016. During that time, the trap was inoperable for 62 days because of low stream discharge or flooding. Daily trap efficiencies were estimated from a flow-efficiency regression model. The daily number of fish captured was expanded by the estimated trap efficiency to estimate total emigration. If a viable flow-efficiency regression could not be developed, a pooled efficiency was used to expand daily catch. All pooled estimates will be recalculated as flow-efficiency models are developed.

Wild yearling spring Chinook (2014 brood year) were captured primarily from March through April 2016 (Figure 6.1). Because a viable yearling emigrant flow-efficiency regression model could not be established at the downstream trap location, a pooled estimate was employed as a temporary method of expansion. Based on this pooled efficiency, the total number of wild yearling Chinook from the Nason Creek basin was 930 (±5,083). Combining the number of subyearling spring Chinook (2,851) that emigrated during the fall of 2015 with the total number of yearling Chinook (930) that emigrated during 2016 resulted in an emigrant estimate of 3,781 (±5,102) spring Chinook (Table 6.13). Based on PIT-tag analysis, an additional 29 (±37) spring Chinook immigrated during the winter (1 December – 28 February) when the trap was inoperable. Thus, the total number of emigrants was 3,810 (±5,126) spring Chinook for the 2014 brood year.

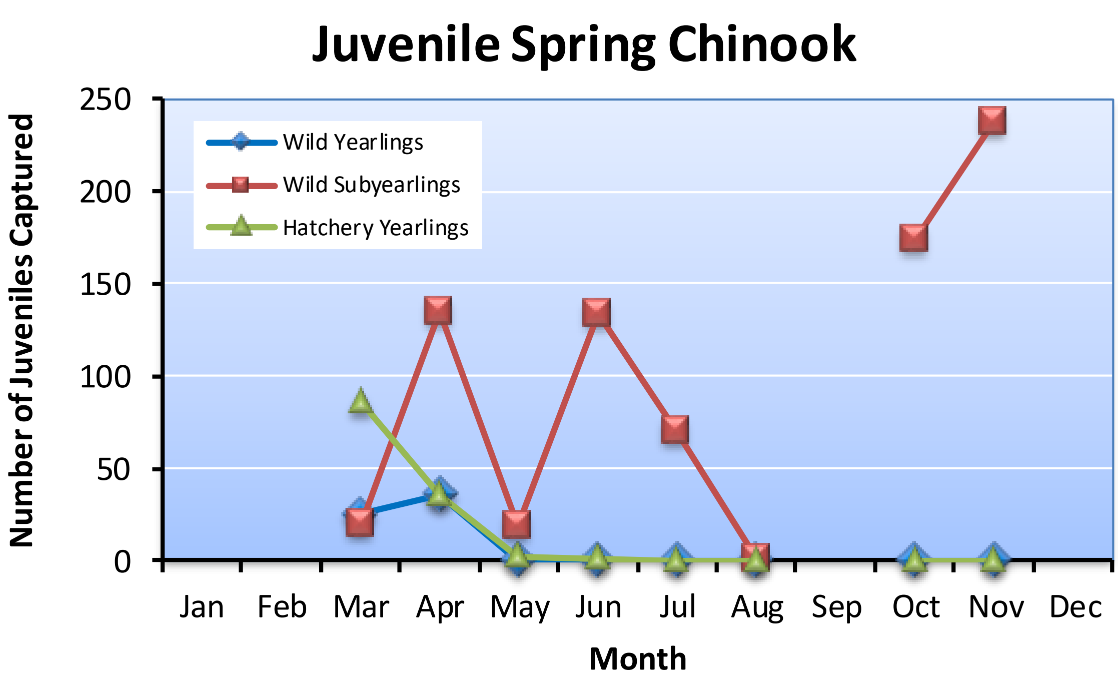


Figure 6.1. Monthly captures of wild subyearling and wild and hatchery yearling spring Chinook at the Nason Creek Trap, 2016.

Table 6.13. Numbers of redds and juvenile spring Chinook at different life stages in the Nason Creek basin for brood years 2002-2015; ND = no data.

Brood year	Number of redds	Egg deposition[a]	Number of subyearling emigrants[b]	Number of smolts produced within Nason Creek basin	Number of emigrants[c]
2002	294	1,368,276	ND	4,683	ND
2003	83	485,052	8,829	6,358	15,187
2004	169	811,031	11,822	2,597	14,419
2005	193	835,111	11,814	8,696	20,510
2006	152	657,248	4,144	7,798	11,942
2007	101	448,541	15,556	5,679	21,235
2008	336	1,542,912	23,182	3,611	26,793
2009	167	763,691	27,720	1,705	29,425
2010	188	811,032	8,491	3,535	12,026
2011	170	745,450	17,991	2,422	20,413
2012	413	1,744,099	28,110	4,561	32,671
2013	212	859,024	43,711	6,992	57,525
2014	115	435,505	2,880	930	3,810
2015	85	379,355	5,540	--	--
Average	***191***	***849,023***	***14,899***	***4,582***	***21,748***
Median	***170***	***787,361***	***11,822***	***4,561***	***20,462***

[a] Egg deposition is calculated as the number of redds times the fecundity of both wild and hatchery spring Chinook salmon (from Table 5.5.

[b] Subyearling emigrants does not include fry that left the watershed before 1 July.

[c] Brood years 2002-2012 do not include estimates of numbers of juvenile spring Chinook that emigrated during non-trapping periods (1 Dec to 28 Feb). Brood years 2013 to present include estimates of numbers of juvenile spring Chinook that emigrated during non-trapping periods.

Wild subyearling spring Chinook (2015 brood year) were captured between 10 March and 29 November 2016 (Figure 6.1). Based on capture efficiencies estimated from the flow model, the total number of wild subyearling Chinook emigrating from Nason Creek was 5,540 (±997).

Yearling spring Chinook sampled in 2016 averaged 96 mm in length, 9.0 g in weight, and had a mean condition of 1.01 (Table 6.14). Estimated length and weight for these fish were greater than the overall mean of yearling spring Chinook sampled in previous years (overall means, 93 mm and 8.5 g), while the estimated condition was less (overall mean, 1.05). Subyearling spring Chinook sampled in 2016 at the Nason Creek Trap averaged 85 mm in length, 6.9 g in weight, and had a mean condition of 1.07 (Table 6.14). These size estimates were greater than the overall mean of subyearling spring Chinook sampled in previous years (overall means, 77 mm, 5.1 g, and condition of 1.07).

Table 6.14. Mean fork length (mm), weight (g), and condition factor of subyearling and yearling spring Chinook collected in the Nason Creek Trap, 2004-2016. Numbers in parentheses indicate 1 standard deviation.

Sample year	Life stage	Sample size[a]	Mean size		
			Length (mm)	Weight (g)	Condition (K)
2004	Subyearling	656	82 (7)	5.9 (1.7)	1.04 (0.11)
	Yearling	323	92 (8)	8.2 (2.3)	1.04 (0.08)
2005	Subyearling	872	76 (9)	4.8 (1.7)	1.02 (0.13)
	Yearling	276	94 (7)	8.7 (2.0)	1.04 (0.12)
2006	Subyearling	1422	73 (9)	3.9 (1.9)	0.92 (0.16)
	Yearling	362	91 (7)	7.5 (1.8)	0.98 (0.11)
2007	Subyearling	609	78 (14)	5.9 (2.6)	1.15 (0.16)
	Yearling	678	88 (9)	7.4 (2.4)	1.05 (0.13)
2008	Subyearling	1,001	75 (14)	5.0 (2.5)	1.10 (0.11)
	Yearling	881	96 (6)	9.5 (2.0)	1.06 (0.09)
2009	Subyearling	2,147	72 (11)	4.4 (2.1)	1.08 (0.08)
	Yearling	162	96 (8)	9.6 (2.4)	1.08 (0.09)
2010	Subyearling	3,032	81 (11)	6.2 (2.3)	1.13 (0.10)
	Yearling	366	97 (7)	10.2 (2.3)	1.10 (0.09)
2011	Subyearling	1,064	72 (13)	4.7 (2.5)	1.13 (0.12)
	Yearling	150	89 (10)	7.7 (1.8)	1.09 (0.12)
2012	Subyearling	2,141	78 (11)	5.3 (2.0)	1.05 (0.09)
	Yearling	363	93 (6)	9.3 (2.2)	1.11 (0.08)
2013	Subyearling	4,408	70 (11)	3.8 (1.7)	1.03 (0.10)
	Yearling	239	91 (7)	7.9 (2.1)	1.03 (0.07)
2014	Subyearling	1,543	69 (12)	3.8 (2.3)	1.05 (0.06)
	Yearling	464	90 (7)	7.5 (1.8)	1.03 (0.06)
2015	Subyearling	209	84 (8)	6.5 (1.7)	1.08 (0.08)
	Yearling	152	93 (7)	8.4 (2.1)	1.03 (0.09)
2016	Subyearling	490	85 (13)	6.9 (2.5)	1.07 (0.09)
	Yearling	61	96 (6)	9.0 (1.7)	1.01 (0.06)
Average	***Subyearling***	***1,507***	***77 (5)***	***5.1 (1.1)***	***1.07 (0.06)***
	Yearling	***344***	***93 (3)***	***8.5 (0.9)***	***1.05 (0.04)***
Median	***Subyearling***	***1,064***	***76 (5)***	***5.0 (1.1)***	***1.07 (0.06)***
	Yearling	***323***	***93 (3)***	***8.4 (0.9)***	***1.04 (0.04)***

[a] Sample size represents the number of fish that were measured for both length and weight.

Freshwater Productivity

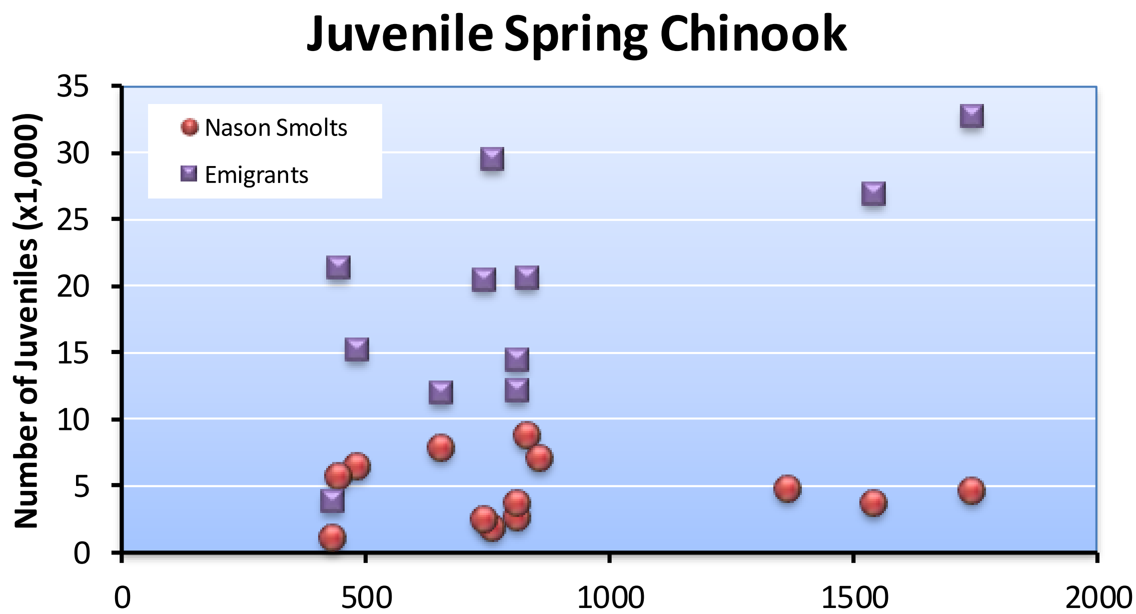
Both productivity and survival estimates for different life stages of spring Chinook in the Nason Creek watershed are provided in Table 6.15. Estimates for brood year 2014 were generally lower than estimates for brood years 2002-2013. During the period 2002-2014, freshwater productivities ranged from 8-77 smolts/redd and 33-271 emigrants/redd. Survivals during the same period ranged from 0.2-1.3% for egg-smolt and 0.9-5.8% for egg-emigrants.

Table 6.15. Productivity (fish/redd) and survival (%) estimates for different juvenile life stages of spring Chinook in the Nason Creek watershed for brood years 2002-2014; ND = no data. These estimates were derived from data in Table 6.13.

Brood year	Smolts/Redd[a]	Emigrants/ Redd	Egg-Smolt[a] (%)	Egg-Emigrant (%)
2002	16	ND	0.3	ND
2003	77	183	1.3	3.1
2004	15	85	0.3	1.8
2005	45	106	1.0	2.5
2006	51	79	1.2	1.8
2007	56	210	1.3	4.7
2008	11	80	0.2	1.7
2009	10	176	0.2	3.9
2010	19	64	0.4	1.5
2011	14	120	0.3	2.7
2012	11	79	0.3	1.9
2013	33	271	0.8	6.7
2014	8	33	0.2	0.9
Average	***28***	***124***	***0.6***	***2.8***
Median	***16***	***96***	***0.3***	***2.2***

[a] These estimates include Nason Creek smolts produced only within the Nason Creek basin.

Seeding level (egg deposition) explained most of the variability in productivity and survival of juvenile spring Chinook in the Nason Creek watershed. That is, for estimates based on smolts produced within the Nason Creek watershed, survival and productivity decreased as seeding levels increased (Figure 6.2). This suggests that density dependence regulates juvenile productivity and survival within the Nason Creek watershed.



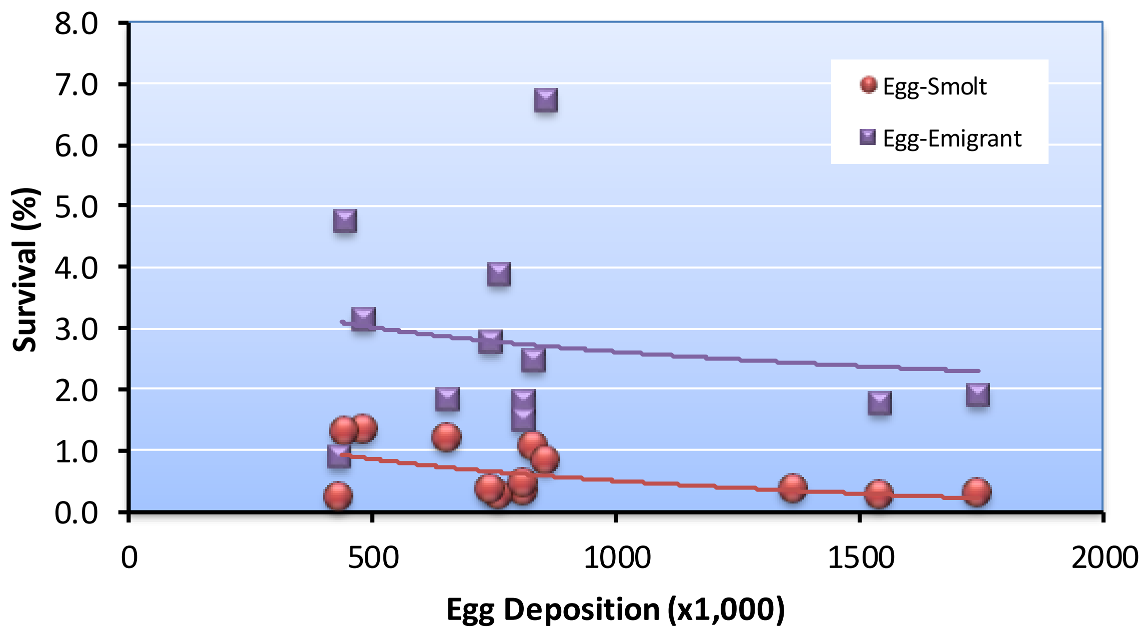


Figure 6.2. Relationships between seeding levels (egg deposition) and juvenile life-stage survivals and productivities for Nason Creek spring Chinook, brood years 2002-2014. Nason Creek smolts are smolts produced only in the Nason Creek watershed.

Population Carrying Capacity

Population carrying capacity (K) is defined as the maximum equilibrium population size estimated with population models (e.g., logistic equation, Beverton-Holt model, hockey stick model, and the

Ricker model).[16] Maximum equilibrium population size is generated from density dependent mechanisms that reduce population growth rates as population size increases (negative density dependence). This is referred to as compensation. Population size fluctuates about the maximum equilibrium size because of variability in vital rates that are unrelated to density (density independent factors) and measurement error. In this section, we estimate smolt carrying capacities using the Ricker stock-recruitment model (see Appendix C in Hillman et al. 2012 for a detailed description of methods). The Ricker model was the only stock-recruitment model that could be fit to the juvenile spring Chinook data.

Based on the Ricker model, the population carrying capacity for spring Chinook smolts in the Nason Creek watershed is 4,412 smolts (95% CI: 0 – 7,833) (Figure 6.3). Here, smolts are defined as the number of yearling spring Chinook produced entirely within Nason Creek. These estimates reflect current environmental conditions (most recent 13 years) within the Nason Creek watershed. Land use activities such as logging, roads, railways, development, and recreation have altered the historical conditions of the watershed. Thus, the estimated population capacity estimates may not reflect historical capacities for spring Chinook smolts in Nason Creek.

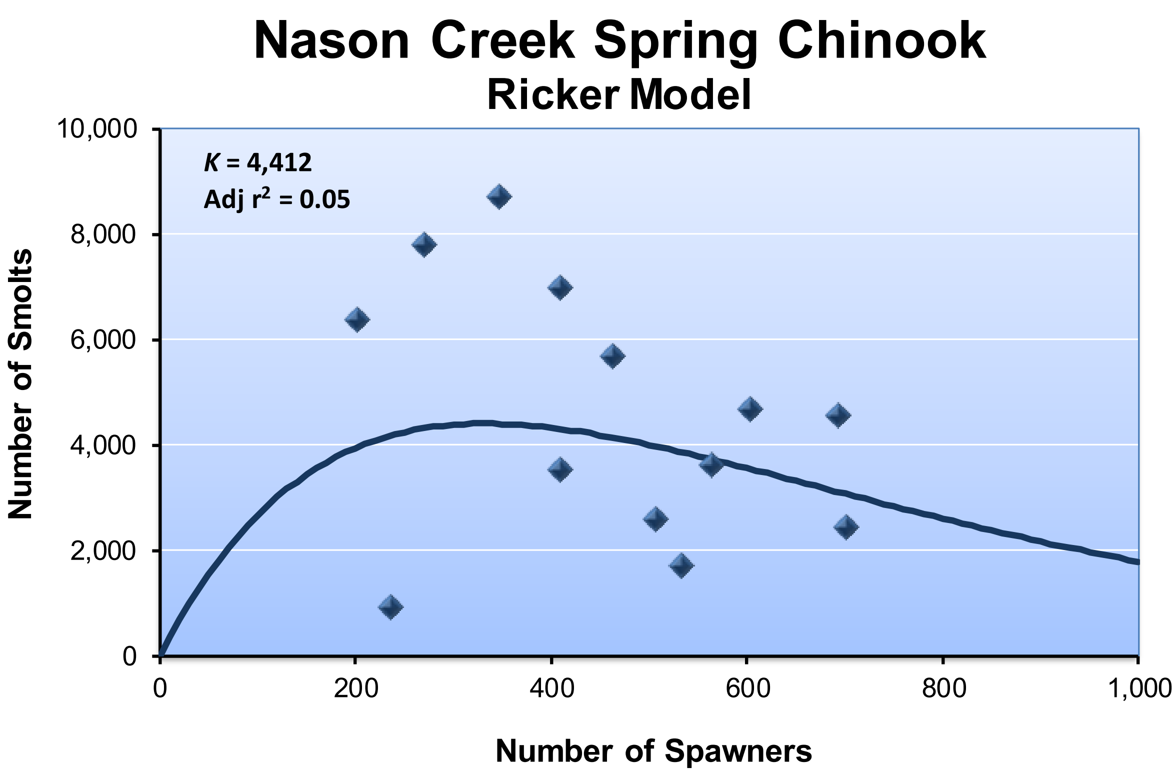


Figure 6.3. Relationship between spawners and number of yearling smolts produced in the Nason Creek watershed. Population carrying capacity (*K*) was estimated using the Ricker model.

[16] Population carrying capacity (*K*) should not be confused with habitat carrying capacity (*C*), which is defined as the maximum population of a given species that a particular environment can sustain.

We tracked the precision of the Ricker parameters for Nason Creek spring Chinook smolts over time to see if precision improves with additional years of data, and the parameters and statistics stabilize over time. Examination of variation in the alpha (*A*) and beta (*B*) parameters of the Ricker model and their associated standard errors and confidence intervals indicates that the parameters have not stabilized and they lack precision (Table 6.16; Figure 6.4). This was also apparent in the estimates of population carrying capacity (Figure 6.5).

Table 6.16. Estimated parameters and statistics associated with fitting the Ricker model to spawning escapement and smolt data. Smolts represent numbers of smolts produced entirely within the Nason Creek watershed. *A* = alpha parameter; *B* = beta parameter; SE = standard error (estimated from 5,000 bootstrap samples); and r^2 = coefficient of determination. Spawners represent the stock size needed to achieve population capacity.

Years of data	Parameter				Population capacity	Intrinsic productivity	Spawners	r^2
	A	SE	*B*	SE				
5	90.60	87.13	0.0046	0.0015	7,293	91	219	0.453
6	90.02	5618.57	0.0045	0.0014	7,360	90	222	0.442
7	92.67	1696.44	0.0046	0.0009	7,395	93	217	0.517
8	107.07	1208.15	0.0052	0.0012	7,575	107	192	0.454
9	99.89	1125.42	0.0051	0.0012	7,149	100	195	0.409
10	90.35	50.04	0.0049	0.0008	6,825	90	205	0.470
11	72.26	34.50	0.0043	0.0009	6,240	72	235	0.308
12	76.76	31.24	0.0043	0.0008	6,522	77	231	0.337
13	35.98	32.48	0.0030	0.0013	4,412	36	333	0.049

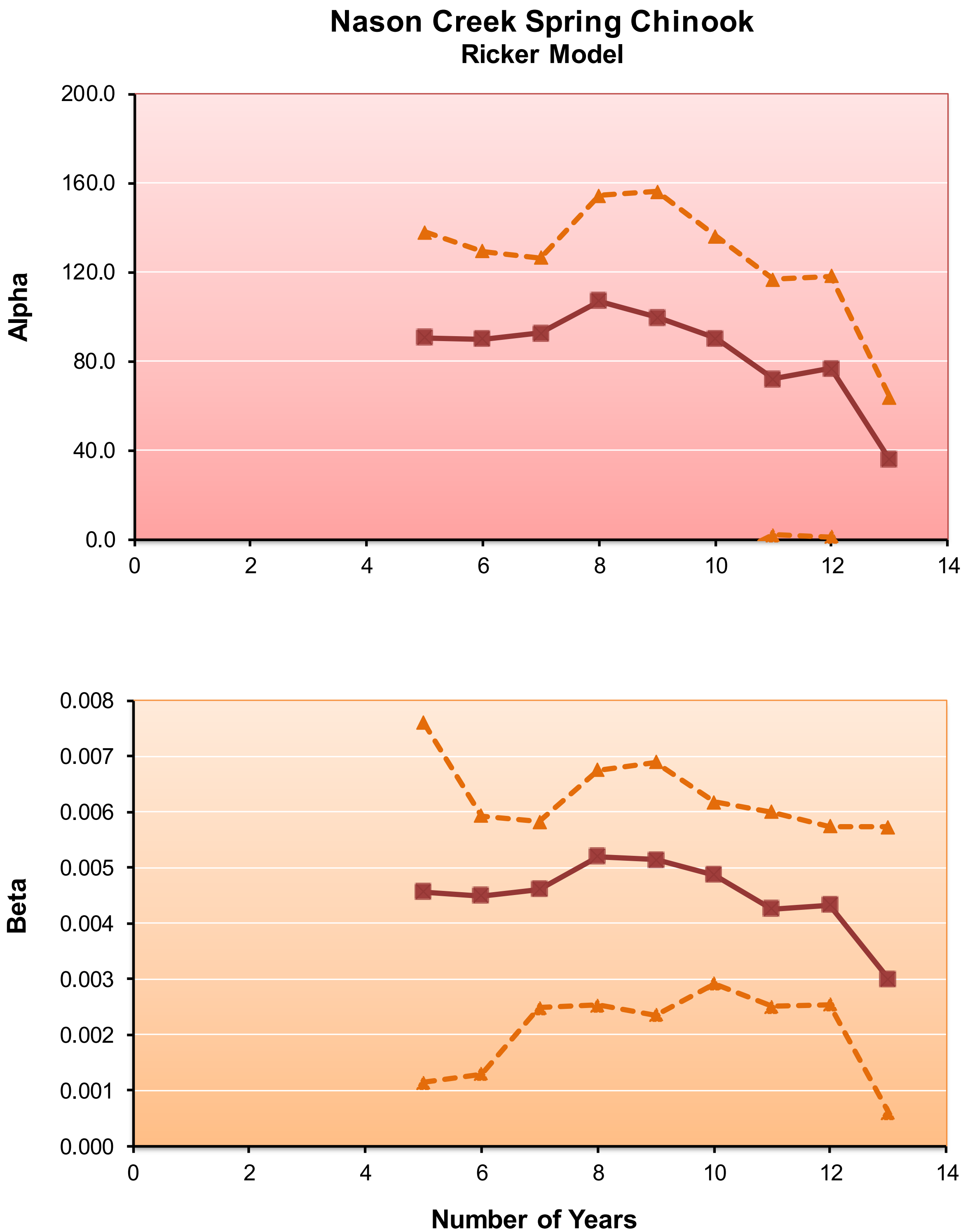


Figure 6.4. Time series of alpha and beta parameters and 95% confidence intervals for the Ricker model that was fit to Nason Creek spring Chinook smolt and spawning escapement data. Confidence intervals were estimated from 5,000 bootstrap samples.

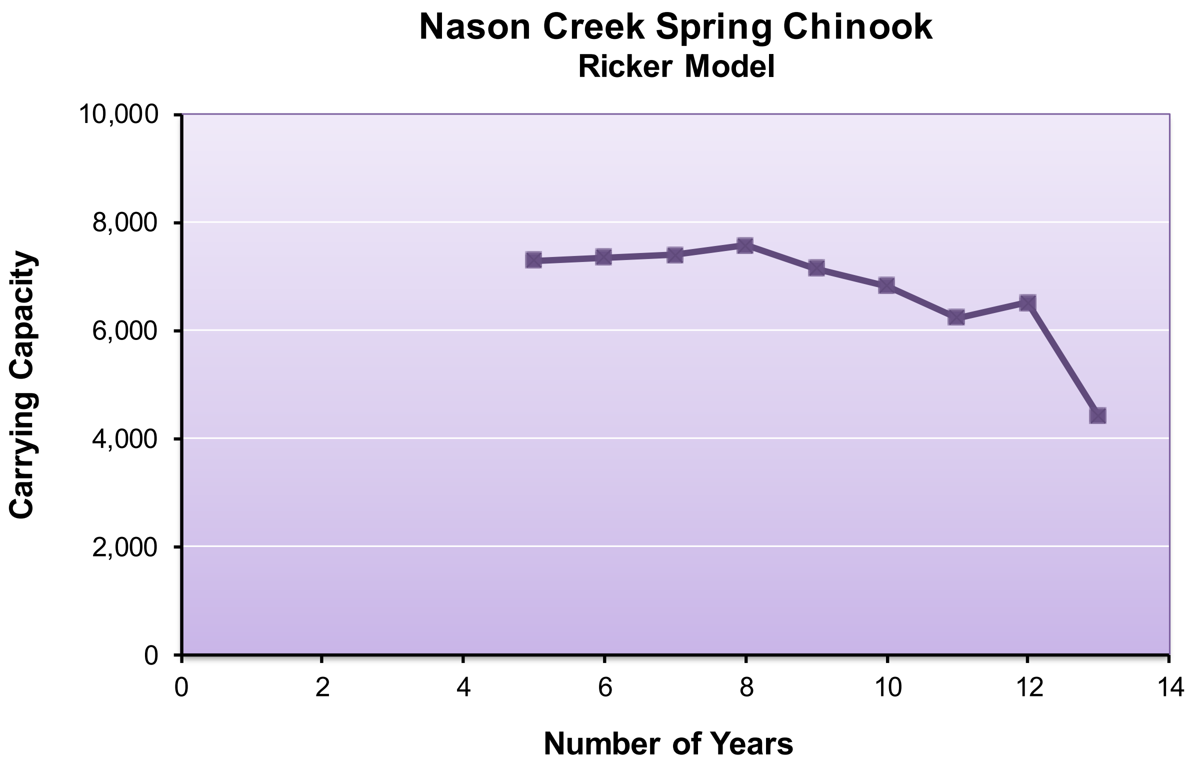


Figure 6.5. Time series of population carrying capacity estimates derived from fitting the Ricker model to Nason Creek spring Chinook smolt and spawning escapement data.

6.5 Spawning Surveys

Surveys for spring Chinook redds were conducted during late July through September 2016 in the Chiwawa River (including Rock, Chikamin, and Phelps creeks), Nason Creek, Icicle Creek, Peshastin Creek (including Ingalls Creek), Upper Wenatchee River (including Chiwaukum Creek), Little Wenatchee River, and White River (including the Napeequa River and Panther Creek). See Section 5.5 for complete coverage of spring Chinook redd surveys in the Wenatchee River basin. In the following section, we describe the number and distribution of redds within the Nason Creek basin.

Redd Counts and Distribution

A total of 85 spring Chinook redds were counted in Nason Creek in 2016 (Table 6.17; see Table 5.20 for the complete time series of redd counts). This is lower than the average of 144 redds counted during the period 1989-2015 in Nason Creek. Redds were not distributed evenly among the four reaches in Nason Creek. Most redds (68%) were located in Reach 2 and Reach 3 (Table 6.17).

Table 6.17. Numbers (both counted and estimated) and proportions of spring Chinook redds counted within different reaches within Nason Creek during August through September 2016. See Table 2.8 for description of survey reaches.

Stream/watershed	Reach	Number of observed redds	Estimated number of redds*	Proportion of redds estimated within stream/watershed
Nason	Nason 1 (N1)	14	14	0.14
	Nason 2 (N2)	20	23	0.23
	Nason 3 (N3)	37	45	0.45
	Nason 4 (N4)	14	18	0.18
Total		***85***	***100***	***1.00***

* Estimated redds represent the “true” number of redds based on Guassian area-under-the-curve method (see Appendix J).

Spawn Timing

Spring Chinook began spawning during the last week of July in Nason Creek and peaked the first week of September (Figure 6.6). Spawning in Nason Creek ended the fourth week of September.

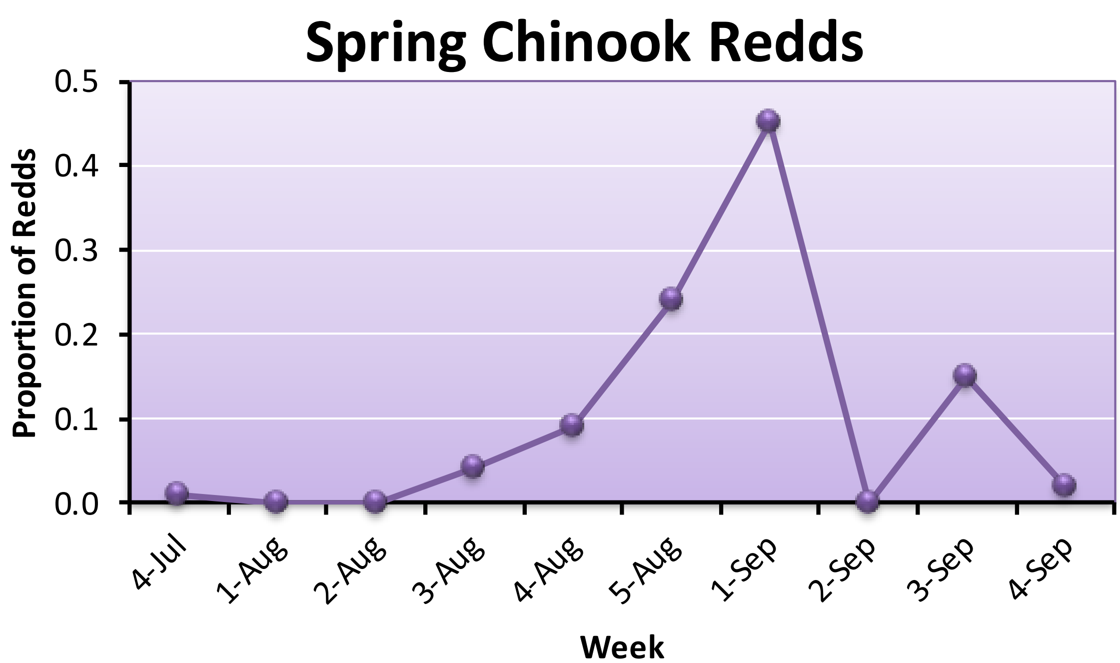


Figure 6.6. Proportion of spring Chinook redds counted during different weeks within Nason Creek, August through September 2016.

Spawning Escapement

Spawning escapement for spring Chinook was calculated as the number of redds times the male-to-female ratio (i.e., fish per redd expansion factor) estimated from broodstock and fish sampled at adult trapping sites.[17] The estimated fish per redd ratio for spring Chinook upstream from Tumwater in 2016 was 1.83 (based on sex ratios estimated at Tumwater Dam). Multiplying this ratio by the number of redds counted in Nason Creek resulted in a total spawning escapement of 156 spring Chinook. The estimated total spawning escapement of spring Chinook in 2016 was less than the overall average of 313 spring Chinook in Nason Creek (see Table 5.23).

6.6 Carcass Surveys

Surveys for spring Chinook carcasses were conducted during August through September 2016 in the Chiwawa River (including Rock, Chikamin, and Phelps creeks), Nason Creek, Icicle Creek, Peshastin Creek (including Ingalls Creek), Upper Wenatchee River (including Chiwaukum Creek), Little Wenatchee River, and the White River (including the Napeequa River and Panther Creek). In 2016, 95 spring Chinook carcasses were sampled in Nason Creek. Most of these were sampled in Reach 3. The number of carcasses sampled in 2016 was less than the overall average of 148 carcasses sampled during the period 1996-2015. See Section 5.6 for a complete coverage of spring Chinook carcass surveys in the Wenatchee River basin.

In the Nason Creek watershed, the spatial distribution of hatchery and wild fish was not equal among survey reaches (Table 6.18). In 2016, more wild fish were collected during surveys than hatchery fish. On average, over the survey years, more wild fish were collected than hatchery fish in each of the reaches except Reach 1 where more hatchery fish have been collected (Figure 6.7). It should be noted that the hatchery fish spawning in Nason Creek are primarily strays from the Chiwawa spring Chinook Program. Nason Creek hatchery fish began returning to Nason Creek in 2016 as age-3 fish.

Table 6.18. Numbers of wild and hatchery spring Chinook carcasses sampled within different reaches in the Nason Creek watershed, 1999-2016. Numbers represent recovered carcasses that had definitive origins. See Table 2.8 for description of survey reaches.

Survey year	Origin	Survey Reach				Total
		N-1	N-2	N-3	N-4	
1999	Wild	2	3	0	0	**5**
	Hatchery	0	0	0	0	**0**
2000	Wild	19	21	0	9	**49**
	Hatchery	11	9	0	1	**21**
2001	Wild	25	22	0	41	**88**
	Hatchery	91	54	0	22	**167**
2002	Wild	16	34	0	37	**87**
	Hatchery	33	29	0	35	**97**
2003	Wild	6	19	0	22	**47**
	Hatchery	3	9	0	3	**15**
2004	Wild	29	33	18	24	**104**
	Hatchery	42	26	11	3	**82**
2005	Wild	19	6	11	7	**43**
	Hatchery	130	17	22	4	**173**
2006	Wild	24	17	28	9	**78**

[17] Expansion factor = (1 + (number of males/number of females)).

Survey year	Origin	Survey Reach				Total
		N-1	N-2	N-3	N-4	
	Hatchery	50	31	17	14	**112**
2007	Wild	2	13	8	6	**29**
	Hatchery	54	77	26	15	**172**
2008	Wild	14	13	16	10	**53**
	Hatchery	102	39	36	13	**190**
2009	Wild	1	12	10	16	**39**
	Hatchery	25	21	20	23	**89**
2010	Wild	3	6	6	4	**19**
	Hatchery	47	29	30	16	**122**
2011	Wild	8	11	11	5	**35**
	Hatchery	22	12	21	8	**63**
2012	Wild	24	11	65	7	**107**
	Hatchery	95	37	70	23	**225**
2013	Wild	4	2	9	8	**23**
	Hatchery	51	12	28	27	**118**
2014	Wild	19	5	13	2	**39**
	Hatchery	25	1	3	0	**29**
2015	Wild	8	4	20	2	**34**
	Hatchery	2	0	7	0	**9**
2016	Wild	9	8	39	15	**71**
	Hatchery	10	0	9	3	**22**
Average	***Wild***	***13***	***13***	***14***	***12***	***53***
	Hatchery	***44***	***22***	***17***	***12***	***95***
Median	***Wild***	***12***	***12***	***11***	***9***	***45***
	Hatchery	***38***	***19***	***14***	***11***	***93***

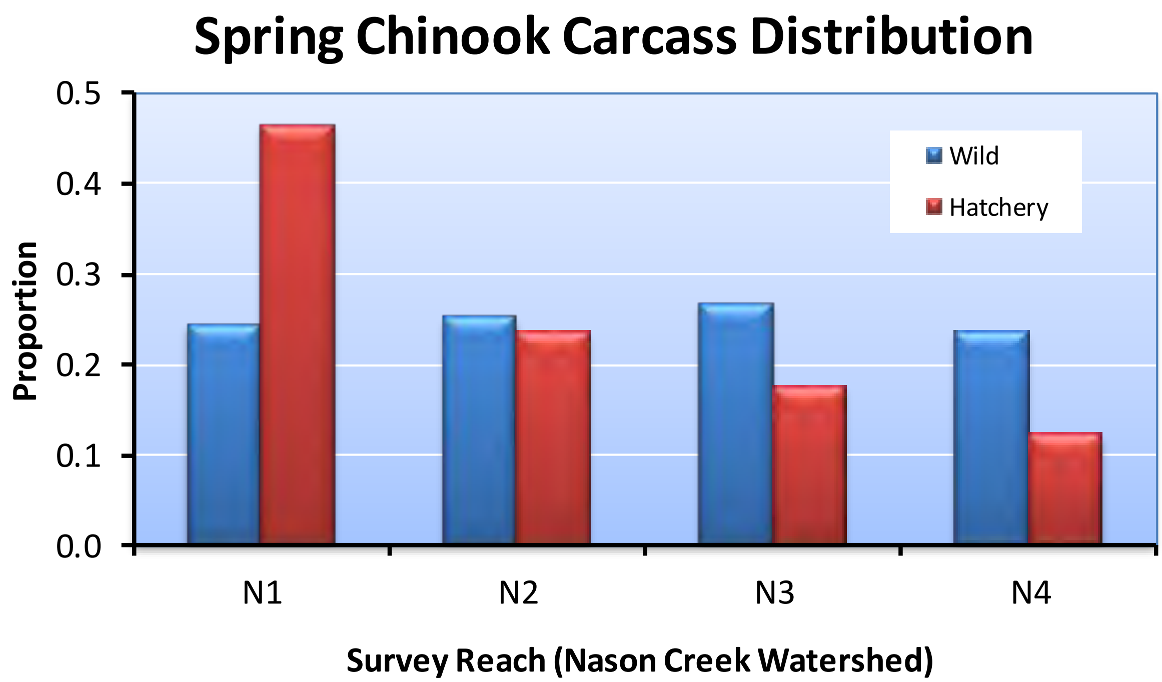


Figure 6.7. Distribution of wild and hatchery produced carcasses in different reaches in the Nason Creek watershed, 1999-2016. Reach codes are described in Table 2.8.

6.7 Life History Monitoring

Life history characteristics of spring Chinook were assessed by examining carcasses on spawning grounds and fish collected at broodstock collection sites, and by reviewing tagging data and fisheries statistics.

Migration Timing

See Section 5.7 for a description of migration timing of spring Chinook at Tumwater Dam.

Age at Maturity

Most of the wild and hatchery spring Chinook sampled during the period 1999-2016 in the Nason Creek watershed were age-4 fish (total age) (Table 6.19; Figure 6.8). Except for 2014 fish, hatchery fish made up a higher percentage of age-3 Chinook than did wild fish. As in other years, a higher proportion of age-5 wild fish returned than did age-5 hatchery fish. Thus, wild fish tended to return at an older age than hatchery fish.

Table 6.19. Numbers of wild and hatchery spring Chinook of different ages (total age) sampled on spawning grounds in the Nason Creek watershed, 1999-2016.

Sample year	Origin	Total age					Sample size
		2	3	4	5	6	
1999	Wild	0	0	5	0	0	**5**
	Hatchery	0	0	0	0	0	**0**
2000	Wild	0	1	45	0	0	**46**

Sample year	Origin	Total age					Sample size
		2	3	4	5	6	
	Hatchery	0	18	3	0	0	**21**
2001	Wild	0	0	63	13	0	**76**
	Hatchery	0	5	159	3	0	**167**
2002	Wild	0	0	58	23	0	**81**
	Hatchery	0	0	85	11	0	**96**
2003	Wild	0	4	3	36	0	**43**
	Hatchery	0	3	1	5	0	**9**
2004	Wild	0	1	101	1	0	**103**
	Hatchery	0	57	23	2	0	**82**
2005	Wild	0	1	25	17	0	**43**
	Hatchery	0	3	170	0	0	**173**
2006	Wild	0	0	60	18	0	**78**
	Hatchery	0	12	78	22	0	**112**
2007	Wild	0	0	18	11	0	**29**
	Hatchery	0	123	40	9	0	**172**
2008	Wild	0	2	46	4	0	**52**
	Hatchery	0	21	163	6	0	**190**
2009	Wild	0	1	36	2	0	**39**
	Hatchery	0	19	65	4	0	**88**
2010	Wild	0	1	18	0	0	**19**
	Hatchery	0	5	116	1	0	**122**
2011	Wild	0	3	24	8	0	**35**
	Hatchery	0	33	17	13	0	**63**
2012	Wild	0	1	89	17	0	**107**
	Hatchery	0	25	198	2	0	**225**
2013	Wild	0	0	16	7	0	**23**
	Hatchery	0	22	92	5	0	**119**
2014	Wild	0	16	19	3	0	**38**
	Hatchery	0	9	20	0	0	**29**
2015	Wild	0	1	25	4	0	**30**
	Hatchery	0	4	9	0	0	**13**
2016	Wild	0	3	61	7	0	**71**
	Hatchery	0	11	10	0	0	**21**
Average	***Wild***	***0***	***2***	***40***	***10***	***0***	***51***
	Hatchery	***0***	***22***	***73***	***5***	***0***	***100***
Median	***Wild***	***0***	***1***	***31***	***7***	***0***	***43***
	Hatchery	***0***	***12***	***65***	***3***	***0***	***96***

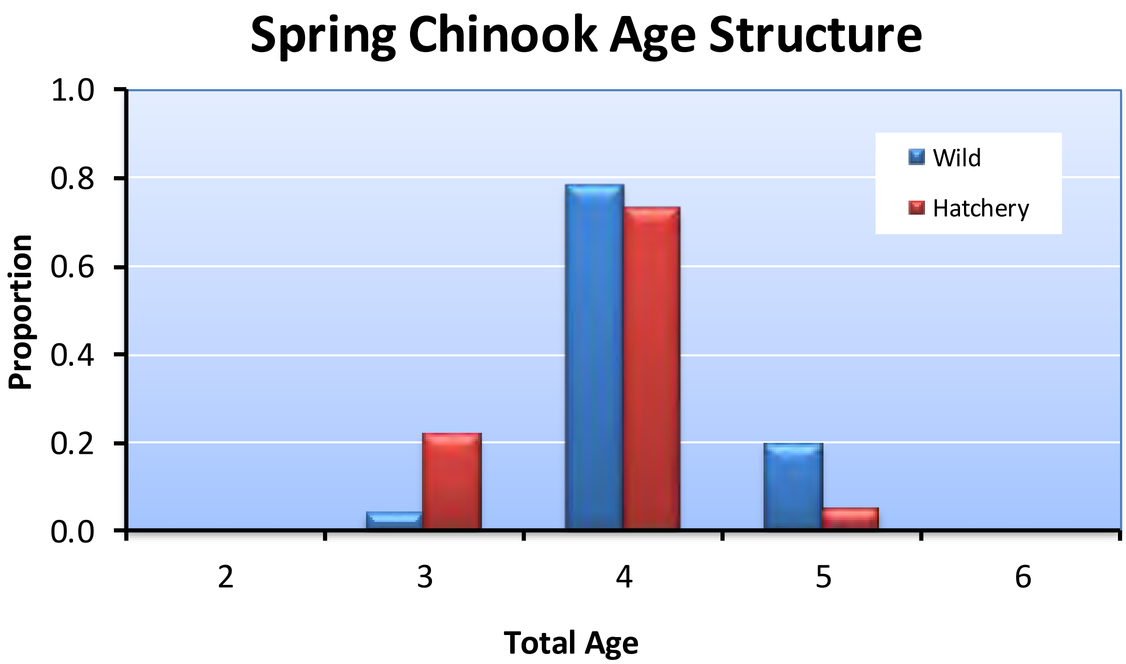


Figure 6.8. Proportions of wild and hatchery spring Chinook of different total ages sampled on spawning grounds in the Nason Creek watershed for the combined years 1999-2016.

Size at Maturity

On average, hatchery and wild spring Chinook of a given age differed little in length (Table 6.20). Differences were usually no more than 5 cm between hatchery and wild fish of the same age.

Table 6.20. Mean lengths (POH in cm; ±1SD) and sample sizes (in parentheses) of different ages (total age) of male and female spring Chinook of wild and hatchery-origin sampled in the Nason Creek watershed, 1999-2016.

Return year	Total age	Mean length (cm)			
		Male		Female	
		Wild	Hatchery	Wild	Hatchery
1999	3	0	0	0	0
	4	71 ±2 (2)	0	64 ±2 (3)	0
	5	0	0	0	0
	6	0	0	0	0
2000	3	46 ±0 (1)	44 ±4 (14)	0	52 ±10 (4)
	4	62 ±4 (19)	0	63 ±3 (25)	60 ±1 (3)
	5	0	0	0	0
	6	0	0	0	0
2001	3	0	47 ±12 (5)	0	0
	4	65 ±4 (21)	66 ±5 (36)	63 ±4 (42)	63 ±4 (123)
	5	81 ±5 (3)	0	72 ±3 (10)	71 ±7 (3)
	6	0	0	0	0
2002	3	0	0	0	0

Return year	Total age	Mean length (cm)			
		Male		Female	
		Wild	Hatchery	Wild	Hatchery
	4	62 ±6 (24)	66 ±5 (35)	63 ±4 (34)	62 ±5 (50)
	5	77 ±4 (12)	81 ±7 (8)	75 ±3 (11)	71 ±5 (3)
	6	0	0	0	0
2003	3	44 ±7 (3)	43 ±5 (3)	0	0
	4	58 ±7 (2)	79 ±0 (1)	67 ±0 (1)	0
	5	75 ±9 (11)	81 ±6 (2)	72 ±6 (25)	71 ±2 (3)
	6	0	0	0	0
2004	3	46 ±0 (1)	43 ±4 (56)	0	0
	4	61 ±4 (35)	60 ±3 (6)	61 ±3 (66)	62 ±4 (17)
	5	0	0	81 ±0 (1)	73 ±4 (2)
	6	0	0	0	0
2005	3	37 ±0 (1)	41 ±7 (3)	0	0
	4	59 ±6 (8)	63 ±4 (54)	61 ±3 (17)	61 ±3 (116)
	5	73 ±5 (4)	0	71 ±1 (13)	0
	6	0	0	0	0
2006	3	0	41 ±3 (12)	0	0
	4	60 ±5 (26)	62 ±3 (29)	61 ±3 (34)	59 ±4 (49)
	5	72 ±5 (10)	73 ±5 (6)	69 ±4 (8)	70 ±4 (16)
	6	0	0	0	0
2007	3	0	44 ±4 (122)	0	51 ±0 (1)
	4	62 ±4 (6)	60 ±7 (13)	63 ±4 (12)	61 ±4 (27)
	5	77 ±5 (7)	67 ±5 (3)	68 ±2 (4)	70 ±2 (6)
	6	0	0	0	0
2008	3	51 ±21 (2)	45 ±5 (20)	0	45 ±0 (1)
	4	60 ±5 (15)	63 ±4 (42)	61 ±3 (31)	63 ±3 (121)
	5	0	77 ±2 (3)	71 ±3 (4)	64 ±7 (3)
	6	0	0	0	0
2009	3	41 ±0 (1)	46 ±5 (18)	0	65 ±0 (1)
	4	60 ±5 (12)	63 ±4 (19)	60 ±3 (24)	61 ±4 (46)
	5	0	71 ±1 (2)	72 ±4 (2)	73 ±3 (2)
	6	0	0	0	0
2010	3	44 ±0 (1)	45 ±5 (5)	0	0
	4	62 ±5 (7)	63 ±4 (42)	61 ±3 (10)	62 ±4 (74)
	5	0	75 ±0 (1)	0	0
	6	0	0	0	0
2011	3	48 ±11 (3)	43 ±4 (31)	0	48 ±2 (2)
	4	61 ±5 (11)	59 ±11 (6)	60 ±5 (12)	63 ±5 (11)
	5	79 ±2 (3)	73 ±3 (6)	75 ±4 (5)	70 ±3 (7)
	6	0	0	0	0
2012	3	41 ±0 (1)	42 ±3 (24)	0	0
	4	61 ±7 (35)	60 ±5 (45)	61 ±4 (54)	60 ±4 (151)

Return year	Total age	Mean length (cm)			
		Male		Female	
		Wild	Hatchery	Wild	Hatchery
	5	77 ±4 (6)	0	66 ±5 (11)	70 ±3 (2)
	6	0	0	0	0
2013	3	0	42 ±4 (21)	0	0
	4	60 ±6 (5)	62 ±4 (23)	60 ±4 (10)	60 ±4 (69)
	5	71 ±0 (1)	75 ±0 (1)	68 ±3 (6)	70 ±4 (4)
	6	0	0	0	0
2014	3	44 ±5 (15)	49 ±4 (9)	60 ±0 (1)	0
	4	64 ±7 (8)	59 ±4 (8)	63 ±3 (11)	60 ±3 (12)
	5	0	0	69 ±8 (3)	0
	6	0	0	0	0
2015	3	44 ±0 (1)	45 ±1 (4)		
	4	61 ±7 (15)	56 ±4 (3)	63 ±5 (10)	58 ±2 (6)
	5	72 ±7 (3)		65 ±0 (1)	
	6				
2016	3	43 ±2 (3)	46 ±5 (10)		45 ±0 (1)
	4	64 ±6 (32)	65 ±1 (3)	64 ±5 (29)	60 ±2 (7)
	5	67 ±0 (1)		71 ±5 (6)	
	6				

Contribution to Fisheries

Because the Nason Creek program began in 2013, there will be no harvest information on Nason Creek hatchery spring Chinook until 2018, when brood year 2013 fish have returned.

Straying

Stray rates will be determined by examining CWTs and PIT tags recovered on spawning grounds within and outside the Wenatchee River basin. Targets for strays based on return year (recovery year) within the Wenatchee River basin should be less than 10% and targets for strays outside the Wenatchee River basin should be less than 5%. The target for brood year stray rates should be less than 5%. Straying of Nason Creek spring Chinook will be estimated beginning in 2017 when the 2013 brood fish return.

Genetics

Because the Nason Creek spring Chinook program began in 2013 with the collection of broodstock, there are no studies that examine the effects of the program on the genetics of natural-origin spring Chinook in the Wenatchee River basin. However, genetic studies were conducted to determine the potential effects of the Chiwawa Supplementation Program on natural-origin spring Chinook in the upper Wenatchee River basin (Blankenship et al. 2007; the entire report is appended as Appendix K). This work included the analysis of Nason Creek spring Chinook. Researchers collected microsatellite DNA allele frequencies from temporally replicated natural and hatchery-origin spring Chinook to statistically assign individual fish to specific demes (locations) within the Wenatchee population.

Significant differences in allele frequencies were observed within and among major spawning areas in the Upper Wenatchee River basin. However, these differences made up only a very small portion of the overall variation, indicating genetic similarity among the major spawning areas. There was no evidence that the Chiwawa program has changed the genetic structure (allele frequency) of spring Chinook in Nason Creek and the White River, despite the presence of hatchery-origin spawners in both systems.

Proportionate Natural Influence

Another method for assessing the genetic risk of a supplementation program is to determine the influence of the hatchery and natural environments on the adaptation of the composite population. This is estimated by the proportion of natural-origin fish in the hatchery broodstock (pNOB) and the proportion of hatchery-origin fish in the natural spawning escapement (pHOS). We calculated Proportionate Natural Influence (PNI) by iterating Ford's (2002) equations 5 and 6 to equilibrium, using a heritability of 0.3 and a selection strength of three standard deviations.[18] The larger the PNI value, the greater the strength of selection in the natural environment relative to that of the hatchery environment. For the natural environment to dominate selection, PNI should be greater than 0.50, and important integrated populations should have a PNI of at least 0.67 (HSRG/WDFW/NWIFC 2004).

For brood years 1989-2012, when no brood stock was collected for the Nason Creek Program, the PNI values ranged from 0.28 to 1.00 (Table 6.21). During this period, PNI values varied over time because of Chiwawa spring Chinook straying into Nason Creek. For brood years 2013-2016, a period when brood stock was collected for the Nason Creek Program, PNI values for the Nason Creek Program ranged from 0.46 to 0.77 (Table 6.21).

Table 6.21. Proportionate Natural Influence (PNI) Index of hatchery spring Chinook spawning in Nason Creek, brood years 1989-2016. See notes below the table for description of each metric.

Brood year	Spawners					Broodstock			PNI
	NOS	HOS_N	HOS_S	$pHOS_N$	$pHOS_{N+S}$	NOB_N	HOB_N	pNOB	
1989	222	0	0	0.00	0.00	0	0	*1.00*	1.00
1990	231	0	0	0.00	0.00	0	0	*1.00*	1.00
1991	156	0	0	0.00	0.00	0	0	*1.00*	1.00
1992	181	0	0	0.00	0.00	0	0	*1.00*	1.00
1993	430	0	61	0.00	0.12	0	0	*1.00*	0.90
1994	60	0	0	0.00	0.00	0	0	*0.67*	1.00
1995	18	0	0	0.00	0.00	0	0	*0.00*	1.00
1996	58	0	25	0.00	0.30	0	0	*0.44*	0.61
1997	67	0	55	0.00	0.45	0	0	*0.29*	0.42
1998	61	0	3	0.00	0.05	0	0	*0.28*	0.86
1999	22	0	0	0.00	0.00	0	0	*0.00*	1.00
2000	189	0	81	0.00	0.30	0	0	*0.30*	0.52

[18] According to authorized annual take permits, PNI is calculated using the PNI approximate equation 11 (HSRG 2009; Appendix A). However, in this report, we used Ford's (2002) equations 5 and 6 with a heritability of 0.3 and a selection strength of three standard deviations to calculate PNI (C. Busack, NOAA Fisheries, 21 March 2016, provided the model for calculating PNI). This approach is more accurate than using the PNI approximate equation.

Brood year	Spawners					Broodstock			PNI
	NOS	HOS_N	HOS_S	$pHOS_N$	$pHOS_{N+S}$	NOB_N	HOB_N	pNOB	
2001	257	0	341	0.00	0.57	0	0	*0.30*	0.37
2002	313	0	290	0.00	0.48	0	0	*0.28*	0.39
2003	152	0	50	0.00	0.25	0	0	*0.44*	0.65
2004	297	0	210	0.00	0.41	0	0	*0.39*	0.51
2005	81	0	266	0.00	0.77	0	0	*0.33*	0.32
2006	117	0	154	0.00	0.57	0	0	*0.29*	0.36
2007	83	0	380	0.00	0.82	0	0	*0.29*	0.28
2008	139	0	426	0.00	0.75	0	0	*0.27*	0.29
2009	163	0	371	0.00	0.69	0	0	*0.46*	0.42
2010	59	0	351	0.00	0.86	0	0	*0.44*	0.35
2011	250	0	452	0.00	0.64	0	0	*0.46*	0.43
2012	220	0	474	0.00	0.68	0	0	*0.66*	0.50
Average*	***159***	***0***	***166***	***0.00***	***0.36***	***0***	***0***	***0.48***	***0.63***
Median*	***154***	***0***	***71***	***0.00***	***0.36***	***0***	***0***	***0.42***	***0.52***
2013	70	0	339	0.00	0.83	21	4	0.84	0.55
2014	169	0	68	0.00	0.29	21	0	1.00	0.54
2015	28	0	123	0.00	0.81	59	63	0.48	0.46
2016	125	0	31	0.00	0.20	70	66	0.51	0.77
Average**	***98***	***0***	***140***	***0.00***	***0.53***	***43***	***33***	***0.71***	***0.58***
Median**	***98***	***0***	***96***	***0.00***	***0.55***	***40***	***34***	***0.68***	***0.55***

HOS_N = hatchery-origin spawners in Nason Creek from the Nason Creek spring Chinook Supplementation Program.
$pHOS_N$ = proportion of hatchery-origin spawners from Nason Creek spring Chinook Supplementation Program.
HOS_S = stray hatchery-origin spawners in Nason Creek.
$pHOS_S$ = proportion of stray hatchery-origin spawners.
NOB_N = natural-origin broodstock spawned in the Nason Creek spring Chinook Supplementation Program.
HOB_N = hatchery-origin broodstock spawned in the Nason Creek spring Chinook Supplementation Program.
pNOB = proportion of hatchery-origin broodstock. Because of the high incidence of strays to Nason Creek from the Chiwawa River spring Chinook program, pNOB values from the Chiwawa program were used to estimate PNI values during the period from 1989 to 2012 (*italicized*). The weighting for those years was 100% based on the Chiwawa program broodstock selection, because there have been no hatchery returns from the Nason Creek spring Chinook program (see Table 5.1 for Chiwawa broodstock selection).
PNI_N = Proportionate Natural Influence for Nason Creek spring Chinook calculated using the gene-flow model for multiple programs.
* Average and median for the period 1989-2012, a period when no brood stock were collected for the Nason Creek Program.
** Average and median for the period 2013-present, a period when brood stock was collected for the Nason Creek Program.

Post-Release Survival and Travel Time

We used PIT-tagged fish to estimate survival rates and travel time (arithmetic mean days) of hatchery spring Chinook from the Nason Creek release site to McNary Dam, and smolt to adult ratios (SARs) from release to detection at Bonneville Dam (Table 6.22).[19] Over the two brood years for which PIT-tagged hatchery fish were released, survival rates from Nason Creek to McNary Dam ranged from 0.346 to 0.572. Average travel time from Nason Creek to McNary Dam ranged from 21 to 38 days. SARs from release to detection at Bonneville Dam will be calculated in 2018 with the return of 2013 brood fish.

[19] It is important to point out that because of fish size differences among rearing tanks or raceways, fish PIT tagged in one tank or raceway may not represent untagged fish rearing in other tanks or raceways.

Table 6.22. Total number of Nason hatchery spring Chinook released with PIT tags, their survival and travel times (mean days) to McNary Dam, and smolt-to-adult (SAR) ratios for brood years 2013-2014. Standard errors are shown in parentheses. NA = not available (i.e., not all the adults from the release groups have returned to the Columbia River).

Brood year	Number of tagged fish released	Survival to McNary Dam	Travel time to McNary Dam (d)	SAR to Bonneville Dam
2013	20,139	0.346 (0.030)	38.1 (5.9)	NA
2014	5,007	0.572 (0.038)	20.6 (5.3)	NA

Natural and Hatchery Replacement Rates

Natural replacement rates (NRR) were calculated as the ratio of natural-origin recruits (NOR) to the parent spawning population (spawning escapement). Natural-origin recruits are naturally produced (wild) fish that survive to contribute to harvest (directly or indirectly), to broodstock, and to spawning grounds. We do not account for fish that died in route to the spawning grounds (migration mortality) or died just before spawning (pre-spawn mortality) (see Appendix B in Hillman et al. 2012). We calculated NORs with and without harvest. NORs without harvest include all returning fish that either returned to the basin or were collected as wild broodstock. NORs with harvest include all fish harvested and are based on brood-year harvest rates from the Chiwawa Hatchery program. For brood years 1989-2010, NRR for spring Chinook in Nason Creek averaged 0.84 (range, 0.05-5.48) if harvested fish were not included in the estimate and 0.92 (range, 0.05-5.86) if harvested fish were included in the estimate (Table 6.23). NRRs for more recent brood years will be calculated as soon as all tag recoveries and sampling rates have been loaded into the database.

Hatchery replacement rates (HRR) are the hatchery adult-to-adult returns and will be calculated as the ratio of hatchery-origin recruits (HOR) to the parent broodstock collected. These rates should be greater than the NRRs and greater than or equal to 6.7 (the calculated target value in Hillman et al. 2013). The target value of 6.7 includes harvest and was based on HRRs for Chiwawa spring Chinook salmon. HRRs will be calculated beginning in 2018 with the return of 2013 brood fish.

Table 6.23. Spawning escapements, natural-origin recruits (NOR), and natural replacement rates (NRR; with and without harvest) for spring Chinook in the Nason Creek watershed, brood years 1989-2010.

Brood year	Spawning Escapement	Harvest not included		Harvest included	
		NOR	NRR	NOR	NRR
1989	222	171	0.77	249	1.12
1990	231	15	0.06	18	0.08
1991	156	21	0.13	23	0.15
1992	181	47	0.26	49	0.27
1993	491	133	0.27	137	0.28
1994	60	3	0.05	3	0.05
1995	18	22	1.22	23	1.28
1996	83	229	2.76	250	3.01
1997	122	306	2.51	339	2.78
1998	64	351	5.48	375	5.86

Brood year	Spawning Escapement	Harvest not included		Harvest included	
		NOR	NRR	NOR	NRR
1999	22	14	0.64	15	0.68
2000	270	337	1.25	354	1.31
2001	598	77	0.13	79	0.13
2002	603	123	0.20	128	0.21
2003	202	63	0.31	67	0.33
2004	507	131	0.26	141	0.28
2005	347	155	0.45	160	0.46
2006	271	118	0.44	148	0.55
2007	463	210	0.45	251	0.54
2008	565	244	0.43	274	0.48
2009	534	71	0.13	77	0.14
2010	410	113	0.28	140	0.34
Average	***292***	***134***	***0.84***	***150***	***0.92***
Median	***251***	***123***	***0.37***	***139***	***0.40***

Smolt-to-Adult Survivals

Smolt-to-adult survival ratios (SARs) will be calculated as the number of hatchery adult recaptures divided by the number of tagged hatchery smolts released. SARs will be calculated beginning in 2018 with the return of all 2013 brood fish.

6.8 ESA/HCP Compliance

Broodstock Collection

Collection of brood year 2014 broodstock for Nason Creek spring Chinook used a combination of natural-origin adults previously PIT tagged as juveniles and intercepted at Tumwater Dam, and tangle netting in Nason Creek to target up to 64 natural-origin broodstock. Additionally, 130 Chiwawa hatchery-origin adults were collected at Tumwater Dam to secure Grant PUD's Wenatchee spring Chinook production obligation. Total broodstock achieved for the 2014 brood Nason Creek spring Chinook program was 28 and 130 natural and hatchery-origin adults, respectively. A total of 177 bull trout were handled and/or observed during broodstock collection at Tumwater Dam. One bull trout was handled/observed during tangle netting in Nason Creek in 2014.

Hatchery Rearing and Release

The 2014 brood Nason Creek spring Chinook reared throughout all life stages without significant mortality (defined as >10% population mortality associated with a single event). A total of 32,215 WxW and 196,866 HxH smolts were released (25.5% of 2014 conservation program goal and 102.4% of the aggregate Nason program goal). Survival from green-egg through release survival was 87.4%, well above the 81.0% target.

From November 2015 through February 2016, a total of five major freshets occurred in the Nason Creek basin resulting in significant damage and blockage of the Nason Acclimation Facility (NAF) intake structure. To minimize the potential for major fish loss, in March 2016 the HxH component (derived from returning Chiwawa hatchery adults) were transferred to the Chiwawa Acclimation facility for the remainder of their rearing and release. This allowed the limited amount of surface water available at the NAF to be prioritized for the small conservation program. No additional mortality occurred as a result of these actions.

Hatchery Effluent Monitoring

Per ESA Permits 1196, 1347, 1395, 18118, 18120, and 18121, permit holders shall monitor and report hatchery effluents in compliance with applicable National Pollution Discharge Elimination Systems (NPDES) (EPA 1999) permit limitations. There were no NPDES violations reported at PUD Hatchery facilities during the period 1 January through 31 December 2015. NPDES monitoring and reporting for PUD Hatchery Programs during 2015 are provided in Appendix F.

Smolt and Emigrant Trapping

Per ESA Section 10 Permit No. 1196, 18118, 18120, and 18121 the permit holders are authorized a direct take of 20% of the emigrating spring Chinook population during juvenile emigration monitoring and a lethal take not to exceed 2% of the fish captured (NMFS 2003). Based on the estimated wild spring Chinook population (smolt trap expansion) and hatchery juvenile spring Chinook population estimate (hatchery release data) for the Wenatchee River basin, the reported spring Chinook encounters during 2015 emigration monitoring complied with take provisions in the Section 10 permit. Spring Chinook encounter and mortality rates for each trap site (including PIT tag mortalities) are detailed in Table 6.24. Additionally, juvenile fish captured at the trap locations were handled consistent with provisions in ESA Section 10 Permit 1196, 18118, 18120, and 18121, Section B. Table 6.24 includes incidental and direct take associated with the Nason Creek smolt trap operated by the Yakama Nation under separate permits.

Table 6.24. Estimated take of Upper Columbia River spring Chinook resulting from juvenile emigration monitoring in the Wenatchee River basin, 2016.

Trap location	Population estimate			Number trapped			Total	Take allowed under Permit
	Wild[a]	Hatchery[b]	Sub-yearling[c]	Wild	Hatchery	Sub-yearling		
Chiwawa Trap								
Population	37,170	341,226	145,971	2,807	2,525	16,393	21,725	
Encounter rate	NA	NA	NA	0.0755	0.0074	0.1123	0.0414	0.20
Mortality[e]	NA	NA	NA	4	0	82	86	
Mortality rate	NA	NA	NA	0.0014	0.0000	0.0050	0.0040	0.02
White River Trap								
Population	386	NA	2,430	3	NA	197	200	
Encounter rate	NA	NA	NA	0.0078	NA	0.0811	0.0710	0.2
Mortality[d]	NA	NA	NA	0	NA	2	2	
Mortality rate	NA	NA	NA	0.0000	NA	0.0102	0.0100	0.02
Nason Creek Trap								
Population	2,372	32,215	6,813	61	124	791	976	
Encounter rate	NA	NA	NA	0.0257	0.0038	0.1161	0.0236	0.2

Trap location	Population estimate			Number trapped			Total	Take allowed under Permit
	Wild[a]	Hatchery[b]	Sub-yearling[c]	Wild	Hatchery	Sub-yearling		
Mortality[d]	NA	NA	NA	0	0	6	6	
Mortality rate	NA	NA	NA	0.0000	0.0000	0.0076	0.0061	0.02
Lower Wenatchee Trap								
Population	36,752	373,441	4,023,310	610	7,702	27,407	35,719	
Encounter rate	NA	NA	NA	0.0166	0.0206	0.0019	0.0024	0.20
Mortality[d]	NA	NA	NA	2	3	184	189	
Mortality rate	NA	NA	NA	0.0033	0.001	0.0067	0.0053	0.02
Wenatchee River Basin Total								
Population	73,922	373,441	4,169,281	3,417	10,227	40,800	57,444	
Encounter rate	NA	NA	NA	0.0462	0.0274	0.0030	0.0039	0.20
Mortality[d]	NA	NA	NA	6	3	266	275	
Mortality rate	NA	NA	NA	0.0018	0.0001	0.0061	0.0048	0.02

[a] Smolt population estimate derived from juvenile emigration trap data.

[b] 2014 BY smolt release data for the Wenatchee River basin.

[c] Based on size, date of capture and location of capture, subyearling Chinook encountered at the Lower Wenatchee Trap are categorized as summer Chinook salmon.

[d] Combined trapping and PIT tagging mortality.

Spawning Surveys

Spring Chinook spawning ground surveys were conducted in the Wenatchee River basin during 2016, as authorized by ESA Section 10 Permits 18118, 18120, and 18121. Because of the difficulty of quantifying the level of take associated with spawning ground surveys, the Permit does not specify a take level associated with these activities, even though it does authorize implementation of spawning ground surveys. Therefore, no take levels are reported. However, to minimize potential effects to established redds, wading was restricted to the extent practical, and extreme caution was used to avoid established redds when wading was required.

Spring Chinook Reproductive Success Study

ESA Section 10 Permit 1196 (expired) and new Section 10 Permits 18118, 18120, and 18121 specifically provide authorization to capture, anesthetize, biologically sample, PIT tag, and release adult spring Chinook at Tumwater Dam for reproductive success studies and general program monitoring. During 2010 through 2016, all spring Chinook passing Tumwater Dam were enumerated, anesthetized, biologically sampled, PIT tagged, and released (not including hatchery-origin and natural-origin Chinook retained for broodstock) as a component of the reproductive success study (BPA Project No. 2003-039-00). Please refer to Ford et al. (2010, 2011, 2012, 2013, 2014, 2015, and 2016) for complete details on the methods and results of the spring Chinook reproductive success study for the period 2010-2016.

SECTION 7: WHITE RIVER SPRING CHINOOK

The White River spring Chinook salmon captive brood program began in 1997 with goals to conserve, aid in the recovery, and prevent the extinction of naturally spawning spring Chinook in the White River, and to meet the mitigation responsibilities of Grant County PUD. Collection of eggs or juveniles from the White River (brood years 1997-2009) made up the first-generation (F_1) component of the White River captive brood program. Initially, rearing occurred at AquaSeed in Rochester, Washington, but transitioned to the Little White Salmon National Fish Hatchery near Cook, Washington, in 2006. The F_1 component was reared to maturation and spawned within the hatchery. The resulting progeny (F_2) were then reared in the hatchery until final acclimation and released in the upper Wenatchee Basin. The first large release of F_2 juveniles was in 2008. The last release of juveniles from the captive brood program occurred in 2015.

The production goal for the White River captive brood program following the 2013 hatchery recalculation was to release 74,556 yearling smolts into the upper Wenatchee River basin at 18-24 fish per pound. Fish lengths and weights for the recent broods were manipulated to evaluate different approaches for reducing precocious maturation. All fish were marked with CWTs. In addition, from 2008 through 2015, juvenile spring Chinook were PIT tagged annually.

Since its inception, the captive brood program underwent several adaptive changes designed to improve program success. These changes included: (1) use of a pedigree approach to reduce the use of stray fish in the broodstock, (2) transfer of fish from Aquaseed to the Little White Salmon National Fish Hatchery to improve fish quality, (3) injection of hormones into F_1 females to improve maturation of eggs, (4) manipulation of diet and ration for the F_2 fish to reduce precocious maturation of males, (5) use of temporary tanks and natural enclosures during acclimation to improve homing, and (6) trucking juvenile fish around Lake Wenatchee to improve survival.

The following information focuses on results from monitoring the White River spring Chinook program. More detailed information on the White River program can be found in Lauver et al. (2012). Information on spring Chinook collected throughout the Wenatchee River basin is presented in Section 5.

7.1 Captive Brood Collection

The captive brood program was designed to provide a rapid, short-term demographic boost to the White River spring Chinook spawning aggregate, which was at a high risk of local extinction (Lauver et al. 2012). This section describes the collection of broodstock for the White River program.

Brood Collection and Rearing

A primary objective of the White River program was to collect progeny of naturally spawning spring Chinook in the White River. The progeny (eggs or juveniles) make up the first-generation (F_1) of the captive brood program. However, strays from the Chiwawa supplementation program made this a challenge. As a result, researchers attempted to identify the origin of spawners on redds in the White River and then focused egg and juvenile collection efforts on those redds that had the highest likelihood of being produced from White River parents. During most years, this limited the number of redds from which eggs or juveniles could be collected. Starting with brood year 2006, a pedigree approach was adopted to improve the likelihood that eggs or juveniles used in the captive brood program were of White River origin.

During 1997 to 2009, first-generation broodstock for the captive brood program originated from about 10,353 natural-origin eggs and juveniles collected from 122 redds in the White River. Broodstock from brood year 1997 were trapped as parr with nets in the fall of 1998. Broodstock from brood year 2006 were trapped as fry with nets in the spring of 2007. It was assumed that the parr and fry near known redds were produced from those redds, and origin was confirmed with pedigree analyses. All other brood years were collected as eggs in the fall using redd pumping techniques. Broodstock collection levels were calculated based on the following assumptions and the known number of suitable redds each year (Tonseth and Maitland 2011):

1. 150,000 smolt target/0.70 (green egg to release survival) = 214,000 green eggs
2. 214,000 green eggs/1,500 eggs per female = 143 females/0.50 (sex ratio) = 286 fish
3. 286 fish/0.30 (eyed egg to maturity survival) = 953 eyed eggs
4. 953 eyed eggs/**X** redds = **Y** eyed-eggs per redd

Eyed eggs or juveniles collected in the White River were transported to Aquaseed (brood years 1997-2007) or to the Little White Salmon Hatchery (brood years 2008-2009) and reared to adults. Table 7.1 summarizes the collection of eyed eggs or juveniles for the captive brood program.

Table 7.1. Numbers of eyed eggs or juvenile brood stock collected for the White River captive brood program, brood years 1997-2009 (2009 was the last year for broodstock collection). Also shown are the number of redds that were sampled for eggs or juveniles and the hatchery in which the fish were reared (LWSFH = Little White Salmon Fish Hatchery); NS = no sample.

Brood year	Number of eyed eggs collected	Number of juvenile Chinook collected	Number of redds sampled	Rearing facility
1997	0	527 (parr)	8	Aquaseed
1998	182	0	4	Aquaseed
1999	NS	NS	NS	--
2000	272	0	NS	Aquaseed
2001	NS	NS	NS	--
2002	167	0	3	Aquaseed
2003	250	0	8	Aquaseed
2004	1,216	0	10	Aquaseed
2005	2,733	0	21	Aquaseed/LWSFH[1]
2006	0	1,487 (fry)	29	Aquaseed/ LWSFH[2]
2007	1,153	0	13	Aquaseed/ LWSFH[3]
2008	933	0	11	LWSFH
2009	1,433	0	15	LWSFH
Average	***927***	***1,007***	***12***	

[1] Fish were transferred on 30 June and 2 July 2008 and 20 January 2009.
[2] Fish were transferred on 21 October and 13 November 2008.
[3] Fish were transferred on 26 September and 21 October 2008.

7.2 Hatchery Spawning and Release

Captive Brood Spawning

As noted above, eyed eggs or juveniles collected in the White River were transported to Aquaseed (for brood years 1997-2007) or to the Little White Salmon Hatchery (for brood years 2008-2009) and reared to adults (Lauver et al. 2012). After rearing broodstock to maturity in captivity, adult spring Chinook were spawned and their progeny were grown to smolt size, acclimated to White River water, and ultimately released into the White River, Lake Wenatchee, or trucked and released below Lake Wenatchee.

During spawning, eggs and sperm were collected and those gametes were crossed based on a 2x2 factorial spawning matrix. That is, each female was spawned with two males and each male was spawned with two females. Using pedigree analysis, spawning crosses were arranged to maximize genetic diversity. Because incomplete maturation of ova was an issue in the program, implementation of hormone treatments began in 2011 to facilitate maturation. In addition, following spawning, milt from excess males was collected for cryopreservation. Based on a pilot study, the cryopreserved milt was relatively ineffective at fertilizing eggs, so it was not used widely in the program. There are no plans to use the cryopreserved milt in the future. It is noteworthy that most of the males used in spawning were mini-jacks. Table 7.2 shows the ages of first-generation males and females spawned for the captive brood program.

Table 7.2. Total ages of first-generation (F_1) male and female spring Chinook spawned for the White River captive brood program, spawning years 2001-2011; NA = not available.

Spawning year	Sex	Total age				Total
		2	3	4	5	
2001	Female	0	0	3	0	3
	Male	0	2	0	0	2
2002	Female	0	0	4	4	8
	Male	10	0	0	0	10
2003	Female	0	5	0	0	5
	Male	0	2	0	0	2
2004	Female	0	0	2	0	2
	Male	4	0	0	0	4
2005	Female	0	85*	0	0	85
	Male	90	1	0	0	91
2006	Female	2	104	110	0	216
	Male	104	6	0	0	110
2007	Female	0	21	118	1	140
	Male	113	7	0	0	120
2008	Female	0	58	0	0	58
	Male	NA	NA	NA	NA	NA
2009	Female	0	0	119	0	119

Spawning year	Sex	Total age				Total
		2	3	4	5	
	Male	65	54	0	0	119
2010	Female	0	0	42	0	42
	Male	22	23	0	0	45
2011	Female	0	0	0	150	150
	Male	0	148	2	0	150
Average	***Female***	***0***	***25***	***36***	***14***	***75***
	Male	***41***	***24***	***0***	***0***	***65***
Median	***Female***	***0***	***0***	***3***	***0***	***58***
	Male	***16***	***4***	***0***	***0***	***68***

* Included some unknown number of second-generation females.

Release Information

Numbers released

Several different acclimation and release scenarios were conducted since 1997. Acclimation scenarios have involved naturalized features such as in-channel enclosures, stream-side tanks supplied with pass-through surface water, and net pens in Lake Wenatchee near the mouth of the White River. Release scenarios have included on-site releases from tanks, in-channel enclosures, and net pens in Lake Wenatchee. The low survival of fish released in the lake and White River prompted exploring the release of fish near the mouth of the lake and downstream from the lake. In 2010, acclimated fish were towed in net pens to the mouth of the lake and released there. In 2011, tank and net-pen acclimated fish were loaded into transport trucks and released into the Wenatchee River. In addition, subyearling and yearling Chinook with no acclimation have been released from transport trucks directly into Lake Wenatchee and the White River. A total of 944,591 second-generation (F_2) juvenile spring Chinook have been released from the captive brood program. Table 7.3 summarizes the acclimation and release history of F_2 spring Chinook released into the upper Wenatchee River basin.

Table 7.3. Numbers of White River juvenile spring Chinook released and their acclimation histories for brood years 2002-2013.

Brood year	Acclimation site	Acclimation vessel	Number of smolts released	Release scenario	Release date	Number of acclimation days
2002	WR RM 11.5	Tanks	2,589	White River	4/22/2004	17
2003	WR RM 11.5	Tanks	2,096	White River	5/2/2005	47
2004	WR RM 11.5	Tanks	1,639	White River	4/4/2006	0
2005	Lake Wen	Net Pens	69,032	Lake Wen	5/2/2007	34
2006	NA	NA	139,644*	White River	4/17, 4/25/2007	0
	NA	NA	142,033	White River	3/18, 3/20/2008	0
2007	Lake Wen	Net Pens	87,671	Lake Wen	5/5/2009	35-40
	None	None	44,172	Lake Wen	4/1/2009	0

Brood year	Acclimation site	Acclimation vessel	Number of smolts released	Release scenario	Release date	Number of acclimation days
2008	WR Bridge	Eddy Pen	10,156	Escape	~4/12/2010	~10
	Lake Wen	Net Pens	38,400	Mouth of lake	5/5, 5/6/2010	38-41
2009	WR RM 11.5	Side Channel	12,000	Escape	~3/31/2011	~7
	WR RM 11.5	Tanks	10,000	White River	5/12/2011	49
	WR Bridge	Tanks	28,000	White River	5/14/2011	51
	WR Bridge	Tanks		Wen River	5/13/2011	50
	WR Bridge	Eddy Pen	14,596	Escape	~3/27/2011	~3
	Lake Wen	Net Pens	48,000	Wen River	5/14/2011	46
	Lake Wen	Net Pens		Wen River	5/14/2011	44
2010	WR Bridge	Tanks	18,850	Wen River	5/9/2012	44
2011	WR Bridge	Tanks	42,000	Wen & White R	5/6, 5/7, 5/8/13	49, 50, 51
	Lake Wen	Net Pens	105,000	Wen River	5/8, 5/13, 5/14/13	51, 56, 57
2012	WR Bridge	Tanks	42,000	Wen River	5/6/14	50
	Lake Wen	Net Pens	55,713	Wen River	5/8/14	49
2013	WR Bridge	Tanks	31,000	Wen River	5/4/15	56

* Subyearling release.

Numbers tagged

Brood years 2005 and 2007-2014 spring Chinook were tagged with a CWT in their peduncle. None of these fish were adipose fin clipped.[20] Subyearling fish from the 2006 brood year were tagged with half of a CWT in their snouts. Yearling fish from the 2006 brood year were tagged with CWTs in the peduncle. None of these fish were adipose fin clipped. In addition, beginning in 2008 (brood year 2006), 303,207 juvenile spring Chinook have been PIT tagged before release. Table 7.4 identifies the number of second-generation (F_2) juvenile spring Chinook tagged with PIT tags.

Table 7.4. Numbers of second-generation (F2) White River spring Chinook smolts tagged and released in the upper Wenatchee River basin, brood years 2002-2013.

Brood year	Acclimation site	Acclimation vessel	Release scenario	CWT mark rate	Number released that were PIT tagged	Number of smolts released
2002	WR RM 11.5	Tanks	White River	0.00	0	2,589
2003	WR RM 11.5	Tanks	White River	0.00	0	2,096
2004	WR RM 11.5	Tanks	White River	0.00	0	1,639
2005	Lake Wen	Net Pens	Lake Wen	1.00	0	69,032

20 Given that juvenile spring Chinook were tagged with CWTs in the peduncle and were not ad-clipped, it is possible that field crews missed hatchery-origin adults on the spawning grounds because they did not know they were supposed to sample fish with adipose fins. Thus, this bias in carcass sampling may bias derived metrics such as spawning distribution of hatchery and natural-origin fish, spawn timing of hatchery and natural-origin fish, age at maturity, size at maturity, contributions to fisheries, HOR, NOR, HRR, NRR, PNI, straying, and SARs.

Brood year	Acclimation site	Acclimation vessel	Release scenario	CWT mark rate	Number released that were PIT tagged	Number of smolts released
2006	NA	NA	White River	0.00	29,881	139,644*
	NA	NA	White River	0.00		142,033
2007	Lake Wen	Net Pens	Lake Wen	1.00	29,863	87,671
	None	None	Lake Wen	1.00	9,957	44,172
2008	WR Bridge	Eddy Pen	Escape	1.00	38,148	10,156
	Lake Wen	Net Pens	Lake Mouth	1.00		38,400
2009	WR RM 11.5	Side Channel	Escape	1.00	41,886	12,000
	WR RM 11.5	Tanks	White River	1.00		10,000
	WR Bridge	Tanks	White River	1.00		28,000
	WR Bridge	Tanks	Wen River	1.00		
	WR Bridge	Eddy Pen	Escape	1.00		14,596
	Lake Wen	Net Pens	Wen River	1.00		48,000
	Lake Wen	Net Pens	Wen River	1.00		
2010	WR Bridge	Tanks	Wen River	1.00	12,283	18,850
2011	WR Bridge	Tanks	Wen & White	1.00	2,490	42,000
	Lake Wen	Net Pens	Wen River	1.00	51,697	105,000
2012	WR Bridge	Tanks	Wen River	1.00	52,097	42,000
	Lake Wen	Net Pens	Wen River	1.00		55,713
2013	WR Bridge	Tanks	Wen River	1.00	34,905	31,000

* Subyearling release.

Fish size and condition at release

Table 7.5 summarizes the size and condition of second-generation White River juvenile spring Chinook released in the upper Wenatchee River basin.

Table 7.5. Mean lengths (FL, mm), weight (g and fish/pound), and coefficient of variation (CV) of second-generation White River (WR) juvenile spring Chinook released in the upper Wenatchee River basin, brood years 2002-2013. Size targets are provided in the last row of the table. NA = not available.

Brood year	Acclimation site	Release scenario	Fork length (mm)		Mean weight	
			Mean	CV	Grams (g)	Fish/pound
2002	WR RM 11.5	White River	NA	NA	NA	NA
2003	WR RM 11.5	White River	166	12.4	53.7	8
2004	WR RM 11.5	White River	207	11.6	117.7	4
2005	Lake Wen	Lake Wen	145	9.7	36.9	31
2006	NA	White River	NA	NA	NA	NA
	NA	White River	NA	NA	NA	NA
2007	Lake Wen	Lake Wen	135	7.8	29.2	29

Brood year	Acclimation site	Release scenario	Fork length (mm)		Mean weight	
			Mean	CV	Grams (g)	Fish/pound
	None	Lake Wen	NA	NA	NA	NA
2008	WR Bridge	Escape	--	--	--	--
	Lake Wen	Mouth of lake	138	10.0	32.5	14
2009	WR RM 11.5	Escape	--	--	--	--
	WR RM 11.5	White River	134	8.7	29.3	16
	WR Bridge	White River	138	9.3	28.6	16
	WR Bridge	Wen River	NA	NA	NA	NA
	WR Bridge	Escape	--	--	--	--
	Lake Wen	Wen River	140	8.9	31.6	14
	Lake Wen	Wen River	142	9.8	39.3	12
2010	WR Bridge	Wen River	125	8.0	22.8	20
2011	WR Bridge	Wen & White	130	8.4	24.1	19
	Lake Wen	Wen River	128	8.2	24.0	19
2012	WR Bridge	Wen River	131	8.1	24.2	18.8
	Lake Wen	Wen River	NA	NA	NA	NA
2013	WR Bridge	Wen River	132	8.7	24.5	19
Average			142	9.3	37.0	17

Post-Release Survival

We used PIT-tagged fish to estimate survival rates and travel time (arithmetic mean days) of released second-generation (F_2) White River spring Chinook smolts to McNary Dam, and smolt to adult ratios (SARs) from release to detection at Bonneville Dam.[21] Based on the available data, post-release survival has been low for fish released into the White River and Lake Wenatchee (Table 7.6). In contrast, survival of fish released in the Wenatchee River tends to be higher than those released in the White River or in Lake Wenatchee. These results suggest that high mortality in Lake Wenatchee may explain why adult returns of program fish have been consistently poor; however, other factors such as high precocious maturation may also contribute to the estimated low survival (e.g., see Ford et al. 2015).

Average travel time from release to McNary Dam ranged from 21 to 82 days (Table 7.6). Spring Chinook released in the Wenatchee River typically traveled faster to McNary Dam than those released in the White River or in Lake Wenatchee. Because of uncertain release times for several groups, we were unable to estimate travel times for all release groups.

[21] It is important to point out that because of fish size differences among rearing net pens, tanks, or raceways, fish PIT tagged in one pen, tank, or raceway may not represent untagged fish rearing in other pens, tanks, or raceways.

Table 7.6. Survival and travel times (mean days) of second-generation (F2) White River spring Chinook smolts to McNary Dam and SARs to Bonneville Dam for different release scenarios, brood years 2006-2013. Values in parentheses represent the standard error of the estimate. NA = not available (i.e., not all the fish from the release groups have returned to the Columbia River).

Brood year	Release scenario	Number of Chinook released with PIT tags	Survival to McNary Dam	Travel time to McNary Dam (d)	SAR to Bonneville Dam
2006	White River	29,881	0.037 (0.008)	82.3 (16.1)	0.000 (0.000)
2007	Lake Wen Pens	29,863	0.096 (0.010)	NA	0.000 (--)
	Lake Wenatchee	9,957	0.080 (0.015)	NA	0.000 (--)
2008	Lake Wenatchee	38,146	0.065 (0.010)	65.2 (14.0)	0.001 (0.000)
2009	White and Wenatchee rivers	19,913	0.269 (0.027)	22.9 (9.2)	0.002 (0.000)
	White River	21,829	0.055 (0.013)	45.6 (21.0)	0.000 (0.000)
2010	Wenatchee River	12,283	0.267 (0.017)	NA	0.001 (0.000)
2011	Wenatchee River	2,490	0.385 (0.042)	NA	0.004 (0.001)
	White and Wenatchee rivers	51,697	0.434 (0.010)	NA	0.003 (0.000)
2012	Wenatchee River	52,115	0.353 (0.013)	NA	NA
2013	Wenatchee River	34,905	0.767 (0.064)	20.6 (5.7)	NA

7.3 Disease Monitoring

First-Generation Health Maintenance

First-generation (F_1) adults were fed an azithromycin-medicated feed in the spring to prevent bacterial kidney disease (BKD), which is a common affliction of spring Chinook salmon. As needed, fish received a dose of 20 mg/kg of body weight. The fish also received formalin treatments as needed throughout the year to prevent and treat fungus infections. This was especially important during the pre-spawning period when individual fish were maturing in preparation for spawning. Formalin treatments were conducted three times per week and consist of one hour of flow-through at a concentration of 167 parts per million (ppm).

Second-Generation Health Maintenance

Following fertilization and initial incubation in September, second-generation (F_2) eggs were shocked in October. Eggs were treated with a 1,667 ppm formalin solution in a 15-minute flow-through treatment three times a week to prevent fungus growth. Formalin treatments ended after hatching, and water flow was increased from three to five gallons per minute. Dead and deformed fry were removed before relocating the fry to nursery tanks in late January or early February. Fry were then relocated to raceways in July, where they remained until transfer to the White River for acclimation the following March. Coded-wire tagging was typically conducted in July, and PIT tagging occurred the following January or February, just before the fish were transferred to acclimation facilities on the White River in March.

7.4 Natural Juvenile Productivity

Juvenile productivity estimation began with the monitoring of emigration of spring Chinook in the White River in 2007 (Lauver et al. 2012). A five-foot diameter rotary screw trap is operated annually from about 1 March through November. The purpose of the program is to estimate the number and timing of subyearlings and yearling spring Chinook emigrating from the White River basin.

Smolt and Emigrant Estimates

In 2016, the White River Trap operated between 1 March and 30 November 2016. During that period, the trap was not intentionally disabled under any circumstance. Daily trap efficiencies were estimated by conducting mark-recapture trials. The daily number of fish captured was expanded by the estimated trap efficiency to estimate daily total emigration. If trap efficiencies could not be assessed because of low numbers of juvenile Chinook trapped, a composite model based on efficiency trials from previous years was used to calculate abundance. Daily captures of fish and results of mark-recapture efficiency tests at the White River trap are reported in Appendix M.

Wild yearling spring Chinook (2014 brood year) were captured primarily from March through April 2016 (Figure 7.1). Based on a composite regression model, the total number of wild yearling Chinook emigrating from the White River was 386 (±701). Combining the total number of subyearling spring Chinook (1,950 ±400) that emigrated during the fall of 2015 with the total number of yearling Chinook (386) that emigrated during 2016 resulted in a total emigrant estimate of 2,336 (±847) spring Chinook for the 2014 brood year (Table 7.7).

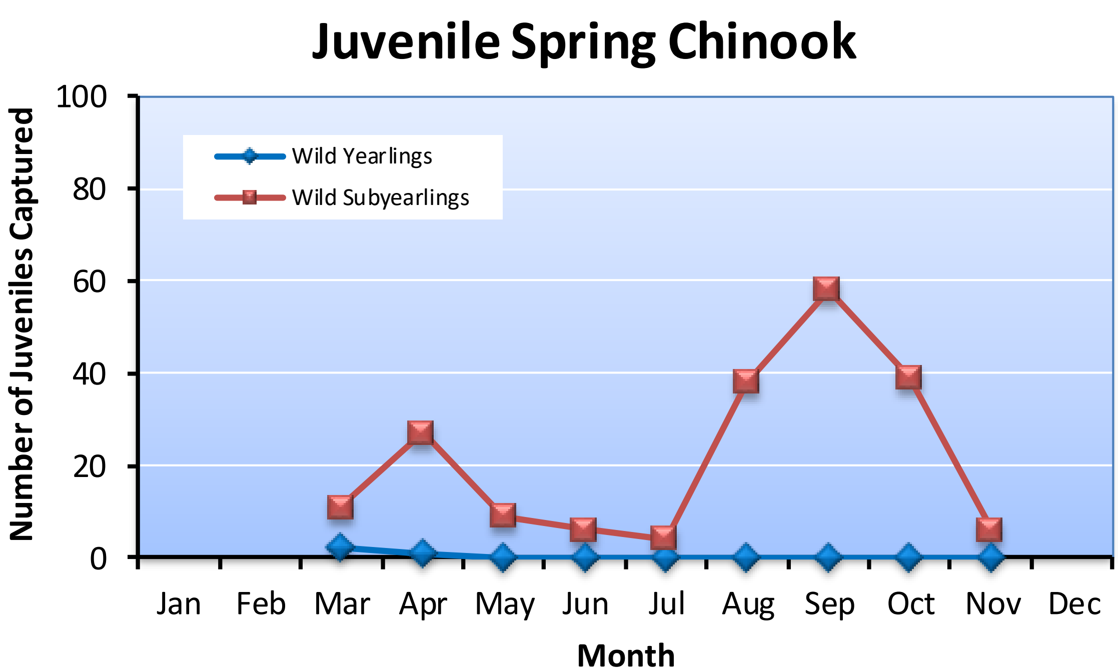


Figure 7.1. Monthly captures of wild subyearling (parr) and yearling spring Chinook at the White River Trap, 2016.

Table 7.7. Numbers of redds and juvenile spring Chinook at different life stages in the White River basin for brood years 2005-2015; ND = no data.

Brood year	Number of redds	Egg deposition[a]	Number of subyearling emigrants[b]	Number of smolts produced within White River basin	Number of emigrants
2005	86	372,122	ND	4,856	ND
2006	31	134,044	642	2,004	2,646
2007	20	88,820	2,293	3,399	5,692
2008	31	142,352	5,552	5,193	10,745
2009	54	246,942	2,485	2,939	5,424
2010	33	142,362	1,859	4,121	5,980
2011	20	87,700	3,128	1,659	4,787
2012	86	363,178	3,905	3,995	7,900
2013	54	254,664	2,461	3,023	5,484
2014	26	105,170	1,950	386	2,336
2015	70	339,290	2,430	--	--
Average[c]	***46***	***206,968***	***2,659***	***3,158***	***5,666***
Median[c]	***33***	***142,362***	***2,429***	***3,211***	***5,484***

[a] Egg deposition is calculated as the number of redds times the fecundity of both wild and hatchery spring Chinook salmon (from Table 5.5.

[b] Subyearling emigrants do not include fry that left the watershed before 1 July.

[c] Average and median are based on the entire time series of data, not just the period 2006 through 2012.

Wild subyearling spring Chinook (2015 brood year) were captured between 7 March and 30 November 2016, with peak catch during August (Figure 7.1). Based on a composite regression model, the total number of wild subyearling Chinook emigrating from the White River was 2,430 (±723).

Yearling spring Chinook sampled in 2016 averaged 106 mm in length, 12.4 g in weight, and had a mean condition of 1.05 (Table 7.8). The estimated length and weight were greater than the overall mean of yearling spring Chinook sampled in previous years (overall means, 100 mm and 11.3 g). The estimated condition for the 2014 brood was less than the overall mean (overall mean, 1.10). Subyearling spring Chinook parr sampled in 2016 at the White River Trap averaged 89 mm in length, averaged 8.3 g, and had a mean condition of 1.13 (Table 7.8). Estimated length and weight were less than the overall mean of subyearling spring Chinook sampled in previous years (overall means, 90 mm and 8.5 g), while the estimated condition was greater (overall mean, 1.10).

Table 7.8. Mean fork length (mm), weight (g), and condition factor of subyearling (parr) and yearling spring Chinook collected in the White River Trap, 2007-2016. Numbers in parentheses indicate 1 standard deviation.

Sample year	Life stage	Sample size[a]	Mean size		
			Length (mm)	Weight (g)	Condition (K)
2007	Subyearling	33	95 (12)	9.8 (4.1)	1.07 (0.11)
	Yearling	173	93 (9)	8.6 (2.2)	1.03 (0.09)

Sample year	Life stage	Sample size[a]	Mean size		
			Length (mm)	Weight (g)	Condition (K)
2008	Subyearling	202	95 (9)	9.4 (2.5)	1.08 (0.13)
	Yearling	105	100 (12)	11.3 (3.3)	1.07 (0.13)
2009	Subyearling	499	85 (11)	7.1 (2.6)	1.09 (0.11)
	Yearling	274	104 (6)	12.5 (2.6)	1.11 (0.10)
2010	Subyearling	168	87 (13)	7.8 (3.1)	1.12 (0.11)
	Yearling	346	100 (7)	11.2 (2.4)	1.12 (0.09)
2011	Subyearling	145	94 (9)	9.3 (2.5)	1.10 (0.10)
	Yearling	64	99 (8)	11.3 (2.8)	1.14 (0.09)
2012	Subyearling	285	91 (10)	8.9 (2.7)	1.13 (0.09)
	Yearling	179	98 (8)	10.9 (2.8)	1.14 (0.08)
2013	Subyearling	444	84 (12)	6.6 (2.5)	1.05 (0.09)
	Yearling	20	102 (7)	12.3 (3.0)	1.12 (0.14)
2014	Subyearling	185	86 (14)	7.5 (3.3)	1.10 (0.11)
	Yearling	43	94 (7)	9.4 (2.2)	1.11 (0.13)
2015	Subyearling	148	96 (8)	9.9 (2.3)	1.11 (0.07)
	Yearling	31	104 (7)	13.0 (2.8)	1.14 (0.07)
2016	Subyearling	147	89 (11)	8.3 (2.8)	1.13 (0.10)
	Yearling	3	106 (2)	12.4 (0.3)	1.05 (0.03)
Average	***Subyearling***	***226***	***90 (5)***	***8.5 (1.1)***	***1.10 (0.03)***
	Yearling	***124***	***100 (4)***	***11.3 (1.4)***	***1.10 (0.04)***
Median	***Subyearling***	***177***	***90 (5)***	***8.6 (1.2)***	***1.10 (0.03)***
	Yearling	***85***	***100 (4)***	***11.3 (1.4)***	***1.12 (0.04)***

[a] Sample size represents the number of fish that were measured for both length and weight.

Freshwater Productivity

Both productivity and survival estimates for different life stages of spring Chinook in the White River basin are provided in Table 7.9. Estimates for brood year 2014 generally fall below the range of productivity and survival estimates for brood years 2005-2013. During that period, freshwater productivities ranged from 15-170 smolts/redd and 85-347 emigrants/redd. Survivals during the same period ranged from 0.4-3.8% for egg-smolt and 2.0-7.5% for egg-emigrants.

Table 7.9. Productivity (fish/redd) and survival (%) estimates for different juvenile life stages of spring Chinook in the White River basin for brood years 2005-2014. These estimates were derived from data in Table 7.7. ND = no data.

Brood year	Smolts/Redd[a]	Emigrants/ Redd	Egg-Smolt[a] (%)	Egg-Emigrant (%)
2005	56	ND	1.3	ND
2006	65	85	1.5	2.0
2007	170	285	3.8	6.4
2008	168	347	3.6	7.5
2009	54	100	1.2	2.2

Brood year	Smolts/Redd[a]	Emigrants/ Redd	Egg-Smolt[a] (%)	Egg-Emigrant (%)
2010	125	181	2.9	4.2
2011	83	239	1.9	5.5
2012	46	92	1.1	2.2
2013	56	102	1.2	2.2
2014	15	90	0.4	2.2
Average	***84***	***169***	***1.9***	***3.8***
Median	***61***	***102***	***1.4***	***2.2***

[a] These estimates include White River smolts produced only within the White River basin.

Seeding level (egg deposition) explained part of the variability in productivity and survival of juvenile spring Chinook in the White River basin. That is, for estimates based on smolts produced within the White River basin, survival and productivity decreased as seeding levels increased (Figure 7.2). This suggests that density dependence in part regulates juvenile productivity and survival within the White River basin.

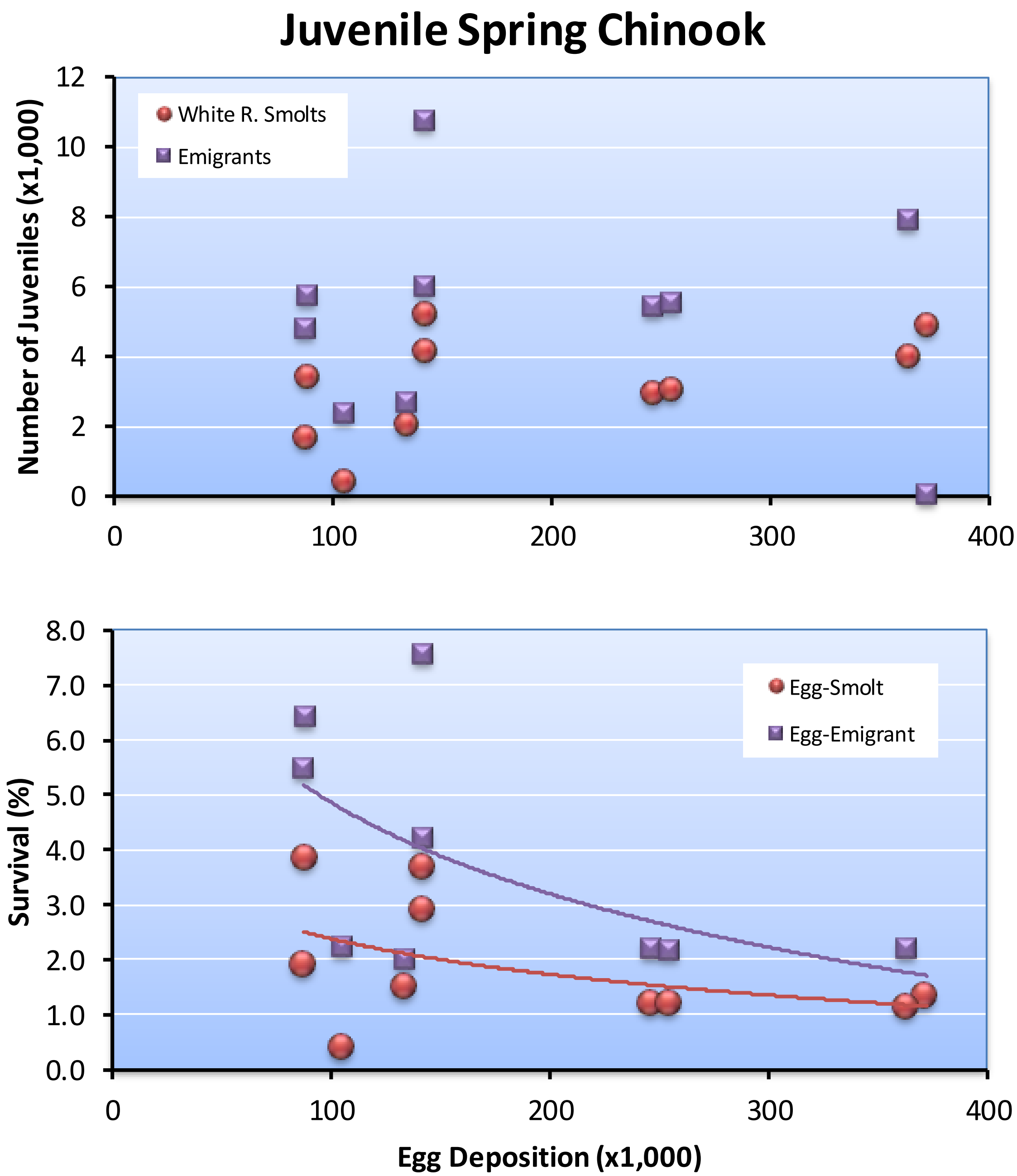


Figure 7.2. Relationships between seeding levels (egg deposition) and juvenile life-stage survivals and productivities for White River spring Chinook, brood years 2005-2014. White River smolts are smolts produced only within the White River basin.

Population Carrying Capacity

Population carrying capacity (*K*) is defined as the maximum equilibrium population size estimated with population models (e.g., logistic equation, Beverton-Holt model, hockey stick model, and the

Ricker model).[22] Maximum equilibrium population size is generated from density dependent mechanisms that reduce population growth rates as population size increases (negative density dependence). This is referred to as compensation. Population size fluctuates about the maximum equilibrium size because of variability in vital rates that are unrelated to density (density independent factors) and measurement error. In this section, we estimate smolt carrying capacities using the Ricker stock-recruitment model (see Appendix C in Hillman et al. 2012 for a detailed description of methods). The Ricker model was the only stock-recruitment model that could be fit to the juvenile spring Chinook data.

Based on the Ricker model, the population carrying capacity for spring Chinook smolts in the White River basin is 4,659 smolts (95% CI: 0 – 7,075) (Figure 7.3). Here, smolts are defined as the number of yearling spring Chinook produced entirely within the White River basin. These estimates reflect current conditions (most recent decades) within the White River basin. Land use activities such as logging, roads, development, and recreation have altered the historical conditions of the watershed. Thus, the estimated population capacity estimates may not reflect historical capacities for spring Chinook smolts in the White River basin.

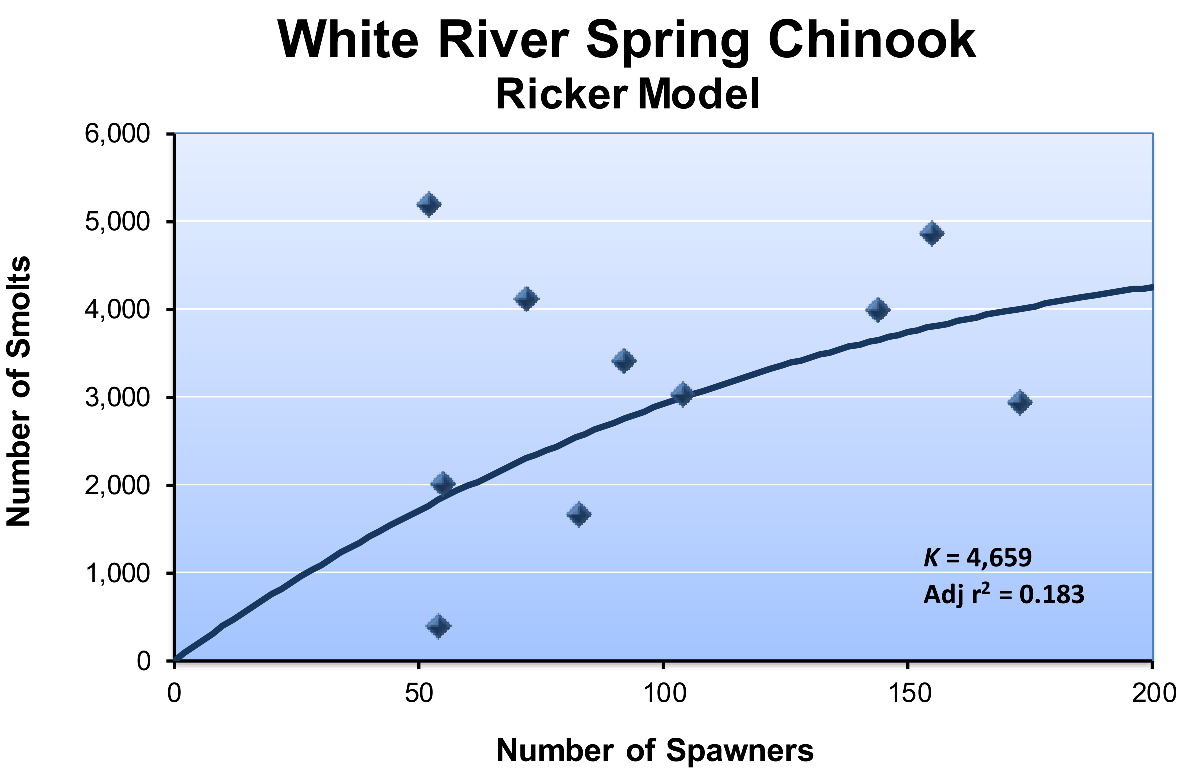


Figure 7.3. Relationship between spawners and number of smolts produced in the White River basin. Population carrying capacity (*K*) was estimated using the Ricker model.

[22] Population carrying capacity (*K*) should not be confused with habitat carrying capacity (*C*), which is defined as the maximum population of a given species that a particular environment can sustain.

We tracked the precision of the Ricker parameters for White River spring Chinook smolts over time to see if precision improves with additional years of data, and the parameters and statistics stabilize over time. Examination of variation in the alpha (*A*) and beta (*B*) parameters of the Ricker model and their associated standard errors and confidence intervals indicates that the parameters have not stabilized and lack precision (Table 7.10; Figure 7.4). This was also apparent in the estimates of population carrying capacity (Figure 7.5).

Table 7.10. Estimated parameters and statistics associated with fitting the Ricker model to spawning escapement and smolt data. Smolts represent numbers of smolts produced entirely within the White River basin. *A* = alpha parameter; *B* = beta parameter; SE = standard error (estimated from 5,000 bootstrap samples); and r^2 = coefficient of determination. Spawners represent the stock size needed to achieve population capacity.

Years of data	Parameter				Population capacity	Intrinsic productivity	Spawners	r^2
	A	SE	*B*	SE				
5	95.89	44.84	0.0090	0.0040	3,928	96	111	0.001
6	100.65	37.65	0.0092	0.0034	4,007	101	108	0.019
7	81.75	36.97	0.0084	0.0042	3,602	82	120	0.001
8	80.32	32.78	0.0080	0.0036	3,675	80	124	0.009
9	78.79	42.85	0.0080	0.0037	3,605	79	124	0.014
10	40.02	33.48	0.0032	0.0040	4,659	40	316	0.183

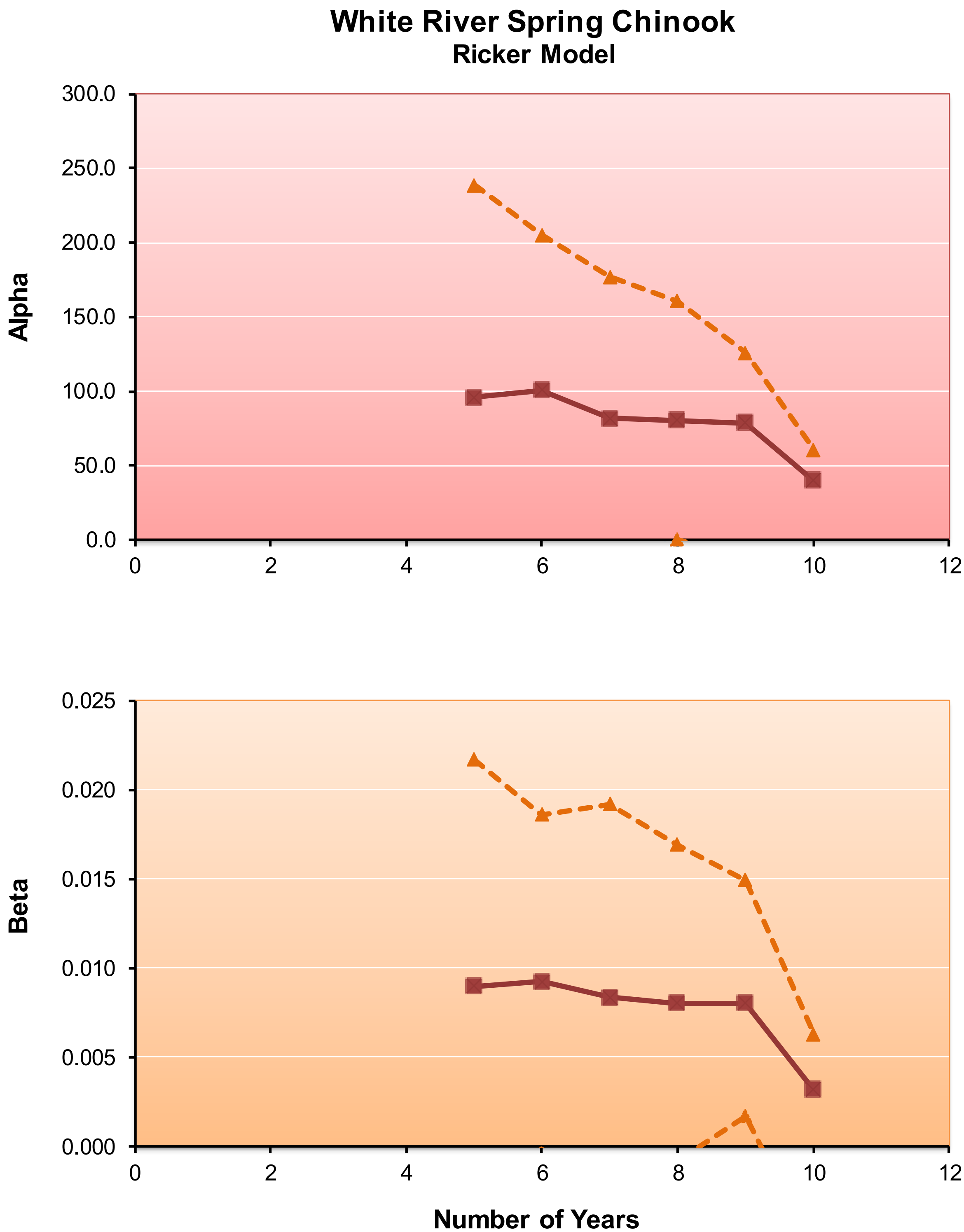


Figure 7.4. Time series of alpha and beta parameters and 95% confidence intervals for the Ricker model that was fit to White River spring Chinook smolt and spawning escapement data. Confidence intervals were estimated from 5,000 bootstrap samples.

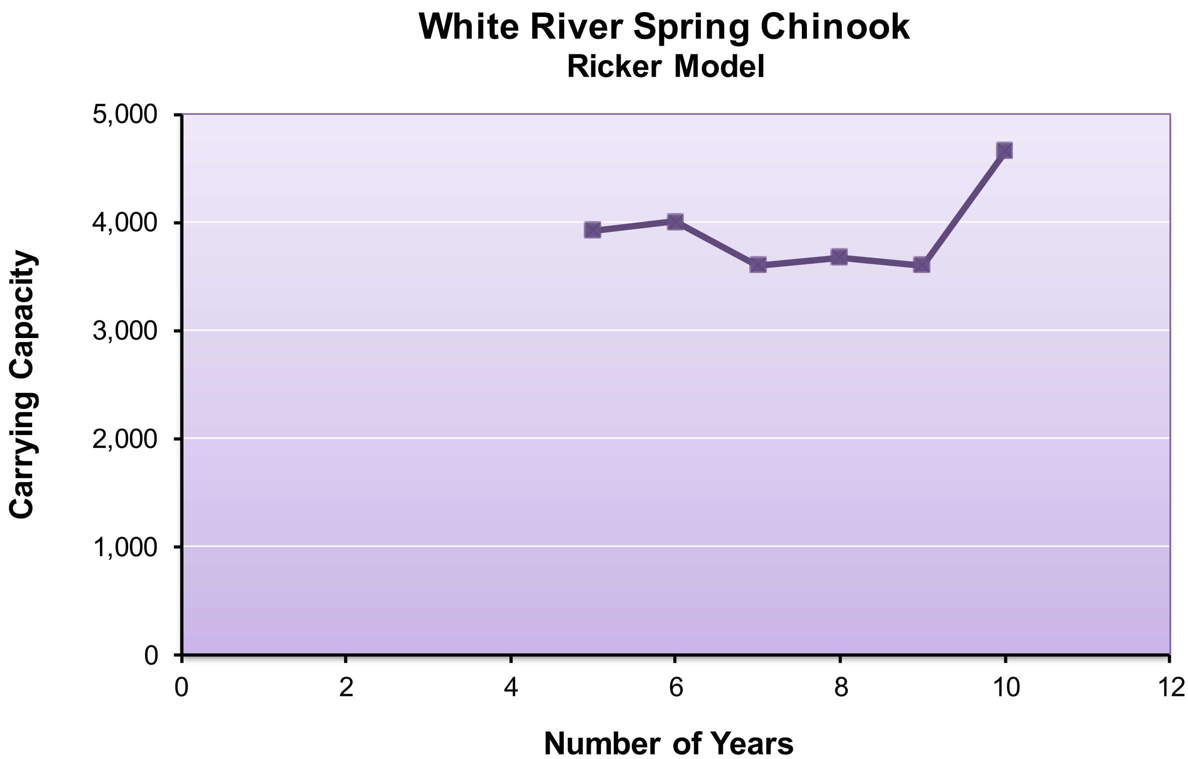


Figure 7.5. Time series of population carrying capacity estimates derived from fitting the Ricker model to White River spring Chinook smolt and spawning escapement data.

7.5 Spawning Surveys

Surveys for spring Chinook redds were conducted during August through September 2016 in the Chiwawa River (including Rock, Phelps, and Chikamin creeks), Nason Creek, Icicle Creek, Peshastin Creek (including Ingalls Creek), Upper Wenatchee River (including Chiwaukum Creek), Little Wenatchee River, and White River (including the Napeequa River and Panther Creek). See Section 5.5 for a complete coverage of spring Chinook redd surveys in the Wenatchee River basin. In the following section, we describe the number and distribution of redds within the White River basin.

Redd Counts and Distribution

A total of 44 spring Chinook redds were counted in the White River basin in 2016 (Table 7.11; see Table 5.20 for the complete time series of redd counts). This is higher than the average of 35 redds counted during the period 1989-2015 in the White River. Redds were not distributed evenly among the six survey areas in the White River basin. Most redds (81%) were located in Reach 3 (Napeequa River to Grasshopper Meadows) in the White River (Table 7.11).

Table 7.11. Numbers (both observed and estimated) and proportions of spring Chinook redds counted within different survey areas within the White River basin during August through September 2016. See Table 2.8 for description of survey reaches.

Stream/watershed	Reach	Number of observed redds	Estimated number of redds*	Proportion of estimated redds within stream/watershed
White River	White 1 (H1)	0	--	--
	White 2 (H2)	4	6	0.11
	White 3 (H3)	37	43	0.81
	White 4 (H4)	2	3	0.06
	Napeequa 1 (Q1)	1	1	0.02
	Panther 1 (T1)	0	0	0.00
Total		***44***	***53***	***1.00***

* Estimated redds represent the "true" number of redds based on Guassian area-under-the-curve method (see Appendix J).

Spawn Timing

Spring Chinook began spawning during the third week of August in the White River and peaked the second week of September (Figure 7.6). Spawning in the White River ended the third week of September.

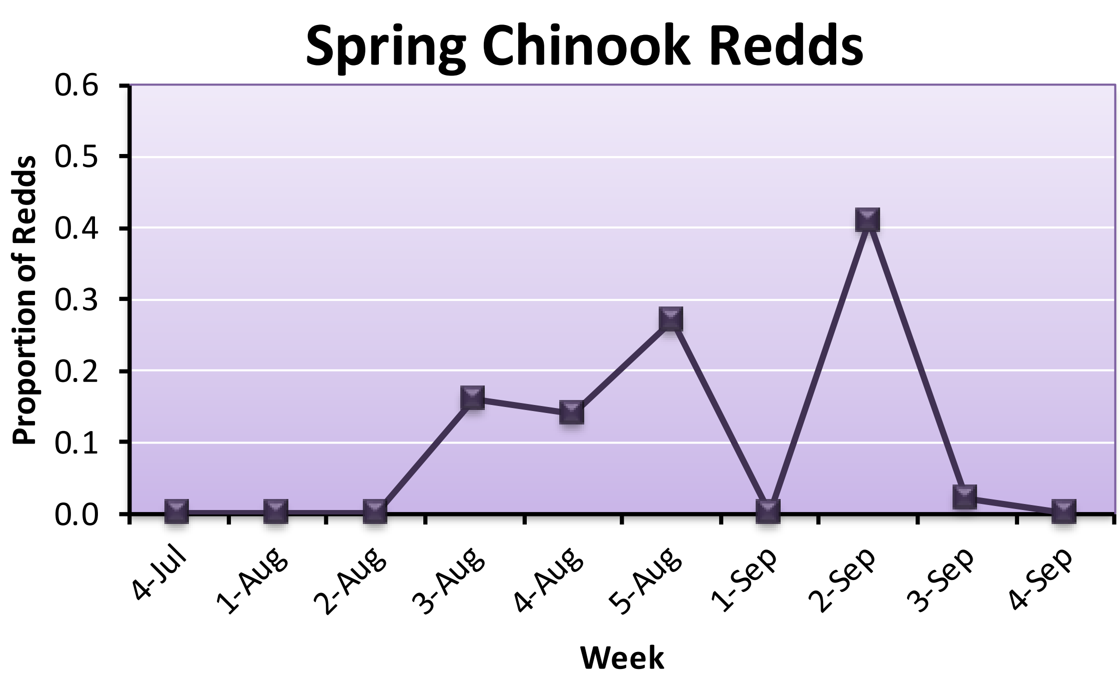


Figure 7.6. Proportion of spring Chinook redds counted during different weeks within the White River basin, August through September 2016.

Spawning Escapement

Spawning escapement for spring Chinook was calculated as the number of redds times the male-to-female ratio (i.e., fish per redd expansion factor) estimated from broodstock and fish sampled at adult trapping sites.[23] The estimated fish per redd ratio for spring Chinook upstream from Tumwater in 2016 was 1.83 (based on sex ratios estimated at Tumwater Dam). Multiplying this ratio by the number of redds counted in the White River basin resulted in a total spawning escapement of 81 spring Chinook. The estimated total spawning escapement of spring Chinook in 2016 was greater than the overall average of 76 spring Chinook in the White River basin (see Table 5.23).

7.6 Carcass Surveys

Surveys for spring Chinook carcasses were conducted during August through September 2016 in the Chiwawa River (including Rock, Phelps, and Chikamin creeks), Nason Creek, Icicle Creek, Peshastin Creek (including Ingalls Creek), Upper Wenatchee River (including Chiwaukum Creek), Little Wenatchee River, and the White River (including the Napeequa River and Panther Creek). In 2016, 13 spring Chinook carcasses were sampled in the White River basin. Most of these were sampled in Reach 3. The total number of carcasses sampled in 2016 was less than the overall average of 20 carcasses sampled during the period 1996-2015. See Section 5.6 for a complete coverage of spring Chinook carcass surveys in the Wenatchee River basin.

In the White River basin, the spatial distribution of hatchery strays (primarily from the Chiwawa Spring Chinook program) and wild spring Chinook was not equal (Table 7.12). Only one carcass was recovered in Reach 2, which was of hatchery origin, while Reach 3 had primarily wild fish (91%). In 2016, most carcasses (85%) were observed in the reach between the Napeequa River and Grasshopper Meadows (Reach 3) (Table 7.12). Over the years, spring Chinook have spawned more often in this reach than in other reaches (Figure 7.7).

Table 7.12. Numbers of wild, hatchery strays, and captive brood spring Chinook carcasses sampled within different reaches in the White River basin, 2000-2016. Numbers represent recovered carcasses that had definitive origins. See Table 2.8 for description of survey reaches.

Survey year	Origin	Survey Reach					Total
		H-2	H-3	H-4	Napeequa	Panther	
2000	Wild	1	0	0	0	0	**1**
	Hatchery Strays	0	0	0	0	0	**0**
2001	Wild	5	40	5	3	1	**54**
	Hatchery Strays	1	19	3	1	2	**26**
2002	Wild	3	15	0	0	0	**18**
	Hatchery Strays	0	6	0	0	1	**7**
2003	Wild	0	6	0	0	0	**6**
	Hatchery Strays	0	1	1	0	0	**2**
2004	Wild	1	9	1	0	0	**11**
	Hatchery Strays	0	1	0	0	1	**2**
2005	Wild	1	10	0	1	0	**12**
	Hatchery Strays	3	37	0	0	0	**40**
	Captive Brood	0	0	0	0	0	**0**
2006	Wild	2	16	0	1	0	**19**
	Hatchery Strays	0	6	0	0	0	**6**

[23] Expansion factor = (1 + (number of males/number of females)).

Survey year	Origin	Survey Reach					Total
		H-2	H-3	H-4	Napeequa	Panther	
	Captive Brood	0	0	0	0	0	**0**
2007	Wild	1	6	0	0	2	**9**
	Hatchery Strays	0	4	0	0	0	**4**
	Captive Brood	0	0	0	0	0	**0**
2008	Wild	1	3	0	0	1	**5**
	Hatchery Strays	2	5	0	0	1	**8**
	Captive Brood	0	0	0	0	0	**0**
2009	Wild	0	9	0	0	0	**9**
	Hatchery Strays	0	8	0	0	3	**11**
	Captive Brood	0	0	0	0	0	**0**
2010	Wild	0	4	0	0	0	**4**
	Hatchery Strays	0	7	0	0	0	**7**
	Captive Brood	0	0	0	0	0	**0**
2011	Wild	0	4	0	0	0	**4**
	Hatchery Strays	0	0	0	0	0	**0**
	Captive Brood	0	0	0	0	0	**0**
2012	Wild	0	13	0	0	0	**13**
	Hatchery Strays	0	8	0	0	0	**8**
	Captive Brood	0	0	0	0	0	**0**
2013	Wild	0	8	0	0	0	**8**
	Hatchery Strays	0	10	0	0	3	**13**
	Captive Brood	0	2	0	0	0	**2**
2014	Wild	0	6	0	0	0	**6**
	Hatchery Strays	0	2	0	0	0	**2**
	Captive Brood	0	0	0	0	0	**0**
2015	Wild	0	14	0	0	0	**14**
	Hatchery Strays	4	6	0	0	0	**10**
	Captive Brood	0	1	0	0	0	**1**
2016	Wild	0	10	1	0	0	**11**
	Hatchery Strays	1	1	0	0	0	**2**
	Captive Brood	0	0	0	0	0	**0**
Average	***Wild***	***1***	***10***	***0***	***0***	***0***	***204***
	Hatchery Stray	***1***	***7***	***0***	***0***	***1***	***148***
	Captive Brood	***0***	***0***	***0***	***0***	***0***	***3***
Median	***Wild***	***0***	***9***	***0***	***0***	***0***	***204***
	Hatchery Stray	***0***	***6***	***0***	***0***	***0***	***148***
	Captive Brood	***0***	***0***	***0***	***0***	***0***	***3***

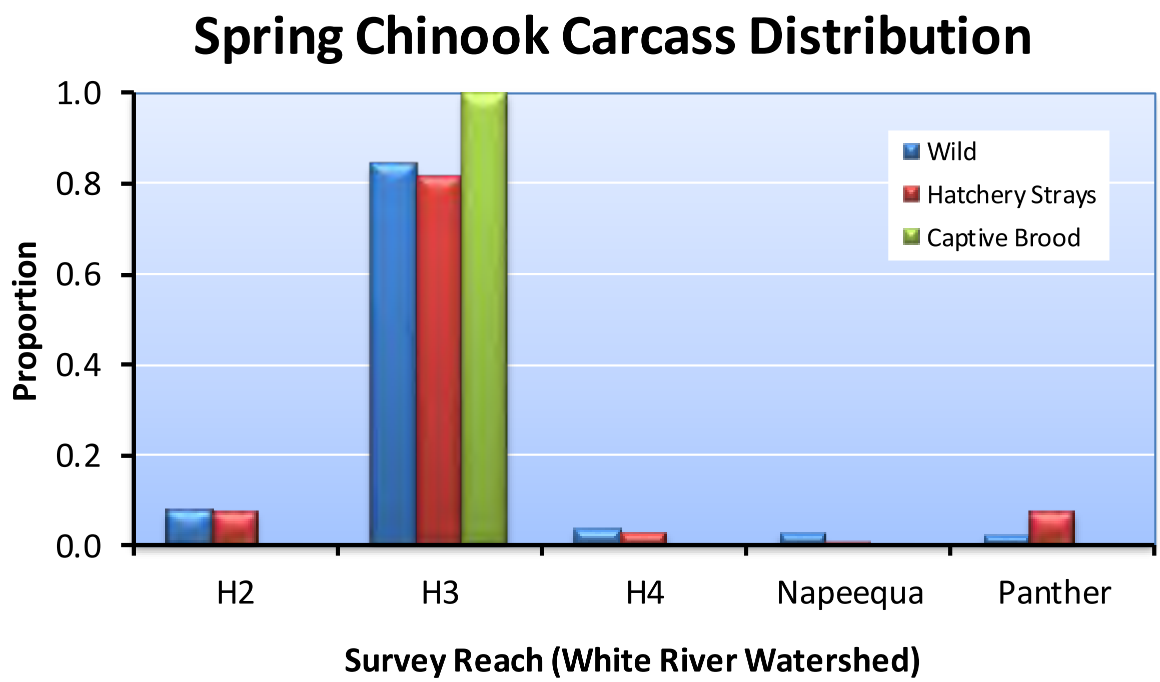


Figure 7.7. Distribution of wild, hatchery strays, and captive brood produced carcasses in different reaches in the White River basin, 2000-2016. Reach codes are described in Table 2.8.

7.7 Life History Monitoring

Life history characteristics of spring Chinook were assessed by examining carcasses on spawning grounds and fish collected at broodstock collection sites, and by reviewing tagging data and fisheries statistics.

Migration Timing

See Section 5.7 for a description of migration timing of spring Chinook at Tumwater Dam.

Age at Maturity

Most of the wild and hatchery stray spring Chinook sampled during the period 2001-2016 in the White River basin were age-4 fish (total age) (Table 7.13; Figure 7.8). A higher proportion of age-5 wild fish returned than did age-5 hatchery strays. Thus, wild fish tended to return at an older age than hatchery strays. Currently, few captive brood carcasses have been identified on the spawning grounds; most were age-4 and one was age-5. There has been a conspicuous absence of age-3 fish recovered as carcasses. In all years except 2007, no age-3 carcasses have been recovered.

Table 7.13. Numbers of wild, hatchery strays, and captive brood spring Chinook of different ages (total age) sampled on spawning grounds in the White River basin, 2001-2016.

Sample year	Origin	Total age					Sample size
		2	3	4	5	6	
2001	Wild	0	0	47	0	0	**47**
	Hatchery Strays	0	0	27	0	0	**27**

Sample year	Origin	Total age					Sample size
		2	3	4	5	6	
2002	Wild	0	0	7	11	0	**18**
	Hatchery Strays	0	0	6	1	0	**7**
2003	Wild	0	0	0	6	0	**6**
	Hatchery Strays	0	0	0	1	0	**1**
2004	Wild	0	0	9	0	0	**9**
	Hatchery Stray	0	0	2	0	0	**2**
2005	Wild	0	0	12	0	0	**12**
	Hatchery Strays	0	0	40	0	0	**40**
	Captive Brood	0	0	0	0	0	**0**
2006	Wild	0	0	7	12	0	**19**
	Hatchery Strays	0	0	3	3	0	**6**
	Captive Brood	0	0	0	0	0	**0**
2007	Wild	0	0	1	8	0	**9**
	Hatchery Strays	0	2	2	0	0	**4**
	Captive Brood	0	0	0	0	0	**0**
2008	Wild	0	0	4	1	0	**5**
	Hatchery Strays	0	0	8	0	0	**8**
	Captive Brood	0	0	0	0	0	**0**
2009	Wild	0	0	8	1	0	**9**
	Hatchery Strays	1	0	10	0	0	**11**
	Captive Brood	0	0	0	0	0	**0**
2010	Wild	0	0	4	0	0	**4**
	Hatchery Strays	0	0	6	0	0	**6**
	Captive Brood	0	0	0	0	0	**0**
2011	Wild	0	0	0	4	0	**4**
	Hatchery Strays	0	0	0	0	0	**0**
	Captive Brood	0	0	0	0	0	**0**
2012	Wild	0	0	13	0	0	**13**
	Hatchery Strays	0	0	8	0	0	**8**
	Captive Brood	0	0	0	0	0	**0**
2013	Wild	0	0	6	2	0	**8**
	Hatchery Strays	0	0	11	1	0	**12**
	Captive Brood	0	0	1	1	0	**2**
2014	Wild	0	0	54	10	0	**64**
	Hatchery Strays	0	0	21	0	0	**21**
	Captive Brood	0	0	0	0	0	**0**
2015	Wild	0	0	13	1	0	**14**
	Hatchery Strays	0	0	10	0	0	**10**

Sample year	Origin	Total age					Sample size
		2	3	4	5	6	
	Captive Brood	0	0	1	0	0	**1**
2016	Wild	0	0	5	6	0	**11**
	Hatchery Strays	0	0	2	0	0	**2**
	Captive Brood	0	0	0	0	0	**0**
Average	***Wild***	***0***	***0***	***12***	***4***	***0***	***252***
	Hatchery Strays	***0***	***0***	***10***	***0***	***0***	***165***
	Captive Brood	***0***	***0***	***0***	***0***	***0***	***3***
Median	***Wild***	***0***	***0***	***7***	***2***	***0***	***252***
	Hatchery Strays	***0***	***0***	***7***	***0***	***0***	***165***
	Captive Brood	***0***	***0***	***0***	***0***	***0***	***3***

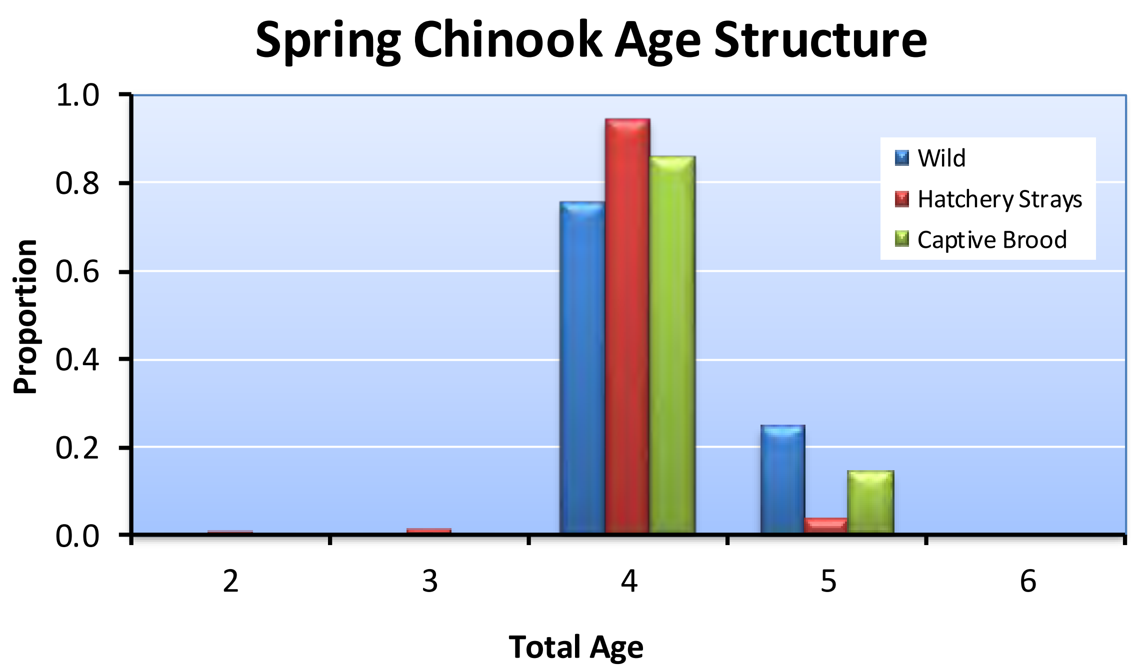


Figure 7.8. Proportions of wild, hatchery strays, and captive brood spring Chinook of different total ages sampled on spawning grounds in the White River basin for the combined years 2000-2016.

For comparison, Table 7.14 and Figure 7.9 show the age structure of spring Chinook carcasses sampled in the Little Wenatchee River. Similar to the White River, most of the wild and hatchery stray spring Chinook sampled during the period 2001-2016 in the Little Wenatchee River basin were age-4 fish (total age). A higher proportion of age-5 wild fish returned than did age-5 hatchery strays. Thus, wild fish tended to return at an older age than hatchery strays. As in the White River, few age-3 fish have been recovered in the Little Wenatchee River.

Table 7.14. Numbers of wild and hatchery stray spring Chinook of different ages (total age) sampled on spawning grounds in the Little Wenatchee River basin, 2001-2016.

Sample year	Origin	Total age					Sample size
		2	3	4	5	6	
2001	Wild	0	0	31	2	0	**33**
	Hatchery Strays	0	0	33	1	0	**34**
2002	Wild	0	0	6	8	0	**14**
	Hatchery Strays	0	0	12	2	0	**14**
2003	Wild	0	0	1	3	0	**4**
	Hatchery Strays	0	0	0	4	0	**4**
2004	Wild	0	0	1	0	0	**1**
	Hatchery Stray	0	0	0	0	0	**0**
2005	Wild	0	0	16	0	0	**16**
	Hatchery Strays	0	0	32	0	0	**32**
2006	Wild	0	0	4	4	0	**8**
	Hatchery Stray	0	1	0	3	0	**4**
2007	Wild	0	0	2	10	0	**12**
	Hatchery Strays	0	1	2	0	0	**3**
2008	Wild	0	0	3	0	0	**3**
	Hatchery Stray	0	0	12	0	0	**12**
2009	Wild	0	0	6	0	0	**6**
	Hatchery Strays	0	1	12	0	0	**13**
2010	Wild	0	0	2	0	0	**2**
	Hatchery Stray	0	0	5	0	0	**5**
2011	Wild	0	0	3	1	0	**4**
	Hatchery Strays	0	2	1	0	0	**3**
2012	Wild	0	0	12	2	0	**14**
	Hatchery Stray	0	0	9	1	0	**10**
2013	Wild	0	0	9	7	0	**16**
	Hatchery Strays	0	0	4	0	0	**4**
2014	Wild	0	1	8	2	0	**11**
	Hatchery Stray	0	0	1	0	0	**1**
2015	Wild	0	0	8	3	0	**11**
	Hatchery Strays	0	0	1	0	0	**1**
2016	Wild	0	0	1	3	0	**4**
	Hatchery Strays	0	0	1	0	0	**1**
Average	***Wild***	***0***	***0***	***7***	***3***	***0***	***10***
	Hatchery Strays	***0***	***0***	***8***	***1***	***0***	***9***
Median	***Wild***	***0***	***0***	***5***	***2***	***0***	***10***
	Hatchery Strays	***0***	***0***	***4***	***0***	***0***	***4***

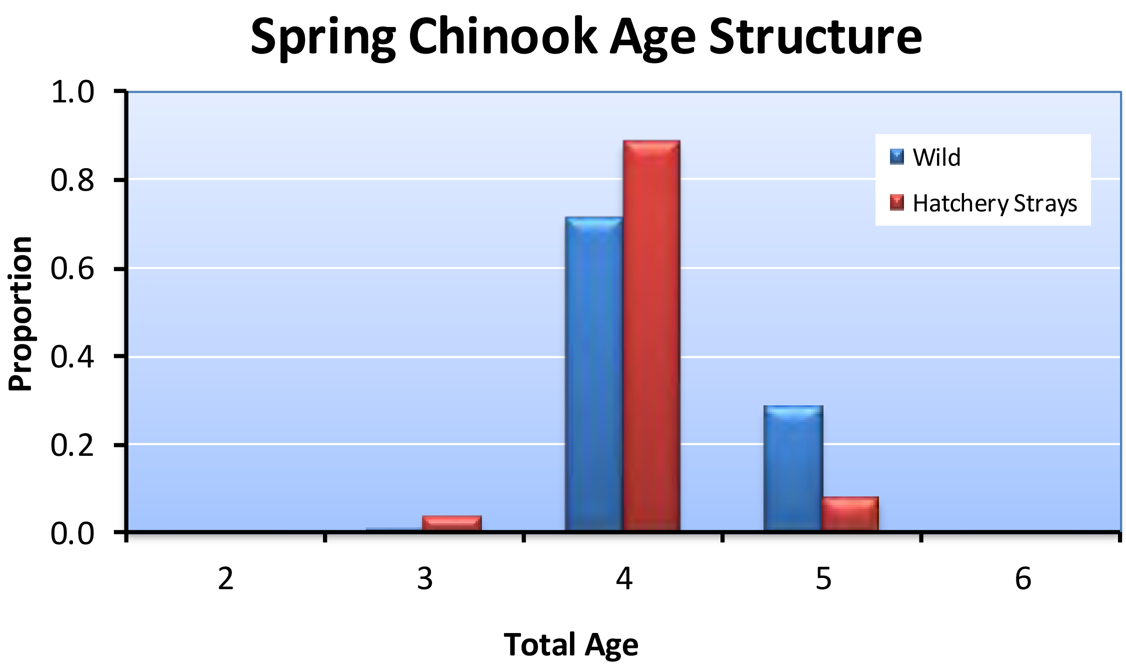


Figure 7.9. Proportions of wild and hatchery stray spring Chinook of different total ages sampled on spawning grounds in the Little Wenatchee River basin for the combined years 2000-2016.

Size at Maturity

On average, hatchery strays and wild spring Chinook of a given age differed little in length (Table 7.15). Differences were small (1-2 cm) and no more than 9 cm between hatchery strays and wild fish of the same age. Few captive brood carcasses have been identified on the spawning grounds; most were females. Those fish were about the same size as wild and hatchery strays of the same age.

Table 7.15. Mean lengths (POH in cm; ±1SD) and sample sizes (in parentheses) of different ages (total age) of male and female spring Chinook of wild, hatchery strays, and captive brood origin sampled in the White River basin, 2001-2016.

Return year	Total age	Mean length (cm)					
		Male			Female		
		Wild	Hatchery stray	Captive brood	Wild	Hatchery stray	Captive brood
2001	3	0	0	0	0	0	0
	4	65 ±3 (17)	66 ±4 (5)	0	63 ±3 (30)	63 ±4 (21)	0
	5	0	0	0	0	0	0
	6	0	0	0	0	0	0
2002	3	0	0	0	0	0	0
	4	66 ±0 (1)	69 ±0 (1)	0	63 ±4 (6)	59 ±6 (5)	0
	5	75 ±11 (2)	0	0	72 ±3 (9)	72 ±0 (1)	0
	6	0	0	0	0	0	0

Return year	Total age	Mean length (cm)					
		Male			Female		
		Wild	Hatchery stray	Captive brood	Wild	Hatchery stray	Captive brood
2003	3	0	0	0	0	0	0
	4	0	0	0	0	0	0
	5	0	0	0	75 ±5 (6)	73 ±0 (1)	0
	6	0	0	0	0	0	0
2004	3	0	0	0	0	0	0
	4	68 ±3 (3)	0	0	63 ±3 (6)	59 ±2 (2)	0
	5	0	0	0	0	0	0
	6	0	0	0	0	0	0
2005	3	0	0	0	0	0	0
	4	64 ±5 (3)	62 ±7 (5)	0	63 ±5 (8)	62 ±4 (33)	0
	5	0	0	0	0	0	0
	6	0	0	0	0	0	0
2006	3	0	0	0	0	0	0
	4	65 ±2 (3)	0	0	61 ±4 (4)	60 ±2 (3)	0
	5	69 ±4 (4)	0	0	67 ±5 (8)	70 ±5 (3)	0
	6	0	0	0	0	0	0
2007	3	0	49 ±5 (2)	0	0	0	0
	4	0	0	0	58 ±0 (1)	66 ±2 (2)	0
	5	75 ±5 (3)	0	0	75 ±1 (5)	0	0
	6	0	0	0	0	0	0
2008	3	0	0	0	0	0	0
	4	56 ±0 (1)	61 ±0 (1)	0	63 ±8 (2)	61 ±2 (7)	0
	5	0	0	0	75 ±0 (1)	0	0
	6	0	0	0	0	0	0
2009	3	0	0	0	0	0	0
	4	61 ±5 (3)	68 ±4 (2)	0	63 ±2 (5)	62 ±2 (8)	0
	5	0	0	0	78 ±0 (1)	0	0
	6	0	0	0	0	0	0
2010	3	0	0	0	0	0	0
	4	0	67 ±0 (1)	0	60 ±3 (3)	61 ±6 (5)	0
	5	0	0	0	0	0	0
	6	0	0	0	0	0	0
2011	3	0	0	0	0	0	0
	4	0	0	0	0	0	0
	5	0	0	0	73 ±5 (4)	0	0
	6	0	0	0	0	0	0
2012	3	0	0	0	0	0	0
	4	47 ±0 (1)	0	0	62 ±4 (12)	60 ±4 (8)	0
	5	0	0	0	0	0	0
	6	0	0	0	0	0	0

Return year	Total age	Mean length (cm)					
		Male			Female		
		Wild	Hatchery stray	Captive brood	Wild	Hatchery stray	Captive brood
2013	3	0	0	0	0	0	0
	4	64 ±4 (3)	60 ±4 (2)	0	61 ±2 (3)	61 ±4 (7)	63 ±0 (1)
	5	0	0	0	67 ±1 (2)	71 ±0 (1)	71 ±0 (1)
	6	0	0	0	0	0	0
2014	3	0	0	0	0	0	0
	4	0	54 ±0 (1)	0	60 ±2 (4)	58 ±0 (1)	0
	5	0	0	0	74 ±0 (1)	0	0
	6	0	0	0	0	0	0
2015	3	0	0	0	0	0	0
	4	60 ±6 (5)	74 ±0 (1)	61 ±(1)	64 ±5 (8)	63 ±4 (9)	65 ±4 (4)
	5	0	0	0	78 ±0 (1)	0	0
	6	0	0	0	0	0	0
2016	3	0	0	0	0	0	0
	4	65 ±0 (1)	0	0	63 ±4 (4)	59 ±4 (2)	0
	5	7 1 ±4 (2)	0	0	71 ±5 (4)	0	0
	6	0	0	0	0	0	0

Contribution to Fisheries

No White River spring Chinook from the captive brood program tagged with CWTs or PIT tags have been recaptured (or reported) in ocean or Columbia River (tribal, commercial, or recreational) fisheries.

Straying

Stray rates of White River spring Chinook from the captive brood program were determined by examining the locations where PIT-tagged Chinook demonstrating anadromy (based on detections at Bonneville Dam) were last detected. PIT tagging of White River spring Chinook began with release year 2008, which allows estimation of stray rates by brood return. Targets for strays based on return year (recovery year) within the Wenatchee River basin should be less than 10% and targets for strays outside the Wenatchee River basin should be less than 5%. The target for brood year stray rates should be less than 5%.

Based on PIT-tag analyses, on average, about 61% of the White River spring Chinook returns were last detected in streams outside the White River (Table 7.16). The numbers in Table 7.16 should be considered rough estimates because they are not based on confirmed spawning (only last detections) and they represent small sample sizes. In addition, last detections in adult fishways (i.e., Bonneville, Rock Island, and Tumwater dams) were not included, nor were detections in areas outside the distribution of known spring Chinook spawning (i.e., Lower and Middle Wenatchee River). All fish reported in Table 7.16 are at least age-3 fish (total age) and some of them may not have migrated all the way to the ocean but rather resided completely in freshwater downstream from Bonneville Dam.

Table 7.16. Number and percent of White River spring Chinook from the captive brood program that homed to target spawning areas on the White River and the target hatchery program (Little White Salmon Fish Hatchery), and number and percent that strayed to non-target spawning areas and hatchery programs for brood years 2006-2011. Only PIT-tagged fish demonstrating anadromy were included in the analysis. Estimates were based on last detections of PIT-tagged spring Chinook. Percent strays should be less than 5%.

Brood year	Homing				Straying			
	Target stream		Target hatchery*		Non-target streams		Non-target hatcheries	
	Number	%	Number	%	Number	%	Number	%
2006	1	100.0	0	0.0	0	0.0	0	0.0
2007	0	0.0	0	0.0	0	0.0	0	0.0
2008	0	0.0	0	0.0	15	100.0	0	0.0
2009	4	14.3	0	0.0	25	85.7	0	0.0
2010	0	0.0	0	0.0	6	100.0	0	0.0
2011	14	17.1	0	0.0	68	82.9	0	0.0
Average	***3***	***21.9***	***0***	***0.0***	***19***	***61.4***	***0***	***0.0***
Median	***1***	***7.2***	***0***	***0.0***	***11***	***84.3***	***0***	***0.0***

* Homing to the target hatchery includes White River hatchery spring Chinook that are captured and included as broodstock in the White River Hatchery program.

The percentage of the PIT-tagged White River spring Chinook from the captive brood program that were last detected in different watersheds within and outside the Wenatchee River basin are shown in Table 7.17. On average, a small percentage of the PIT-tagged White River spring Chinook homed to the White River. Relatively high percentages of them were last detected in the Little Wenatchee River, Upper Wenatchee River, Nason Creek, and the Chiwawa River.

Few returning adults have strayed into spawning areas outside the Wenatchee River basin. One was last detected in the Entiat River. No other returning adults were detected outside the Wenatchee River basin. On the other hand, several juveniles were last detected in rivers outside the Wenatchee River basin. Juveniles were last detected in the Deschutes, Walla Walla, Hood, and North Fork Teanaway rivers. Juveniles were also last detected at the Little White Salmon Fish Hatchery. There is no evidence that these fish entered the ocean and returned as adults.

Table 7.17. Number and percent (in parentheses) of PIT-tagged White River spring Chinook from the captive brood program that were last detected in different tributaries within the Wenatchee River basin, return years 2010-2016. Only PIT-tagged fish demonstrating anadromy were included in the analysis.

Return year	Homing	Straying						
	White River	Chiwawa River	Chiwaukum Creek	Icicle Creek	Little Wenatchee	Nason Creek	Peshastin Creek	Upper Wenatchee	Entiat River
2010	1 (100.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
2011	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	1 (50.0)	1 (50.0)	0 (0.0)	0 (0.0)	0 (0.0)
2012	2 (16.7)	1 (8.3)	0 (0.0)	0 (0.0)	8 (66.7)	1 (8.3)	0 (0.0)	0 (0.0)	0 (0.0)
2013	2 (6.7)	8 (26.7)	1 (3.3)	2 (6.7)	7 (23.3)	8 (26.7)	0 (0.0)	2 (6.7)	0 (0.0)
2014	4 (8.3)	17 (35.4)	0 (0.0)	1 (2.1)	3 (6.3)	17 (35.4)	0 (0.0)	5 (10.4)	1 (2.1)
2015	10 (23.3)	24 (55.8)	1 (2.3)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	8 (18.6)	0 (0.0)

Return year	Homing	Straying							
	White River	Chiwawa River	Chiwaukum Creek	Icicle Creek	Little Wenatchee	Nason Creek	Peshastin Creek	Upper Wenatchee	Entiat River
2016	4 (22.2)	10 (55.6)	0 (0.0)	1 (5.6)	0 (0.0)	1 (5.6)	0 (0.0)	2 (11.1)	0 (0.0)
Average	***3 (25.3)***	***9 (26.0)***	***0 (0.8)***	***1(2.0)***	***3 (20.9)***	***4 (18.0)***	***0 (0.0)***	***2 (6.7)***	***0 (0.3)***
Median	***2 (16.7)***	***8 (26.7)***	***0 (0.0)***	***0 (0.0)***	***1 (6.3)***	***1 (8.3)***	***0 (0.0)***	***2(6.7)***	***0 (0.0)***

Genetics

At this time, there are no studies that examine the effects of the White River captive brood program on the genetics of natural-origin spring Chinook in the Wenatchee River basin. However, genetic studies were conducted to determine the potential effects of the Chiwawa Supplementation Program on natural-origin spring Chinook in the upper Wenatchee River basin (Blankenship et al. 2007; the entire report is appended as Appendix K). This work included the analysis of White River spring Chinook. Researchers collected microsatellite DNA allele frequencies from temporally replicated natural and hatchery-origin spring Chinook to statistically assign individual fish to specific demes (locations) within the Wenatchee population.

Significant differences in allele frequencies were observed within and among major spawning areas in the Upper Wenatchee River basin. However, these differences made up only a very small portion of the overall variation, indicating genetic similarity among the major spawning areas. There was no evidence that the Chiwawa program has changed the genetic structure (allele frequency) of spring Chinook in the White River, despite the presence of hatchery-origin spawners in both systems.

Proportionate Natural Influence

Another method for assessing the genetic risk of a supplementation program is to determine the influence of the hatchery and natural environments on the adaptation of the composite population. This is estimated by the proportion of natural-origin fish in the hatchery broodstock (pNOB) and the proportion of hatchery-origin fish in the natural spawning escapement (pHOS). We calculated Proportionate Natural Influence (PNI) by iterating Ford's (2002) equations 5 and 6 to equilibrium, using a heritability of 0.3 and a selection strength of three standard deviations.[24] The larger the PNI value, the greater the strength of selection in the natural environment relative to that of the hatchery environment. In order for the natural environment to dominate selection, PNI should be greater than 0.50, and important integrated populations should have a PNI of at least 0.67 (HSRG/WDFW/NWIFC 2004).

For brood years 1989-2000, PNI values ranged from 0.95 to 1.00 (Table 7.18). For brood years 2001-2013, PNI for the White River Program averaged 0.60 (range, 0.33-1.00) (Table 7.18).

[24] According to authorized annual take permits, PNI is calculated using the PNI approximate equation 11 (HSRG 2009; Appendix A). However, in this report, we used Ford's (2002) equations 5 and 6 with a heritability of 0.3 and a selection strength of three standard deviations to calculate PNI (C. Busack, NOAA Fisheries, 21 March 2016, provided the model for calculating PNI). This approach is more accurate than using the PNI approximate equation.

Table 7.18. Proportionate Natural Influence (PNI) values for hatchery spring Chinook spawning in the White River, brood years 1989-2013. See notes below the table for description of each metric.

Brood year	Spawners					Broodstock			PNI
	NOS	HOS$_W$	HOS$_S$	pHOS$_W$	pHOS$_S$	NOB$_N$	HOB$_N$	pNOB	
1989	145	0	0	0.00	0.00	0	0	*1.00*	1.00
1990	49	0	0	0.00	0.00	0	0	*1.00*	1.00
1991	49	0	0	0.00	0.00	0	0	*1.00*	1.00
1992	78	0	0	0.00	0.00	0	0	*1.00*	1.00
1993	138	0	7	0.00	0.05	0	0	*0.99*	0.95
1994	7	0	0	0.00	0.00	0	0	*0.67*	1.00
1995	5	0	0	0.00	0.00	0	0	*1.00*	1.00
1996	30	0	0	0.00	0.00	0	0	*0.60*	1.00
1997	33	0	0	0.00	0.00	0	0	*0.30*	1.00
1998	11	0	0	0.00	0.00	0	0	*0.44*	1.00
1999	3	0	0	0.00	0.00	0	0	*1.00*	1.00
2000	22	0	0	0.00	0.00	0	0	*0.48*	1.00
Average*	***48***	***0***	***1***	***0.00***	***0.00***	***0***	***0***	***0.79***	***1.00***
Median*	***32***	***0***	***0***	***0.00***	***0.00***	***0***	***0***	***1.00***	***1.00***
2001	111	0	55	0.00	0.33	5	0	1.00	0.50
2002	60	0	26	0.00	0.30	18	0	1.00	0.51
2003	31	0	5	0.00	0.14	7	0	1.00	0.77
2004	54	0	12	0.00	0.18	6	0	1.00	0.70
2005	38	11	106	0.07	0.68	103	73	0.59	0.33
2006	41	5	9	0.09	0.16	191	135	0.59	0.61
2007	62	23	7	0.25	0.08	254	6	0.98	0.67
2008	20	2	30	0.04	0.58	116	0	1.00	0.34
2009	81	29	63	0.17	0.36	238	0	1.00	0.53
2010	27	22	23	0.31	0.32	90	0	1.00	0.50
2011	83	0	0	0.00	0.00	306	0	1.00	1.00
2012	89	10	45	0.07	0.31	390	0	1.00	0.73
2013	44	55	5	0.53	0.05	383	0	1.00	0.64
Average**	***57***	***12***	***30***	***0.12***	***0.27***	***162***	***16***	***0.94***	***0.60***
Median**	***54***	***5***	***23***	***0.07***	***0.30***	***116***	***0***	***1.00***	***0.61***

HOS$_W$ = hatchery-origin spawners in White River from the White River spring Chinook Supplementation Program.
pHOS$_W$ = proportion of hatchery-origin spawners from White River spring Chinook Supplementation Program.
HOS$_S$ = stray hatchery-origin spawners in the White River.
pHOS$_S$ = proportion of stray hatchery-origin spawners.
NOB$_W$ = natural origin broodstock spawned for the White River spring Chinook Supplementation Program.
HOB$_W$ = hatchery-origin broodstock spawned in the White River spring Chinook Supplementation Program.
pNOB = proportion of hatchery-origin broodstock. Because of the high incidence of strays to the White River from the Chiwawa River spring Chinook program, pNOB values from the Chiwawa program were used to estimate PNI values during the period from 1989 to 2000 (*italicized*). The weighting for those years was 100% based on the Chiwawa program broodstock selection, because there have been no hatchery returns from the White River spring Chinook program during this period (see Table 5.1 for Chiwawa broodstock selection).
PNI = Proportionate Natural Influence for White River spring Chinook calculated using the gene-flow model for multiple programs.
* Average and median for the period 1989-2000.
** Average and median for the period 2001-2013.

Natural and Hatchery Replacement Rates

In general, natural replacement rates (NRR) are calculated as the ratio of natural-origin recruits (NOR) to the parent spawning population (spawning escapement). Natural-origin recruits are naturally produced (wild) fish that survive to contribute to harvest (directly or indirectly), to broodstock, and to spawning grounds. We do not account for fish that died in route to the spawning grounds (migration mortality) or died just before spawning (pre-spawn mortality) (see Appendix B in Hillman et al. 2012). We calculated NORs with and without harvest. NORs include all returning fish that either returned to the basin or were collected as wild broodstock. For brood years 1989-2010, NRR for spring Chinook in the White River basin averaged 1.03 (range, 0.00-4.91) if harvested fish were not included in the estimate and 1.25 (range, 0.00-5.91) if harvested fish were included in the estimate (Table 7.19). NRRs for more recent brood years will be calculated as soon as all tag recoveries and sampling rates have been loaded into the database.

Hatchery replacement rates (HRR) are the hatchery adult-to-adult returns and are calculated as the ratio of hatchery-origin recruits (HOR) to the parent broodstock collected. For brood years 2006-2010, hatchery replacement rates averaged 0.17 (range, 0.00-0.48) if harvest is not included and 0.62 (range, 0.00-1.99) if harvest is included (Table 7.19a). Only for brood year 2009 was HRR greater than the NRR. The HRR values are much higher when they are calculated using the number of adult equivalents taken from the natural environment to initiate the captive brood program (Table 7.19b).

Table 7.19a. Numbers of brood stock spawned, spawning escapements, hatchery-origin recruits (HOR), natural-origin recruits (NOR), hatchery replacement rates (HRR), and natural replacement rates (NRR) with and without harvest for spring Chinook in the White River basin, brood years 1989-2010.

Brood year	Brood stock spawned	Spawning Escapement	Harvest not included				Harvest included			
			HOR[1]	NOR[2]	HRR[1]	NRR[2]	HOR[3]	NOR[4]	HRR[3]	NRR[4]
1989	--	145	--	81	--	0.56	--	118	--	0.81
1990	--	49	--	2	--	0.04	--	2	--	0.04
1991	--	49	--	3	--	0.06	--	3	--	0.06
1992	--	78	--	30	--	0.38	--	32	--	0.41
1993	--	145	--	44	--	0.30	--	45	--	0.31
1994	--	7	--	1	--	0.14	--	1	--	0.14
1995	--	5	--	9	--	1.80	--	9	--	1.80
1996	--	30	--	15	--	0.50	--	16	--	0.53
1997	--	33	--	148	--	4.48	--	173	--	5.24
1998	--	11	--	54	--	4.91	--	65	--	5.91
1999	--	3	--	0	--	0.00	--	0	--	0.00
2000	--	22	--	54	--	2.45	--	58	--	2.64
2001	5	166	--	64	--	0.39	--	66	--	0.40
2002	18	86	--	70	--	0.81	--	77	--	0.90
2003	7	36	--	11	--	0.31	--	12	--	0.33
2004	6	66	--	25	--	0.38	--	30	--	0.45
2005	176	155	--	72	--	0.46	--	79	--	0.51
2006	326	55	5	110	0.02	2.00	17	157	0.05	2.85

Brood year	Brood stock spawned	Spawning Escapement	Harvest not included				Harvest included			
			HOR[1]	NOR[2]	HRR[1]	NRR[2]	HOR[3]	NOR[4]	HRR[3]	NRR[4]
2007	260	92	0	0	0.00	0.00	0	0	0.00	0.00
2008	116	52	30	100	0.26	1.92	83	156	0.72	3.00
2009	238	173	115	39	0.48	0.23	472	52	1.99	0.30
2010	90	72	10	40	0.11	0.56	32	58	0.36	0.81
Average	**124**	**70**	**32**	**44**	**0.17**	**1.03**	**121**	**55**	**0.62**	**1.25**
Median	**103**	**54**	**10**	**40**	**0.11**	**0.43**	**32**	**49**	**0.36**	**0.48**

[1] HOR and HRR values represented here are detections of PIT-tag hatchery fish detected at Tumwater Dam. These values have been expanded based on the untagged proportion of fish released from the White River spring Chinook Program and PIT-tag detection efficiency at Tumwater Dam.
[2] NOR and NRR values represented here are based on carcasses recovery in the White River adjusted by H:W ratios and age composition and expanded to the escapement in the White River.
[3] Harvest on hatchery-origin White River spring Chinook was estimated based on harvest rates observed for Chiwawa spring Chinook.
[4] Expanded NORs for harvest were based on harvest rates from Chiwawa River spring Chinook.

Table 7.19b. Hatchery-origin recruits (HOR) and hatchery replacement rates (HRR) based on adult equivalents for spring Chinook in the White River basin, brood years 2006-2009. HORs were estimated at Tumwater Dam.

Brood year	Adult equivalents	Harvest not included		Harvest included	
		HOR	HRR	HOR	HRR
2006	1.03	5	4.9	17	16.5
2007	1.21	0	0.0	0	0.0
2008	0.36	30	83.6	83	231.4
2009	1.05	115	109.6	472	449.7
Average	***0.91***	***38***	***50***	***191***	***174***
Median	***1.04***	***18***	***44***	***83***	***124***

For comparison, we calculated NRR for spring Chinook within the Little Wenatchee River basin. Fish from both the White River and Little Wenatchee River must migrate through Lake Wenatchee. Therefore, a comparison between the two subpopulations is appropriate.

NRRs for spring Chinook in the Little Wenatchee River basin were generally less than those for spring Chinook in the White River basin. For brood years 1989-2010, NRR for spring Chinook in the Little Wenatchee River basin averaged 0.83 (range, 0.00-4.50) if harvested fish were not included in the estimate and 1.01 (range, 0.00-5.28) if harvested fish were included in the estimate (Table 7.20). NRRs for more recent brood years will be calculated as soon as all tag recoveries and sampling rates have been loaded into the database.

Table 7.20. Spawning escapements, natural-origin recruits (NOR), and natural replacement rates (NRR) with and without harvest for spring Chinook in the Little Wenatchee River basin, brood years 1989-2010.

Brood year	Spawning Escapement	Harvest not included		Harvest included	
		NOR	NRR	NOR	NRR
1989	102	84	0.82	122	1.20
1990	67	0	0.00	0	0.00
1991	42	0	0.00	0	0.00

Brood year	Spawning Escapement	Harvest not included		Harvest included	
		NOR	NRR	NOR	NRR
1992	78	8	0.10	8	0.10
1993	134	21	0.16	22	0.16
1994	16	11	0.69	11	0.69
1995	0	10	0.00	10	0.00
1996	8	14	1.75	15	1.88
1997	18	81	4.50	95	5.28
1998	18	31	1.72	37	2.06
1999	8	4	0.50	4	0.50
2000	24	39	1.63	42	1.75
2001	118	51	0.43	53	0.45
2002	86	79	0.92	87	1.01
2003	29	13	0.45	15	0.52
2004	39	13	0.33	15	0.38
2005	115	43	0.37	47	0.41
2006	37	49	1.32	70	1.89
2007	101	59	0.58	87	0.86
2008	64	73	1.14	114	1.78
2009	125	52	0.42	69	0.55
2010	83	44	0.53	64	0.77
Average	**60**	**35**	**0.83**	**45**	**1.01**
Median	**53**	**35**	**0.52**	**40**	**0.62**

Smolt-to-Adult Survivals

Smolt-to-adult survival ratios (SARs) were calculated as the number of hatchery adults detected at Tumwater Dam divided by the number of tagged hatchery smolts released. SARs were based on PIT-tag detections. For the available brood years, SARs have ranged from 0.00000 to 0.00196 (Table 7.21).

Table 7.21. Smolt-to-adult ratios (SARs) for White River spring Chinook from the captive brood program, brood years 2006-2011. Detections at Tumwater Dam are adjusted for PIT-tag detection efficiency.

Brood year	Number of smolts released	Number of PIT-tagged smolts released	PIT-tags	
			Adjusted Tumwater Detections	SAR
2006	142,033	29,881	1	0.00003
2007	131,843	39,820	0	0.00000
2008	48,556	38,650	23	0.00060
2009	112,596	41,742	42	0.00101
2010	18,850	12,283	6	0.00049

Brood year	Number of smolts released	Number of PIT-tagged smolts released	PIT-tags	
			Adjusted Tumwater Detections	SAR
2011	147,000	54,187	106	0.00196
Average	*100,146*	*36,094*	*30*	*0.00068*
Median	*122,220*	*39,235*	*15*	*0.00054*

7.8 ESA/HCP Compliance

Brood Collection

The last collection of eggs or fry for this program occurred in 2010 (brood year 2009). From 2011 to 2013, the White River Captive Brood Program operated without ESA permit coverage. The hatchery program ended with the last release of juveniles in 2015 (brood year 2013).

Hatchery Rearing, Spawning, and Release

From 2011 to 2013, the White River Captive Brood Program has operated without ESA permit coverage. The hatchery program ended with the last release of juveniles in 2015 (brood year 2013). No release of juveniles occurred under Section 10(a)(1)(A) Permit 18120 in 2016.

Hatchery Effluent Monitoring

No juveniles were reared or released as part of the White River captive brood program in 2016 due to sun-setting of the program with the 2013 brood. Therefore, no effluent monitoring was required or conducted in 2016.

Smolt and Emigrant Trapping

Per ESA Section 10 Permit No. 1196 (expired), 18118, 18120, and 18121, the permit holders are authorized a direct take of 20% of the emigrating spring Chinook population during juvenile emigration monitoring and a lethal take not to exceed 2% of the fish captured (NMFS 2003). Based on the estimated wild spring Chinook population (smolt trap expansion) and hatchery juvenile spring Chinook population estimate (hatchery release data) for the Wenatchee River basin, the reported spring Chinook encounters during 2016 emigration monitoring complied with take provisions in the Section 10 permit. Spring Chinook encounter and mortality rates for each trap site (including PIT tag mortalities) are detailed in Table 7.22. Additionally, juvenile fish captured at the trap locations were handled consistent with provisions in ESA Section 10 Permit 1196 (expired), 18118, 18120, and 18121, Section B. Table 7.22 includes incidental or direct take associated with the White River smolt trap operated by the Yakama Nation under separate permits.

Table 7.22. Estimated take of Upper Columbia River spring Chinook resulting from juvenile emigration monitoring in the Wenatchee River basin, 2016.

Trap location	Population estimate			Number trapped			Total	Take allowed under Permit
	Wild[a]	Hatchery[b]	Sub-yearling[c]	Wild	Hatchery	Sub-yearling		
Chiwawa Trap								
Population	37,170	341,226	145,971	2,807	2,525	16,393	21,725	
Encounter rate	NA	NA	NA	0.0755	0.0074	0.1123	0.0414	0.20
Mortality[e]	NA	NA	NA	4	0	82	86	
Mortality rate	NA	NA	NA	0.0014	0.0000	0.0050	0.0040	0.02
White River Trap								
Population	386	NA	2,430	3	NA	197	200	
Encounter rate	NA	NA	NA	0.0078	NA	0.0811	0.0710	0.2
Mortality[d]	NA	NA	NA	0	NA	2	2	
Mortality rate	NA	NA	NA	0.0000	NA	0.0102	0.0100	0.02
Nason Creek Trap								
Population	2,372	32,215	6,813	61	124	791	976	
Encounter rate	NA	NA	NA	0.0257	0.0038	0.1161	0.0236	0.2
Mortality[d]	NA	NA	NA	0	0	6	6	
Mortality rate	NA	NA	NA	0.0000	0.0000	0.0076	0.0061	0.02
Lower Wenatchee Trap								
Population	36,752	373,441	14,235,288	610	7,702	27,407	35,719	
Encounter rate	NA	NA	NA	0.0166	0.0206	0.0019	0.0024	0.20
Mortality[d]	NA	NA	NA	2	3	184	189	
Mortality rate	NA	NA	NA	0.0033	0.0001	0.0067	0.0053	0.02
Wenatchee River Basin Total								
Population	36,752	373,441	14,381,259	3,417	10,227	43,800	57,444	
Encounter rate	NA	NA	NA	0.0930	0.0274	0.0030	0.0039	0.20
Mortality[d]	NA	NA	NA	6	3	266	275	
Mortality rate	NA	NA	NA	0.0018	0.001	0.0061	0.0048	0.02

[a] Smolt population estimate derived from juvenile emigration trap data.

[b] 2016 BY smolt release data for the Wenatchee River basin.

[c] Based on size, date of capture and location of capture, subyearling Chinook encountered at the Lower Wenatchee Trap are categorized as summer Chinook salmon.

[d] Combined trapping and PIT tagging mortality.

Spawning Surveys

Spring Chinook spawning ground surveys were conducted in the Wenatchee River basin during 2016, as authorized by ESA Section 10 Permits 18118, 18120, and 18121. Because of the difficulty of quantifying the level of take associated with spawning ground surveys, the Permit does not specify a take level associated with these activities, even though it does authorize implementation of spawning ground surveys. Therefore, no take levels are reported. However, to minimize potential effects to established redds, wading was restricted to the extent practical, and extreme caution was used to avoid established redds when wading was required.

Spring Chinook Reproductive Success Study

ESA Section 10 Permit 1196 (expired) and new Section 10 Permits 18118, 18120, and 18121 specifically provide authorization to capture, anesthetize, biologically sample, PIT tag, and release adult spring Chinook at Tumwater Dam for reproductive success studies and general program monitoring. During 2010 through 2016, all spring Chinook passing Tumwater Dam were enumerated, anesthetized, biologically sampled, PIT tagged, and released (not including hatchery-origin and natural-origin Chinook retained for broodstock) as a component of the reproductive success study (BPA Project No. 2003-039-00). Please refer to Ford et al. (2010, 2011, 2012, 2013, 2014, 2015, and 2016) for complete details on the methods and results of the spring Chinook reproductive success study for the period 2010-2016.

SECTION 8: WENATCHEE SUMMER CHINOOK

The goal of summer Chinook salmon supplementation in the Wenatchee Basin is to use artificial production to replace adult production lost because of mortality at Priest Rapids, Wanapum, and Rock Island dams, while not reducing the natural production or long-term fitness of summer Chinook in the basin. The Rock Island Fish Hatchery Complex began operation in 1989 under funding from Chelan PUD and subsequently Grant PUD began cost-sharing the program in 2012. The Complex operated originally through the Rock Island Settlement Agreement, but since 2004 has operated under the Anadromous Fish Agreement and Habitat Conservation Plans as well as the Priest Rapids Project Salmon and Steelhead Settlement Agreement.

Adult summer Chinook are collected for broodstock from the run-at-large at the right and left-bank traps at Dryden Dam, and at Tumwater Dam if the weekly quotas cannot be achieved at Dryden Dam. Before 2012, the goal was to collect up to 492 natural-origin adult summer Chinook for the Wenatchee program for an annual release of 864,000 smolts. In 2011, the Hatchery Committees reevaluated the amount of hatchery compensation needed to achieve NNI. Based on that evaluation, the goal of the program was revised. The current goal (beginning in 2012) is to collect up to 256 adult natural-origin summer Chinook for an annual release of 500,001 smolts. Broodstock collection occurs from about 1 July through 15 September with trapping occurring up to 24 hours per day, seven days a week. If natural-origin broodstock collection falls short of expectation, hatchery-origin adults can be collected to make up the difference.

Adult summer Chinook are spawned and reared at Eastbank Fish Hatchery. Juvenile summer Chinook are transferred from the hatchery to Dryden Acclimation Pond in March. They are released from the pond in late April to early May.

Before 2012, the production goal for the Wenatchee summer Chinook supplementation program was to release 864,000 yearling smolts into the Wenatchee River at ten fish per pound. Beginning with the 2012 brood, the revised production goal is to release 500,001 yearling smolts into the Wenatchee River at 10 and 15 fish per pound. Targets for fork length and weight are 163 mm (CV = 9.0) and 45.4 g, respectively. Over 95% of these fish are marked with CWTs. In addition, since 2009, about 10,000 juvenile summer Chinook have been PIT tagged annually.

8.1 Broodstock Sampling

This section focuses on results from sampling 2014-2016 Wenatchee summer Chinook broodstock, which were collected at Dryden and Tumwater dams.

Origin of Broodstock

Consistent with the broodstock collection protocol, the 2014-2016 broodstock consisted primarily of natural-origin (adipose fin present and no CWT) summer Chinook (Table 8.1). Less than 1% of the 2014-2016 broodstock was comprised of hatchery-origin fish (hatchery-origin was determined by examination of scales and/or CWTs).

Table 8.1. Numbers of wild and hatchery summer Chinook collected for broodstock, numbers that died before spawning, and numbers of Chinook spawned, 1989-2016. Unknown origin fish (i.e., undetermined by scale analysis, no CWT or fin clips, and no additional hatchery marks) were considered naturally produced. Mortality includes fish that died of natural causes typically near the end of spawning and were not needed for the program and surplus fish killed at spawning.

Brood year	Wild summer Chinook					Hatchery summer Chinook					Total number spawned
	Number collected	Prespawn loss[a]	Mortality	Number spawned	Number released	Number collected	Prespawn loss[a]	Mortality	Number spawned	Number released	
1989	346	29	27	290	0	0	0	0	0	0	290
1990	87	6	24	57	0	0	0	0	0	0	57
1991	128	9	14	105	0	0	0	0	0	0	105
1992	341	48	19	274	0	0	0	0	0	0	274
1993	480	28	46	406	0	44	0	0	44	0	450
1994	363	29	1	333	0	55	1	0	54	0	387
1995	382	15	4	363	0	16	0	0	16	0	378
1996	331	34	34	263	0	3	0	0	3	0	266
1997	225	14	6	205	0	15	1	1	13	0	218
1998	378	40	39	299	0	94	4	12	78	0	377
1999	250	7	1	242	0	238	1	1	236	0	478
2000	298	18	5	275	0	194	7	7	180	0	455
2001	311	41	60	210	0	182	8	38	136	0	346
2002	469	28	32	409	0	13	1	2	10	0	419
2003	488	90	61	337	0	8	1	0	7	0	344
2004	494	24	46	424	0	2	0	0	2	0	426
2005	491	29	19	397	46	3	0	0	3	0	400
2006	483	29	21	433	0	5	1	0	4	0	437
2007	415	53	99	263	0	4	0	1	3	0	266
2008	400	11	11	378	0	72	2	1	69	0	447
2009	482	22	8	452	0	9	1	0	8	0	460
2010	427	14	25	388	0	7	2	0	5	0	393
2011	398	11	11	376	0	7	0	0	7	0	405
Average[b]	***368***	***27***	***27***	***312***	***2***	***42***	***1***	***3***	***38***	***0***	***351***
Median[b]	***382***	***28***	***21***	***333***	***0***	***8***	***1***	***0***	***7***	***0***	***387***
2012	273	5	1	267	0	1	0	0	1	0	268
2013	256	12	10	234	0	2	0	0	2	0	236
2014	279	18	0	261	0	2	0	0	2	0	263
2015	252	0	0	245	0	0	0	0	0	0	245
2016	271	9	3	259	0	0	0	0	0	0	259
Average[c]	***266***	***9***	***3***	***253***	***0***	***1***	***0***	***0***	***1***	***0***	***254***
Median[c]	***271***	***9***	***1***	***259***	***0***	***1***	***0***	***0***	***1***	***0***	***259***

[a] Pre-spawn loss represents the number of fish that died during the holding period before spawning. Mortality is the number of fish that were surplused following spawning.
[a] This average represents the program before recalculation in 2011.
[b] This average represents the current program, which began in 2012.

Age/Length Data

Ages of summer Chinook broodstock were determined from analysis of scales and/or CWTs. Broodstock collected from the 2014 return consisted primarily of age-4 and age-5 natural-origin Chinook (94.7%). Age-3 and age-6 natural-origin fish made up 4.5% and 0% of the broodstock, respectively (Table 8.2). The two hatchery Chinook included in the broodstock were age-4 and age-5 fish.

Broodstock collected from the 2015 return consisted primarily of age-4 and age-5 natural-origin Chinook (92.1%). Age-3 and age-6 natural-origin fish made up 7.8% and 0% of the broodstock, respectively (Table 8.2). No hatchery Chinook were included in broodstock.

Broodstock collected from the 2016 return consisted primarily of age-4 and age-5 natural-origin Chinook (98.4%). Age-3 and age-6 natural-origin fish made up 1.3% and 0.4% of the broodstock, respectively (Table 8.2). No hatchery Chinook were included in broodstock.

Table 8.2. Percent of hatchery and wild Wenatchee summer Chinook of different ages (total age) collected from broodstock in the Wenatchee River basin, 1991-2016.

Return Year	Origin	Total age				
		2	3	4	5	6
1991	Wild	0.0	4.6	36.8	57.5	1.1
	Hatchery	0.0	0.0	0.0	0.0	0.0
1992	Wild	0.0	2.6	40.4	50.9	6.1
	Hatchery	0.0	0.0	0.0	0.0	0.0
1993	Wild	0.0	1.5	35.7	60.4	2.3
	Hatchery	0.0	0.0	93.2	6.8	0.0
1994	Wild	0.0	1.0	33.7	64.3	1.0
	Hatchery	0.0	0.0	1.9	98.1	0.0
1995	Wild	0.0	3.3	19.2	76.3	1.2
	Hatchery	0.0	0.0	0.0	0.0	100.0
1996	Wild	0.0	4.6	40.1	53.3	2.0
	Hatchery	0.0	0.0	33.3	66.7	0.0
1997	Wild	0.0	2.3	42.6	53.2	1.9
	Hatchery	0.0	26.7	66.7	6.7	0.0
1998	Wild	0.0	5.5	34.7	58.6	1.2
	Hatchery	0.0	5.3	68.1	20.2	6.4
1999	Wild	0.5	1.9	39.0	56.3	2.3
	Hatchery	0.0	1.3	23.2	72.2	3.4
2000	Wild	2.6	6.3	24.6	66.5	0.0
	Hatchery	0.0	24.2	14.9	42.8	18.0
2001	Wild	0.3	16.6	53.6	27.7	1.7
	Hatchery	0.0	6.1	80.5	10.4	3.0
2002	Wild	0.7	8.4	61.6	28.5	0.7
	Hatchery	0.0	0.0	41.7	58.3	0.0
2003	Wild	0.9	2.8	31.4	64.8	0.0
	Hatchery	0.0	12.5	25.0	62.5	0.0
2004	Wild	0.2	3.6	10.1	83.9	2.1
	Hatchery	0.0	0.0	50.0	50.0	0.0

Return Year	Origin	Total age				
		2	3	4	5	6
2005	Wild	0.0	4.3	53.5	35.1	7.1
	Hatchery	0.0	0.0	0.0	100.0	0.0
2006	Wild	0.9	0.9	14.9	82.1	1.1
	Hatchery	0.0	0.0	0.0	80.0	20.0
2007	Wild	3.1	15.0	18.7	46.6	16.6
	Hatchery	0.0	0.0	0.0	100.0	0.0
2008	Wild	0.5	6.4	65.5	26.0	1.6
	Hatchery	0.0	2.9	13.0	69.6	14.5
2009	Wild	1.1	6.9	45.8	46.8	0.0
	Hatchery	0.0	0.0	11.1	88.9	0.0
2010	Wild	1.0	6.3	66.1	26.6	0.0
	Hatchery	0.0	0.0	62.5	37.5	0.0
2011	Wild	0.8	8.2	50.3	40.4	0.3
	Hatchery	0.0	42.9	14.3	42.9	0.0
2012	Wild	0.0	3.5	47.2	49.2	0.0
	Hatchery	0.0	0.0	0.0	100.0	0.0
2013	Wild	0.0	12.1	57.1	29.1	1.6
	Hatchery	0.0	0.0	50.0	50.0	0.0
2014	Wild	0.0	4.5	74.7	20.0	0.0
	Hatchery	0.0	0.0	100.0	0.0	0.0
2015	Wild	0.0	7.8	33.0	59.1	0.0
	Hatchery	0.0	0.0	0.0	0.0	0.0
2016	Wild	0.0	1.3	46.1	52.3	0.4
	Hatchery	0.0	0.0	0.0	0.0	0.0
Average	***Wild***	***0.48***	***5.5***	***41.4***	***50.6***	***2.0***
	Hatchery	***0.00***	***4.69***	***28.82***	***44.75***	***6.36***
Median	***Wild***	***0.00***	***4.55***	***40.25***	***52.75***	***1.15***
	Hatchery	***0.00***	***0.00***	***14.60***	***46.45***	***0.00***

Mean lengths of natural-origin summer Chinook of a given age differed little among return years 2014-2016 (Table 8.3).

Table 8.3. Mean fork length (cm) at age (total age) of hatchery and wild Wenatchee summer Chinook collected from broodstock in the Wenatchee River basin, 1991-2016; N = sample size and SD = 1 standard deviation.

Return year	Origin	Summer Chinook fork length (cm)														
		Age-2			Age-3			Age-4			Age-5			Age-6		
		Mean	N	SD	Mean	N	SD	Mean	N	SD	Mean	N	SD	Mean	N	SD
1991	Wild	-	0	-	-	4	-	-	32	-	-	50	-	-	1	-
	Hatchery	-	0	-	-	0	-	-	0	-	-	0	-	-	0	-
1992	Wild	-	0	-	66	3	10	69	46	5	81	58	3	87	7	1
	Hatchery	-	0	-	-	0	-	-	0	-	-	0	-	-	0	-
1993	Wild	-	0	-	68	6	10	84	138	9	98	235	6	100	9	6
	Hatchery	-	0	-	-	0	-	79	41	8	101	3	8	-	0	-
1994	Wild	-	0	-	74	3	5	86	101	8	96	193	7	106	3	7
	Hatchery	-	0	-	-	0	-	75	1	-	90	53	8	-	0	-
1995	Wild	-	0	-	66	11	8	85	64	7	97	255	6	106	4	7
	Hatchery	-	0	-	-	0	-	-	0	-	-	0	-	91	16	8
1996	Wild	-	0	-	69	14	5	86	121	6	97	161	6	104	6	5
	Hatchery	-	0	-	-	0	-	63	1	-	96	2	4	-	0	-
1997	Wild	-	0	-	54	5	10	85	92	7	98	115	6	97	4	9
	Hatchery	-	0	-	46	4	2	74	10	4	98	1	-	-	0	-
1998	Wild	-	0	-	66	19	9	85	119	7	99	201	7	106	4	7
	Hatchery	-	0	-	53	5	2	77	64	8	95	19	8	98	6	8
1999	Wild	42	1	-	65	4	6	86	83	6	97	120	7	103	5	8
	Hatchery	-	0	-	52	3	6	79	55	7	90	171	6	100	8	6
2000	Wild	43	7	3	60	17	7	84	67	5	98	181	6	-	0	-
	Hatchery	-	0	-	53	47	7	76	29	8	93	83	7	102	35	9
2001	Wild	48	1	-	66	48	7	88	155	7	97	80	6	102	5	3
	Hatchery	-	0	-	51	10	3	75	132	8	91	17	8	100	5	8
2002	Wild	51	3	3	64	37	8	89	270	7	100	125	7	99	7	5
	Hatchery	-	0	-	-	0	-	78	5	8	95	7	5	-	0	-
2003	Wild	41	4	2	58	13	4	87	144	8	100	297	7	-	0	-
	Hatchery	-	0	-	40	1	-	78	2	4	101	5	8	-	0	-
2004	Wild	51	1	-	69	17	5	84	47	8	99	392	6	109	10	7
	Hatchery	-	0	-	-	0	-	84	1	-	108	1	-	-	0	-
2005	Wild	-	0	-	68	20	7	86	247	8	95	162	6	101	33	6
	Hatchery	-	0	-	-	0	-	-	0	-	90	3	9	-	0	-
2006	Wild	44	4	7	63	4	11	88	66	7	99	363	6	96	5	7
	Hatchery	-	0	-	-	0	-	-	0	-	99	4	7	100	1	-
2007	Wild	44	12	5	65	58	7	89	72	8	99	180	7	102	64	6
	Hatchery	-	0	-	-	0	-	-	0	-	90	4	5	-	0	-
2008	Wild	46	2	3	69	24	7	90	247	6	98	98	7	105	6	9
	Hatchery	-	0	-	63	2	14	81	9	7	93	48	6	99	10	5
2009	Wild	46	5	5	68	31	8	89	207	8	101	209	6	-	0	-

Return year	Origin	Summer Chinook fork length (cm)														
		Age-2			Age-3			Age-4			Age-5			Age-6		
		Mean	N	SD	Mean	N	SD	Mean	N	SD	Mean	N	SD	Mean	N	SD
	Hatchery	-	0	-	61	4	7	81	1	-	98	8	14	-	0	-
2010	Wild	45	4	4	70	26	9	89	273	7	99	110	6	-	0	-
	Hatchery	-	0	-	-	0	-	72	5	8	88	3	7	-	0	-
2011	Wild	49	3	3	66	30	7	88	183	7	98	147	7	114	1	-
	Hatchery	-	0	-	55	3	2	90	1	-	81	3	5	-	0	-
2012	Wild	-	0	-	71	9	4	87	120	7	96	125	7	-	0	-
	Hatchery	-	0	-	-	0	-	-	0	-	83	1	-	-	0	-
2013	Wild	-	0	-	72	30	3	87	141	7	98	72	7	97	4	6
	Hatchery	-	0	-	-	0	-	79	1	-	96	1	-	-	0	-
2014	Wild	-	0	-	74	12	5	88	198	6	98	53	7	-	0	-
	Hatchery	-	0	-	-	0	-	86	2	6	-	0	-	-	0	-
2015	Wild	-	0	-	72	18	3	86	76	6	98	136	6	-	0	-
	Hatchery	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2016	Wild	-	0	-	70	3	8	86	106	7	95	121	7	99	1	-
	Hatchery	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Average	***Wild***	***46***	***2***	***4***	***67***	***18***	***7***	***86***	***131***	***7***	***97***	***163***	***6***	***102***	***7***	***6***
	Hatchery	***-***	***0***	***-***	***53***	***5***	***5***	***78***	***16***	***7***	***94***	***19***	***7***	***99***	***5***	***7***

Sex Ratios

Male summer Chinook in the 2014 and 2015 broodstock made up nearly 50% of the adults collected, resulting in overall male to female ratios of 0.99:1.00 and 0.99:1.00, respectively (Table 8.4). In 2016, males made up just under 50% of the adults collected, resulting in an overall male to female ratio of 0.99:1.00 (Table 8.4). The ratios in 2014-2016 were nearly equal to the 1:1 ratio goal in the broodstock protocol.

Table 8.4. Numbers of male and female wild and hatchery summer Chinook collected for broodstock in the Wenatchee River basin, 1989-2016. Ratios of males to females are also provided.

Return year	Number of wild summer Chinook			Number of hatchery summer Chinook			Total M/F ratio
	Males (M)	Females (F)	M/F	Males (M)	Females (F)	M/F	
1989	166	180	0.92:1.00	0	0	-	0.92:1.00
1990	45	39	1.15:1.00	0	0	-	1.15:1.00
1991	60	68	0.88:1.00	0	0	-	0.88:1.00
1992	154	187	0.82:1.00	0	0	-	0.82:1.00
1993	208	228	0.91:1.00	35	9	3.89:1.00	1.03:1.00
1994	158	179	0.88:1.00	24	31	0.77:1.00	0.87:1.00
1995	169	213	0.79:1.00	1	15	0.07:1.00	0.75:1.00
1996	150	181	0.83:1.00	2	1	2.00:1.00	0.84:1.00
1997	104	121	0.86:1.00	15	0	-	0.98:1.00
1998	211	167	1.26:1.00	64	30	2.13:1.00	1.40:1.00

Return year	Number of wild summer Chinook			Number of hatchery summer Chinook			Total M/F ratio
	Males (M)	Females (F)	M/F	Males (M)	Females (F)	M/F	
1999	130	120	1.08:1.00	108	130	0.83:1.00	0.95:1.00
2000	153	145	1.06:1.00	112	82	1.37:1.00	1.17:1.00
2001	187	124	1.51:1.00	132	50	2.64:1.00	1.83:1.00
2002	266	203	1.31:1.00	5	8	0.63:1.00	1.28:1.00
2003	270	218	1.24:1.00	5	3	1.67:1.00	1.24:1.00
2004	230	264	0.87:1.00	1	1	1.00:1.00	0.87:1.00
2005	291	200	1.46:1.00	2	1	2.00:1.00	1.46:1.00
2006	237	246	0.96:1.00	1	4	0.25:1.00	0.95:1.00
2007	239	176	1.36:1.00	2	2	1.00:1.00	1.35:1.00
2008	208	192	1.08:1.00	29	43	0.67:1.00	1.01:1.00
2009	223	236	0.94:1.00	25	7	3.57:1.00	1.02:1.00
2010	217	198	1.10:1.00	5	2	2.50:1.00	1.12:1.00
2011	198	200	0.99:1.00	4	3	1.33:1.00	0.99:1.00
2012	138	135	1.02:1.00	1	0	-	1.03:1.00
2013	127	130	0.98:1.00	1	1	1.00:1.00	0.98:1.00
2014	140	139	1.01:1.00	0	2	0.00:1.00	0.99:1.00
2015	122	123	0.99:1.00	0	0	--	0.99:1.00
2016	134	136	0.99:1.00	0	0	--	0.99:1.00
Total	***4935***	***4748***	***1.04:1.00***	***574***	***425***	***1.35:1.00***	***1.06:1.00***

Fecundity

Fecundities for the 2014-2016 returns of summer Chinook averaged 4,756, 4,982, and 4,423 eggs per female, respectively (Table 8.5). These values are less than the overall average of 5,112 eggs per female. Mean observed fecundities for the 2014-2016 returns were lower than the expected fecundities of 5,099, 5,031, and 4,902 eggs per female assumed in the broodstock collection protocols, respectively.

Table 8.5. Mean fecundity of wild, hatchery, and all female summer Chinook collected for broodstock in the Wenatchee River basin, 1989-2016; NA = not available.

Return year	Mean fecundity		
	Wild	Hatchery	Total
1989*	NA	NA	5,280
1990*	NA	NA	5,436
1991*	NA	NA	4,333
1992*	NA	NA	5,307
1993*	NA	NA	5,177
1994*	NA	NA	5,899
1995*	NA	NA	4,402
1996*	NA	NA	4,941

Return year	Mean fecundity		
	Wild	Hatchery	Total
1997	5,385	5,272	5,390
1998	5,393	4,825	5,297
1999	5,036	4,942	4,987
2000	5,464	5,403	5,441
2001	5,280	4,647	5,097
2002	5,502	5,027	5,484
2003	5,357	5,696	5,361
2004	5,372	6,681	5,377
2005	5,045	6,391	5,053
2006	5,126	5,633	5,133
2007	5,124	4,510	5,115
2008	5,147	4,919	5,108
2009	5,308	4,765	5,291
2010	4,971	3,323	4,963
2011	4,943	2,983	4,913
2012	4,801	NA	4,801
2013	4,987	5,272	4,990
2014	4,788	4,429	4,756
2015	4,982	NA	4,982
2016	4,423	NA	4,423
Average	***5,122***	***4,983***	***4,948***
Median	***5,125***	***4,942***	***5,112***

* Individual fecundities were not tracked with females until 1997.

8.2 Hatchery Rearing

Rearing History

Number of eggs taken

Based on the unfertilized egg-to-release survival standard of 81%, a total of 1,066,667 eggs were required to meet the program release goal of 864,000 smolts for brood years 1989-2011. An evaluation of the program in 2011 determined that 617,285 eggs are needed to meet the revised release goal of 500,001 smolts. This revised goal began with brood year 2012. From 1989 to 2011, the egg take goal was reached in seven of those years (Table 8.6). The egg takes from 2013-2016 were lower than the revised goal of 617,285 eggs.

Table 8.6. Numbers of eggs taken from Wenatchee summer Chinook broodstock, 1989-2015.

Return year	Number of eggs taken
1989	829,012
1990	163,109
1991	247,000

Return year	Number of eggs taken
1992	827,911
1993	1,133,852
1994	999,364
1995	949,531
1996	756,000
1997	554,617
1998	854,997
1999	1,182,130
2000	1,113,159
2001	733,882
2002	1,049,255
2003	901,095
2004	1,311,051
2005	883,669
2006	1,190,757
2007	655,201
2008	1,145,330
2009	1,217,028
2010	947,875
2011	959,202
Average (1989-2011)	***895,871***
Median (1989-2011)	***947,875***
2012	633,677
2013	578,513
2014	612,422
2015	610,718
2016	***588,606***
Average (2012-present)	***604,787***
Median (2012-present)	***610,718***

Number of acclimation days

The 2014 brood Wenatchee summer Chinook were transferred to the Dryden Acclimation Pond between 21 and 24 March 2016. These fish received 25-37 days of acclimation on Wenatchee River water before being volitionally released from 18-27 April 2016 (Table 8.7).

Table 8.7. Number of days Wenatchee summer Chinook were acclimated at Dryden Acclimation Pond, brood years 1989-2014. Numbers in parenthesis represents the number of days fish reared at Chiwawa Acclimation Facility.

Brood year	Release year	Transfer date	Release date	Number of days
1989	1991	2-Mar	7-May	66
1990	1992	19-Feb	2-May	73
1991	1993	10-Mar	8-May	59
1992	1994	1-Mar	6-May	66
1993	1995	3-Mar	1-May	59
1994	1996	2-Oct	6-May	217 (154)
		5-Mar	6-May	62
1995	1997	16-Oct	8-May	205 (139)
		27-Feb	8-May	70
1996	1998	6-Oct	28-Apr	204 (142)
		25-Feb	28-Apr	62
1997	1999	23-Feb	27-Apr	63
1998	2000	5-Mar	1-May	57
1999	2001	8-Mar	23-Apr	46
2000	2002	1-Mar	6-May	66
2001	2003	19-Feb	23-Apr	63
2002	2004	5-Mar	23-Apr	49
2003	2005	15-Mar	25-Apr	41
2004	2006	25-Mar	27-Apr	33
2005	2007	15-Mar	30-Apr	46
2006	2008	11-14-Mar	28-Apr	45-48
2007	2009	30-31-Mar	29-Apr	29-30
2008	2010	9-12, 15, 22-Mar	28-Apr	38-51
2009	2011	15-18, 21-Mar, 22-Apr	26-Apr	5-43
2010	2012	26-30-Mar	25-Apr	26-30
2011	2013	25-29-Mar	24-Apr	26-30
2012	2014	17-27-Mar	30-Apr	34-44
2013	2015	9-13-Mar, 17-Apr	28-Apr	11-50
2014	2016	21-24-Mar	18-27-Apr	25-37

Release Information

Numbers released

The 2014 Wenatchee summer Chinook program achieved 107.1% of the 500,001 goal with 535,255 fish being released in 2016 (Table 8.8). For brood years 2012-2014, the Wenatchee summer Chinook program has averaged 104% of the smolt obligation.

Table 8.8. Numbers of Wenatchee summer Chinook smolts released from the hatchery, brood years 1989-2014. Up to 2012, the release target for Wenatchee summer Chinook was 864,000 smolts. Beginning in 2012, the release target is 500,001 smolts.

Brood year	Release year	CWT mark rate	Number released with PIT tags	Number of smolts released
1989	1991	0.2013	0	720,000
1990	1992	0.9597	0	124,440
1991	1993	0.9957	0	191,179
1992	1994	0.9645	0	627,331
1993	1995	0.9881	0	900,429
1994	1996	0.9697	0	797,350
1995	1997	0.9725	0	687,439
1996	1998	0.9758	0	600,127
1997	1999	0.9913	0	438,223
1998	2000	0.9869	0	649,612
1999	2001	0.9728	0	1,005,554
2000	2002	0.9723	0	929,496
2001	2003	0.9868	0	604,668
2002	2004	0.9644	0	835,645
2003	2005	0.9778	0	653,764
2004	2006	0.9698	0	892,926
2005	2007	0.9596	0	644,182
2006	2008	0.9676	0	51,550[a]
		0.9676	0	899,107
2007	2009	0.9768	0	456,805
2008	2010	0.9664	10,035	888,811
2009	2011	0.9767	29,930	843,866
2010	2012	0.9964	0	792,746
2011	2013	0.9904	5,020	827,709
Average (1989-2011)		***0.9761***	***1,874***	***667,085***
Median (1989-2011)		***0.9727***	***0***	***720,000***
2012	2014	0.9700	19,911	550,877
2013	2015	0.9872	20,486	470,570
2014	2016	0.9639	10,432	535,255
Average (2012-present)		***0.9737***	***16,943***	***518,901***
Median (2012-present)		***0.9700***	***19,911***	***535,255***

[a] Represents high ELISA group planted directly in the Wenatchee River at Leavenworth Boat Launch.

Numbers tagged

The 2014 brood Wenatchee summer Chinook were 96.4% CWT and adipose fin-clipped (Table 8.8).

In 2016, a total of 10,565 Wenatchee summer Chinook (brood year 2015) were tagged at Eastbank Hatchery on 19-22 September. These were tagged and released into raceway #12. Fish were not fed during tagging or for two days before and after tagging. Fish averaged 84-86 mm in length and 6.1-6.5 g at time of tagging.

An additional 10,429 Wenatchee summer Chinook were tagged at Eastbank Hatchery on 10-13 October 2016. These were tagged and released into water-reuse circular ponds #1 and #2. Fish were not fed during tagging or for two days before and after tagging. Fish averaged 90-95 mm in length and 7.5-7.8 g at time of tagging.

Table 8.9 summarizes the number of hatchery summer Chinook that have been PIT-tagged and released into the Wenatchee River.

Table 8.9. Summary of PIT-tagging activities for Wenatchee hatchery summer Chinook, brood years 2008-2014.

Brood year	Release year	Number of fish tagged	Number of tagged fish that died	Number of tags shed	Number of tagged fish released
2008	2010	10,100	64	1	10,035
2009	2011	10,108 (Control)	140	3	9,965
		10,100 (R1)	129	0	9,971
		10,099 (R2)	105	0	9,994
2010	2012	0	0	0	0
2011	2013	5,100	80	0	5,020
2012	2014 (Raceway)	5,150 (small-size)	90	12	5,048
		5,153 (big-size)	379	34	4,740
	2014 (Reuse Circular)	5,150 (small-size)	109	0	5,041
		5,151 (big-size)	69	0	5,082
2013	2015 (Raceway)	5,150 (small-size)	44	0	5,116
		5,153 (big-size)	31	0	5,129
	2015 (Reuse Circular)	5,150 (small-size)	41	0	5,120
		5,151 (big-size)	38	1	5,121
2014	2016 (Raceway)	5,250 (small-size)	54	0	5,196
		5,250 (big-size)	92	0	5,158
		5,250 (small-size)	19	0	5,231

Brood year	Release year	Number of fish tagged	Number of tagged fish that died	Number of tags shed	Number of tagged fish released
	2016 (Reuse Circular)	5,250 (big-size)	49	0	5,201

Fish size and condition at release

About 535,255 summer Chinook from the 2014 brood were volitionally released from Dryden Acclimation Pond on 18-27 April 2016. Assessing size-target achievement from pre-release sampling was not practical because of size-target studies on the 2012 and 2013 brood years. However, since the program began, Wenatchee summer Chinook have not met the target length and CV values (Table 8.10). The target weight (fish/pound or FPP) of juvenile fish has been met occasionally (Table 8.10).

Table 8.10. Mean lengths (FL, mm), weight (g and fish/pound), and coefficient of variation (CV) of Wenatchee summer Chinook smolts released from the hatchery, brood years 1989-2014; NA = not available. Size targets are provided in the last row of the table.

Brood year	Release year	Fork length (cm)		Mean weight	
		Mean	CV	Grams (g)	Fish/pound
1989	1991	158	13.7	45.4	10
1990	1992	155	14.2	45.4	10
1991	1993	156	15.5	42.3	11
1992	1994	152	13.1	40.1	10
1993	1995	149	NA	34.9	13
1994	1996	138	NA	21.7	21
1995	1997	149	12.2	42.5	11
1996	1998	151	16.6	43.2	10
1997	1999	154	10.1	42.8	11
1998	2000	166	9.7	53.1	9
1999	2001	137	16.1	29.0	16
2000	2002	148	14.6	37.1	12
2001	2003	148	NA	38.9	12
2002	2004	146	15.1	37.3	14
2003	2005	147	13.2	36.5	12
2004	2006	147	10.7	35.4	13
2005	2007	153	16.3	40.6	11
2006	2008	136	21.5	29.2	16
2007	2009	163	21.6	49.7	9
2008	2010	166	15.0	52.0	9
2009	2011	152	15.9	39.0	12
2010	2012	154	17.2	43.1	11
2011	2013	149	13.8	41.4	11
Average (1989-2011)		***151***	***14.8***	***40.0***	***12***

Brood year	Release year	Fork length (cm)		Mean weight	
		Mean	CV	Grams (g)	Fish/pound
Targets (1989-2011)		***176***	***9.0***	***45.4***	***10***
2012	2014	158	12.6	40.7	11
2013	2015	156	10.1	40.7	11
2014	2016	145	10.2	31.1	15
Average (2012-present)		***153***	***11.0***	***37.5***	***12***
Targets (2012-present)[a]		***163***	***9.0***	***45.4***	***18***

[a] For brood year 2012, the fish per pound (fpp) targets were 10 fpp and 15 fpp.

Survival Estimates

Overall survival of the 2014 brood Wenatchee summer Chinook from green (unfertilized) egg to release was higher than the standard set for the program. This was in part because of a high survival at all stages (Table 8.11).

Table 8.11. Hatchery life-stage survival rates (%) for Wenatchee summer Chinook, brood years 1989-2014. Survival standards or targets are provided in the last row of the table.

Brood year	Collection to spawning		Unfertilized egg-eyed	Eyed egg-ponding	30 d after ponding	100 d after ponding	Ponding to release	Transport to release	Unfertilized egg-release
	Female	Male							
1989	90.0	93.4	90.9	97.0	99.7	99.3	98.5	99.4	86.9
1990	89.7	95.6	80.9	96.6	99.6	99.2	97.7	98.8	76.3
1991	88.2	98.3	86.9	96.1	99.3	98.5	94.9	98.1	77.4
1992	84.3	92.2	79.8	97.8	99.9	99.9	97.1	98.1	75.8
1993	92.4	95.9	84.2	97.5	99.6	99.3	96.7	98.8	79.4
1994	90.7	95.3	83.7	100	99.2	97.0	95.3	98.4	79.8
1995	94.7	98.2	86.0	100	96.7	96.4	74.9	90.8	72.4
1996	84.6	96.1	84.1	100	97.9	97.7	94.4	97.7	79.4
1997	89.3	98.3	82.6	97.3	97.1	96.9	98.3	98.2	79.0
1998	85.3	94.6	80.9	98.3	99.4	98.6	95.6	99.8	76.0
1999	98.4	98.3	90.4	97.9	98.1	97.9	96.2	99.4	85.1
2000	93.0	96.6	88.3	98.0	99.6	99.3	96.5	98.9	83.5
2001	87.4	91.5	90.6	97.7	99.8	99.6	93.1	93.3	82.4
2002	93.8	94.1	85.1	99.8	98.1	97.6	93.7	96.5	79.6
2003	77.4	85.1	80.5	98.1	99.6	99.1	91.9	93.5	72.6
2004	92.8	97.8	85.7	87.8	99.9	99.6	86.6	92.1	65.1
2005	97.3	89.6	83.5	98.0	99.7	99.4	89.1	99.5	72.9
2006	92.4	95.2	85.6	98.4	99.3	98.4	94.8	97.2	79.8
2007	73.6	97.5	73.7	97.9	99.5	98.7	96.6	99.1	69.7
2008	96.6	97.9	90.4	97.3	99.4	98.7	88.2	89.6	77.6
2009	95.1	95.6	92.0	99.6	97.3	97.3	84.8	98.2	78.1
2010	94.7	97.8	96.1	99.3	97.6	97.1	87.2	90.3	83.2

Brood year	Collection to spawning		Unfertilized egg-eyed	Eyed egg-ponding	30 d after ponding	100 d after ponding	Ponding to release	Transport to release	Unfertilized egg-release
	Female	Male							
2011	98.0	96.4	92.3	97.9	99.5	98.9	95.9	97.3	86.7
2012	97.8	97.2	92.3	98.1	99.7	99.1	96.1	97.3	86.9
2013	91.5	98.4	87.5	98.8	97.1	96.6	94.1	98.4	81.3
2014	92.2	95.0	92.6	99.4	99.6	98.7	97.8	99.3	90.0
Average	***90.8***	***95.5***	***86.4***	***97.9***	***98.9***	***98.4***	***93.3***	***96.8***	***79.1***
Median	***92.3***	***96.0***	***85.9***	***98.0***	***99.5***	***98.7***	***95.1***	***98.2***	***79.4***
Standard	***90.0***	***85.0***	***92.0***	***98.0***	***97.0***	***93.0***	***90.0***	***95.0***	***81.0***

8.3 Disease Monitoring

Rearing of the 2014 brood Wenatchee summer Chinook was similar to previous years with fish being held on well water before being transferred to Dryden Acclimation Pond for final acclimation in March 2016. Fish were transferred to Dryden Acclimation Pond from 21-24 March. Increased mortality caused by external fungus began to occur during the acclimation period at Dryden Acclimation Pond at which time a formalin treatment for 21 days was initiated to prevent the fungus from proliferating.

Results of the 2016 adult broodstock bacterial kidney disease (BKD) monitoring indicated that all females (100%) had ELISA values less than 0.199. Additionally, all females had ELISA values less than 0.120, which means that none of the progeny needed to be reared at densities less than 0.06 fish per pound (Table 8.12).

Table 8.12. Proportion of bacterial kidney disease (BKD) titer groups for the Wenatchee summer Chinook broodstock, brood years 1997-2016. Also included are the proportions to be reared at either 0.125 fish per pound or 0.060 fish per pound.

Brood year[a]	Optical density values by titer group				Proportion at rearing densities (fish per pound, fpp)[b]	
	Very Low (≤ 0.099)	Low (0.1-0.199)	Moderate (0.2-0.449)	High (≥ 0.450)	≤ 0.125 fpp (<0.119)	≤ 0.060 fpp (>0.120)
1997	0.7714	0.0857	0.0381	0.1048	0.8095	0.1905
1998	0.3067	0.2393	0.1656	0.2883	0.4479	0.5521
1999	0.9590	0.0123	0.0123	0.0164	0.9713	0.0287
2000	0.6268	0.1053	0.1627	0.1053	0.7321	0.2679
2001	0.6513	0.0263	0.0987	0.2237	0.6776	0.3224
2002	0.7868	0.0457	0.0711	0.0964	0.8325	0.1675
2003	0.9825	0.0000	0.0058	0.0117	0.9825	0.0175
2004	0.9593	0.0081	0.0163	0.0163	0.9675	0.0325
2005	0.9833	0.0056	0.0000	0.0111	0.9833	0.0167
2006	0.9134	0.0563	0.0000	0.0303	0.9351	0.0649
2007	0.9535	0.0078	0.0078	0.0310	0.9535	0.0465
2008	0.9868	0.0088	0.0044	0.0000	0.9868	0.0132

Brood year[a]	Optical density values by titer group				Proportion at rearing densities (fish per pound, fpp)[b]	
	Very Low (≤ 0.099)	Low (0.1-0.199)	Moderate (0.2-0.449)	High (≥ 0.450)	≤ 0.125 fpp (<0.119)	≤ 0.060 fpp (>0.120)
2009	0.9957	0.0000	0.0000	0.0043	0.9957	0.0043
2010	0.9897	0.0025	0.0000	0.0025	0.9949	0.0051
2011	0.9585	0.0363	0.0000	0.0052	0.9896	0.0104
2012	0.9697	0.0303	0.0000	0.0000	1.0000	0.0000
2013	0.8120	0.1790	0.0000	0.0090	0.8890	0.1110
2014	0.9462	0.0154	0.0000	0.0385	0.9462	0.0538
2015	0.9919	0.0000	0.0000	0.0081	0.9919	0.0081
2016	1.0000	0.0000	0.0000	0.0000	1.0000	0.0000
Average	***0.8772***	***0.0432***	***0.0291***	***0.0501***	***0.9043***	***0.0957***
Median	***0.9588***	***0.0139***	***0.0022***	***0.0140***	***0.9694***	***0.0306***

[a] Individual ELISA samples were not collected before the 1997 brood.
[b] ELISA values from broodstock BKD testing dictate what density the progeny of the broodstock are reared. Progeny of broodstock with high ELISA values are reared at lower density.

8.4 Natural Juvenile Productivity

During 2016, juvenile summer Chinook were sampled at the Lower Wenatchee Trap located near the town of Cashmere. The Lower Wenatchee Trap was moved to its present location in 2013 and as a result flow efficiency models need to be created and updated. These relationships continue to be developed and improved.

Emigrant Estimates

Lower Wenatchee Trap

The Lower Wenatchee Trap operated between 29 January and 26 July 2016. During that time, the trap was inoperable for 23 days because of high and low river discharge, debris, elevated river temperatures, large hatchery releases, and mechanical issues. During the sampling period, a total of 27,407 wild subyearling Chinook were captured at the Lower Wenatchee Trap. Based on 22 capture efficiencies, a significant relationship between trap efficiency and river discharge was created ($R^2 = 0.56$, $P < 0.040$) and an estimate of 4,023,310 (±676,633; 95% CI) wild subyearling Chinook passed the trap within the sampling period (Table 8.13).

Table 8.13. Numbers of redds and juvenile summer Chinook emigrants in the Wenatchee River basin for brood years 1999-2015; NS = not sampled. From 2000-2010 the trap operated at Monitor; from 2013 to present the trap operated near Cashmere.

Brood year	Number of redds	Egg deposition	Number of emigrants upstream from trap	Total number of emigrants
1999	2,738	13,654,406	9,572,392	9,685,591
2000	2,540	13,820,140	1,299,476	1,322,383
2001	3,550	18,094,350	8,229,920	8,340,342
2002	6,836	37,488,624	13,167,855	13,475,368

Brood year	Number of redds	Egg deposition	Number of emigrants upstream from trap	Total number of emigrants
2003	5,268	28,241,748	20,336,968	20,426,149
2004	4,874	26,207,498	14,764,141	14,935,745
2005	3,538	17,877,514	11,612,939	11,695,581
2006	8,896	45,663,168	9,397,044	9,595,512
2007	1,970	10,076,550	4,470,672	4,546,838
2008	2,800	14,302,400	4,309,496	4,405,473
2009	3,441	18,206,331	6,695,977	6,814,805
2010	3,261	16,184,343	NS	NS
2011	3,078	15,122,214	NS	NS
2012	2,504	12,021,704	9,333,214	10,034,508
2013	3,241	16,162,867	11,936,928	12,605,925
2014	3,458	16,556,904	14,157,778	14,763,064
2015	1,804	11,491,325	4,023,310	4,199,697
Average	***3,345***	***19,480,711***	***9,553,874***	***9,789,799***
Median	***2,953***	***16,184,343***	***9,397,044***	***9,685,591***

A total of 114 summer Chinook redds were observed downstream from the trap in 2016. Thus, the total number of summer Chinook emigrating from the Wenatchee River in 2015 was expanded using the ratio of the number of redds downstream from the trap to the number upstream from the trap. This resulted in a total summer Chinook emigrant estimate of 4,199,697 fish (Table 8.13). Most of the fish emigrated during April with another pulse in June (Figure 8.1). Monthly captures and mortalities of all fish collected at the Lower Wenatchee Trap are reported in Appendix B.

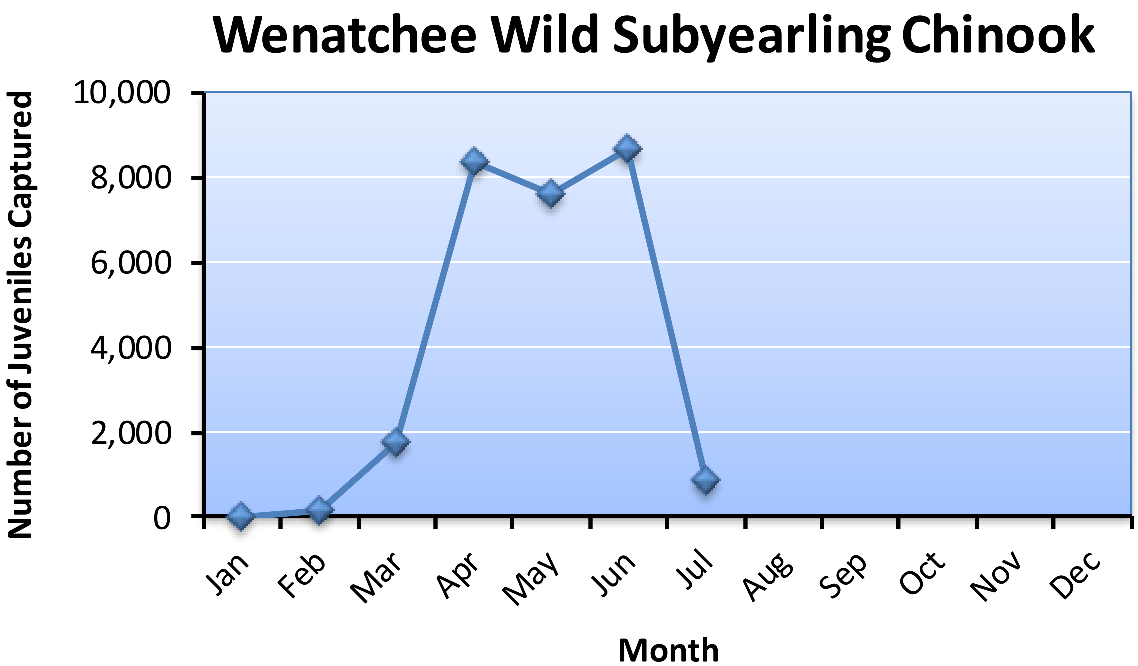


Figure 8.1. Numbers of wild subyearling Chinook captured at the Lower Wenatchee Trap during late January through July 2016.

Subyearling summer Chinook sampled in 2016 averaged 53 mm in length, 2.0 g in weight, and had a mean condition of 1.34 (Table 8.14). These size estimates were similar to the overall mean of subyearling summer Chinook sampled in previous years (overall means: 49 mm, 1.6 g, and condition of 1.28).

Table 8.14. Mean fork length (mm), weight (g), and condition factor of subyearling summer Chinook collected in the Lower Wenatchee Trap, 2000-2016; NS = not sampled. From 2000-2010 the trap operated at Monitor; from 2013 to present the trap operated near Cashmere. Numbers in parentheses indicate 1 standard deviation.

Sample year	Sample size[a]	Mean size		
		Length (mm)	Weight (g)	Condition (K)
2000	1,099	49 (14.7)	1.7 (2.2)	1.40 (0.29)
2001	403	56 (15.1)	2.3 (1.9)	1.33 (0.17)
2002	2,337	59 (18.0)	2.9 (2.7)	1.42 (0.17)
2003	818	59 (15.6)	2.8 (2.6)	1.40 (0.16)
2004	1,725	46 (11.2)	1.2 (1.5)	1.23 (0.20)
2005	2,944	45 (9.2)	1.0 (1.0)	1.13 (0.21)
2006	2,873	50 (15.2)	1.8 (2.0)	1.39 (0.21)
2007	2,864	46 (9.1)	1.0 (1.0)	1.10 (0.28)
2008	2,136	46 (11.6)	1.3 (1.4)	1.29 (0.21)
2009	2,185	45 (9.3)	1.0 (0.9)	1.16 (0.21)
2010	2,318	43 (8.3)	0.9 (0.9)	1.11 (0.29)

Sample year	Sample size[a]	Mean size		
		Length (mm)	Weight (g)	Condition (K)
2011	NS	NS	NS	NS
2012	NS	NS	NS	NS
2013	4,452	51 (16.9)	2.1 (4.0)	1.52 (0.31)
2014	5,166	45 (10.5)	1.1 (1.3)	1.19 (0.44)
2015	4,560	49 (13.0)	1.5 (1.5)	1.25 (0.18)
2016	5,998	53 (14.8)	2.0 (1.9)	1.34 (0.17)
Average	2,792	49 (12.8)	1.6 (1.8)	1.28
Median	2,337	49 (13.0)	1.5 (1.5)	1.29

[a] Sample size represents the number of fish that were measured for both length and weight.

8.5 Spawning Surveys

Surveys for Wenatchee summer Chinook redds were conducted from 5 September to 11 November 2016 in the Wenatchee River and Icicle Creek.

Redd Counts

A total count of summer Chinook redds was estimated in 2016 based on weekly census surveys conducted in the Wenatchee River. Redds were counted in Icicle Creek when feasible. A total of 2,797 summer Chinook redds were counted in the Wenatchee River basin in 2016 (Table 8.15).

In the future, spawning escapement estimates may be derived using the area-under-the-curve (AUC) method described in Millar et al. (2012). WDFW now has three years of data (2014, 2015, and 2016) to inform model parameters (e.g., observer efficiency of redd counts at variable temporal and spatial scales). Model calibration has begun with existing data. After the conclusion of 2018 surveys, WDFW will have a complete model to generate updated spawning escapements with associated variance.

Table 8.15. Numbers of redds counted in the Wenatchee River basin, 1989-2016; ND = no data. From 1989-2013, numbers of redds were based on expanding "peak counts" to generate a Total Count. Since 2014, numbers of redds were based on weekly census surveys that encompass all reaches.

Survey year	Redd counts		Total count
	Wenatchee River	Icicle Creek	
1989	3,331	ND	4,215
1990	2,479	ND	3,103
1991	2,180	ND	2,748
1992	2,328	ND	2,913
1993	2,334	ND	2,953
1994	2,426	ND	3,077
1995	1,872	ND	2,350
1996	1,435	ND	1,814
1997	1,388	ND	1,739
1998	1,660	ND	2,230
1999	2,188	ND	2,738

Survey year	Redd counts		Total count
	Wenatchee River	Icicle Creek	
2000	2,022	ND	2,540
2001	2,857	ND	3,550
2002	5,419	ND	6,836
2003	4,281	ND	5,268
2004	4,003	ND	4,874
2005	2,895	ND	3,538
2006	7,165	68	8,896
2007	1,857	13	1,970
2008	2,338	23	2,800
2009	2,667	21	3,441
2010	2,553	11	3,261
2011	2,583	9	3,078
2012	2,301	2	2,504
2013	2,875	42	3,241
2014	3,383	75	3,458
2015	1,781	23	1,804
2016	2,725	72	2,797
Average			***3,348***
Median			***3,015***

Redd Distribution

Summer Chinook redds were not evenly distributed among reaches within the Wenatchee River basin in 2016 (Table 8.16; Figure 8.2). Most of the spawning occurred upstream from the Leavenworth Bridge in Reaches 6, 9, and 10. The highest density of redds occurred in Reach 6 near the confluence of the Icicle River.

Table 8.16. Total numbers of summer Chinook redds counted in different reaches in the Wenatchee River basin during September through mid-November 2016. Reach codes are described in Table 2.10.

Survey reach	Total redd count
Wenatchee 1 (W1)	1
Wenatchee 2 (W2)	144
Wenatchee 3 (W3)	224
Wenatchee 4 (W4)	41
Wenatchee 5 (W5)	103
Wenatchee 6 (W6)	687
Wenatchee 7 (W7)	192
Wenatchee 8 (W8)	309
Wenatchee 9 (W9)	502
Wenatchee 10 (W10)	522

Survey reach	Total redd count
Icicle Creek (I1)	72
Totals	***2,797***

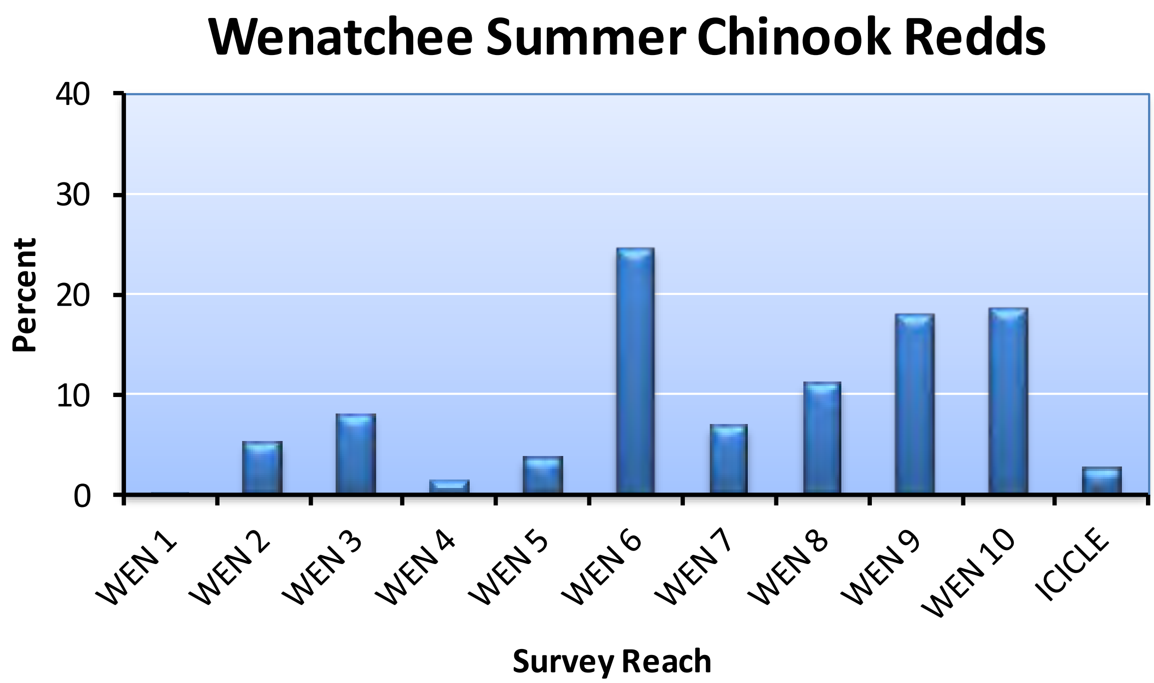


Figure 8.2. Percent of the total number of summer Chinook redds counted in different reaches in the Wenatchee River basin during September through early-November 2016. Reach codes are described in Table 2.10.

Spawn Timing

In 2016, spawning in the Wenatchee River began during the fourth week of September, peaked the first week of October, and ended the first week of November (Figure 8.3).

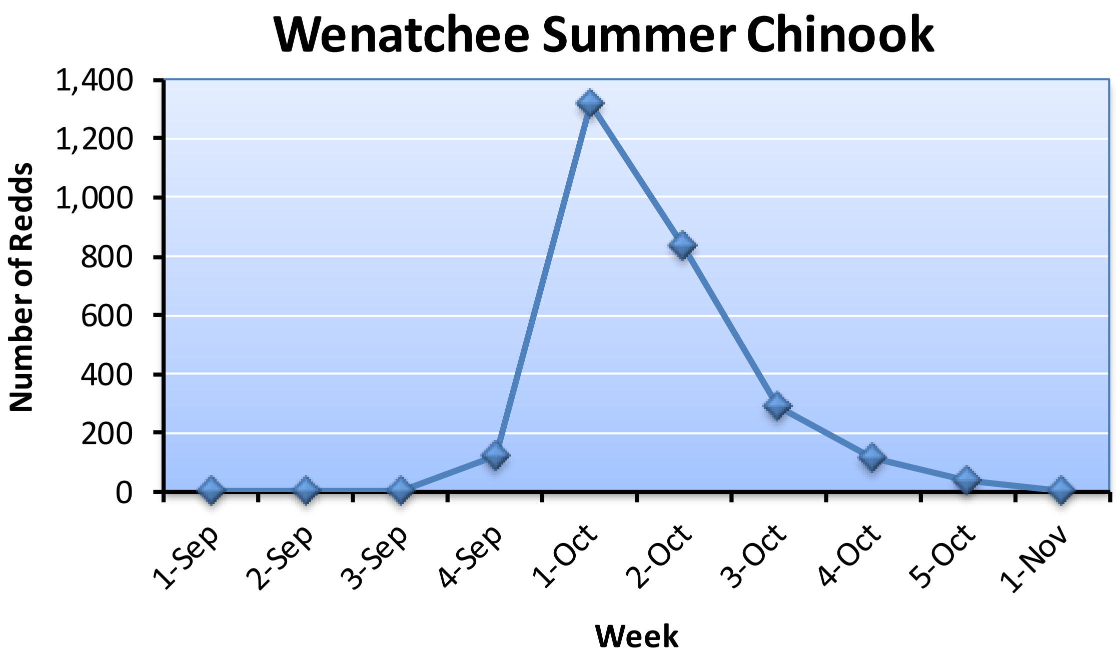


Figure 8.3. Number of new summer Chinook redds counted during different weeks in the Wenatchee River, September through mid-November 2016.

Spawning Escapement

Spawning escapement for Wenatchee summer Chinook was calculated as the total number of redds (expanded peak counts for return years 1989-2013) times the fish per redd ratio estimated from broodstock and fish sampled at adult trapping sites.[25] The estimated fish per redd ratio for summer Chinook in 2016 was 2.11. Multiplying this ratio by the number of redds counted in the Wenatchee River basin resulted in a total spawning escapement of 5,902 summer Chinook (Table 8.17). This is less than the overall average spawning escapement of 9,100 summer Chinook.

Table 8.17. Spawning escapements for summer Chinook in the Wenatchee River basin, return years 1989-2016. Number of redds is based on expanded peak redd counts for the period 1989-2013.

Return year	Fish/Redd	Redds	Total spawning escapement
1989	3.40	4,215	14,331
1990	3.50	3,103	10,861
1991	3.70	2,748	10,168
1992	4.00	2,913	11,652
1993	3.20	2,953	9,450
1994	3.30	3,077	10,154
1995	3.30	2,350	7,755
1996	3.40	1,814	6,168
1997	3.40	1,739	5,913

[25] Expansion factor = (1 + (number of males/number of females)).

Return year	Fish/Redd	Redds	Total spawning escapement
1998	2.40	2,230	5,352
1999	2.00	2,738	5,476
2000	2.17	2,540	5,512
2001	3.20	3,550	11,360
2002	2.30	6,836	15,723
2003	2.24	5,268	11,800
2004	2.15	4,874	10,479
2005	2.46	3,538	8,703
2006	2.00	8,896	17,792
2007	2.33	1,970	4,590
2008	2.32	2,800	6,496
2009	2.42	3,441	8,327
2010	2.29	3,261	7,468
2011	3.20	3,078	9,850
2012	3.41	2,504	8,539
2013	3.15	3,241	10,209
2014	3.02	3,458	10,443
2015	2.40	1,804	4,330
2016	2.11	2,797	5,902
Average	***2.81***	***3,348***	***9,100***
Median	***2.74***	***3,015***	***9,077***

8.6 Carcass Surveys

Surveys for Wenatchee summer Chinook carcasses were conducted from mid-September to early November 2016 in the Wenatchee River and Icicle Creek.

Number sampled

A total of 1,309 summer Chinook carcasses were sampled during early September through early November in the Wenatchee River basin in 2016 (Table 8.18).

Table 8.18. Numbers of summer Chinook carcasses sampled within each survey reach in the Wenatchee River basin, 1993-2016. Reach codes are described in Table 2.10.

Survey year	Number of summer Chinook carcasses											
	W-1	W-2	W-3	W-4	W-5	W-6	W-7	W-8	W-9	W-10	Icicle	Total
1993	68	151	696	13	82	150	215	41	0	0	0	**1,416**
1994	0	6	25	1	21	50	20	49	131	1	0	**304**
1995	0	10	14	0	0	117	50	37	20	0	0	**248**
1996	0	5	84	42	10	206	27	37	43	0	0	**454**
1997	1	47	127	5	29	312	8	80	70	13	0	**692**

Survey year	Number of summer Chinook carcasses											
	W-1	W-2	W-3	W-4	W-5	W-6	W-7	W-8	W-9	W-10	Icicle	Total
1998	6	81	159	4	1	270	32	395	354	65	0	**1,367**
1999	0	169	112	16	35	932	68	146	185	79	0	**1,742**
2000	8	118	178	9	85	693	82	121	172	208	0	**1,674**
2001	0	49	138	31	0	338	36	124	101	94	0	**911**
2002	0	249	189	0	205	848	0	341	564	166	6	**2,568**
2003	6	369	195	72	149	768	66	266	537	58	40	**2,526**
2004	8	157	193	177	173	1,086	103	346	493	409	16	**3,161**
2005	8	85	106	39	46	709	70	140	353	258	7	**1,821**
2006	22	140	160	64	112	953	435	343	703	658	18	**3,608**
2007	3	15	49	10	26	475	38	38	96	91	8	**849**
2008	10	34	63	38	36	676	47	42	106	144	8	**1,204**
2009	11	29	43	32	27	389	16	58	240	175	6	**1,026**
2010	3	31	98	57	122	681	135	49	124	194	15	**1,509**
2011	5	88	126	19	38	1,332	77	45	211	289	9	**2,239**
2012	8	82	95	22	40	600	53	62	173	183	0	**1,318**
2013	3	100	149	22	109	767	5	60	353	265	14	**1,847**
2014	3	42	64	18	59	659	89	160	329	282	34	**1,739**
2015	9	7	36	15	19	296	27	110	314	150	5	**988**
2016	7	55	96	33	90	494	27	79	245	178	5	**1,309**
Average	***8***	***88***	***133***	***31***	***63***	***575***	***72***	***132***	***247***	***165***	***8***	***1522***
Median	***6***	***68***	***109***	***21***	***39***	***630***	***49***	***80***	***198***	***158***	***6***	***1392***

Carcass Distribution and Origin

Summer Chinook carcasses were not evenly distributed among reaches within the Wenatchee River basin in 2016 (Table 8.18; Figure 8.4). Most of the carcasses in the Wenatchee River basin were found upstream from the Leavenworth Bridge. The highest percentage of carcasses (37.8%) was sampled in Reach 6.

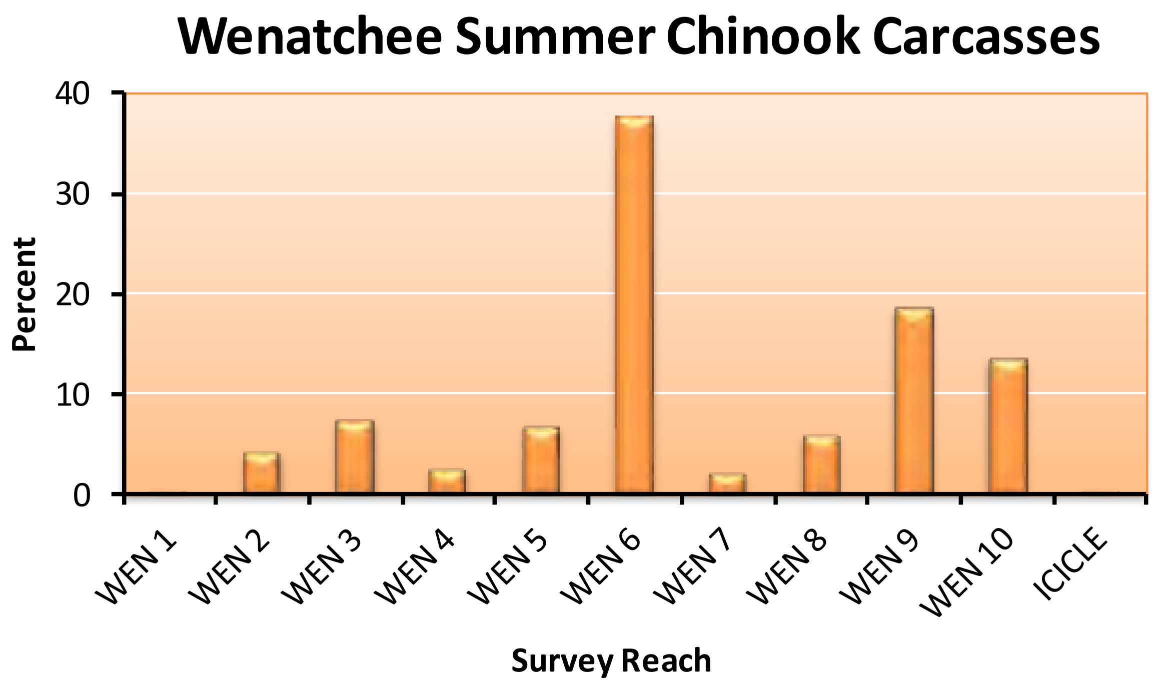


Figure 8.4. Percent of summer Chinook carcasses sampled within different reaches in the Wenatchee River basin during September through mid-November 2016. Reach codes are described in Table 2.10.

As in previous years, regardless of origin, most summer Chinook were found in Reach 6 (Leavenworth Bridge to Icicle Road Bridge) (Table 8.19). In general, a larger percentage of wild fish were found in the upper reaches than were hatchery fish (Figure 8.5). In contrast, a larger percentage of hatchery fish were found in reaches downstream from the Icicle Road Bridge.

Table 8.19. Numbers of wild and hatchery summer Chinook carcasses sampled within different reaches in the Wenatchee River basin, 1993-2016.

Survey year	Origin	Survey reach											Total
		W-1	W-2	W-3	W-4	W-5	W-6	W-7	W-8	W-9	W-10	Icicle	
1993	Wild	59	146	660	12	82	133	213	40	0	0	0	**1,345**
	Hatchery	9	5	36	1	0	17	2	1	0	0	0	**71**
1994	Wild	0	2	18	1	19	36	20	49	130	1	0	**276**
	Hatchery	0	4	7	0	2	14	0	0	1	0	0	**28**
1995	Wild	0	4	11	0	0	105	50	35	20	0	0	**225**
	Hatchery	0	6	3	0	0	12	0	2	0	0	0	**23**
1996	Wild	0	5	82	40	9	196	27	37	43	0	0	**439**
	Hatchery	0	0	2	2	1	10	0	0	0	0	0	**15**
1997	Wild	1	38	112	5	22	266	8	80	69	13	0	**614**
	Hatchery	0	9	15	0	7	46	0	0	1	0	0	**78**
1998	Wild	6	62	124	3	1	191	29	374	327	62	0	**1,179**
	Hatchery	0	19	35	1	0	79	3	21	27	3	0	**188**
1999	Wild	0	88	70	8	18	600	58	137	169	75	0	**1,223**

Survey year	Origin	Survey reach											Total
		W-1	W-2	W-3	W-4	W-5	W-6	W-7	W-8	W-9	W-10	Icicle	
	Hatchery	0	81	42	8	17	332	10	9	16	4	0	**519**
2000	Wild	5	78	115	8	57	485	75	110	167	200	0	**1,300**
	Hatchery	3	40	63	1	28	208	7	11	5	8	0	**374**
2001	Wild	0	37	100	9	0	245	32	122	97	91	0	**733**
	Hatchery	0	12	38	22	0	93	4	2	4	3	0	**178**
2002	Wild	0	151	127	0	103	479	0	330	558	161	3	**1,912**
	Hatchery	0	98	62	0	102	369	0	11	6	5	3	**656**
2003	Wild	5	261	147	32	111	519	62	252	498	57	15	**1,959**
	Hatchery	1	108	48	40	38	249	4	14	39	1	25	**567**
2004	Wild	7	124	163	120	112	749	90	316	481	399	11	**2,572**
	Hatchery	1	33	30	56	61	337	13	30	12	10	5	**588**
2005	Wild	4	49	78	24	26	399	66	125	336	244	0	**1,351**
	Hatchery	4	36	28	15	20	310	4	15	17	14	7	**470**
2006	Wild	15	91	122	44	75	688	388	309	646	593	5	**2,976**
	Hatchery	7	49	38	20	37	265	47	34	57	65	13	**632**
2007	Wild	1	7	24	1	10	197	34	30	95	81	3	**483**
	Hatchery	2	8	25	9	16	278	4	8	1	10	5	**366**
2008	Wild	7	15	38	24	21	361	41	31	98	133	2	**771**
	Hatchery	3	19	25	14	15	315	6	11	8	11	6	**433**
2009	Wild	6	22	32	23	19	288	13	55	236	173	4	**871**
	Hatchery	5	7	11	9	8	101	3	3	4	2	2	**155**
2010	Wild	2	22	62	44	64	477	125	47	121	192	0	**1,156**
	Hatchery	1	9	36	13	58	204	10	2	3	2	15	**353**
2011	Wild	4	46	75	11	25	914	74	45	211	287	3	**1,695**
	Hatchery	1	42	51	7	13	418	3	0	0	2	6	**543**
2012	Wild	4	49	72	13	24	490	47	62	173	182	0	**1,116**
	Hatchery	4	33	23	9	16	110	6	0	0	1	0	**202**
2013	Wild	1	63	89	16	69	374	5	59	340	261	0	**1,277**
	Hatchery	2	52	60	6	40	395	0	1	13	4	0	**573**
2014	Wild	3	35	57	16	48	572	89	158	329	281	12	**1600**
	Hatchery	0	7	7	2	11	87	0	2	0	0	22	**139**
2015	Wild	6	6	36	13	16	263	26	107	301	148	6	**928**
	Hatchery	3	1	0	2	3	33	1	3	13	2	0	**61**
2016	Wild	5	40	78	29	75	426	27	79	243	175	4	**1,181**
	Hatchery	2	15	18	4	15	68	0	0	3	3	1	**129**
Average	***Wild***	***6***	***60***	***104***	***21***	***42***	***394***	***67***	***125***	***237***	***159***	***3***	***1,216***
	Hatchery	***2***	***29***	***29***	***10***	***21***	***181***	***5***	***8***	***10***	***6***	***5***	***306***
Median	***Wild***	***4***	***43***	***78***	***13***	***25***	***387***	***44***	***80***	***192***	***155***	***0***	***1,180***
	Hatchery	***1***	***17***	***29***	***7***	***15***	***157***	***3***	***3***	***4***	***3***	***1***	***278***

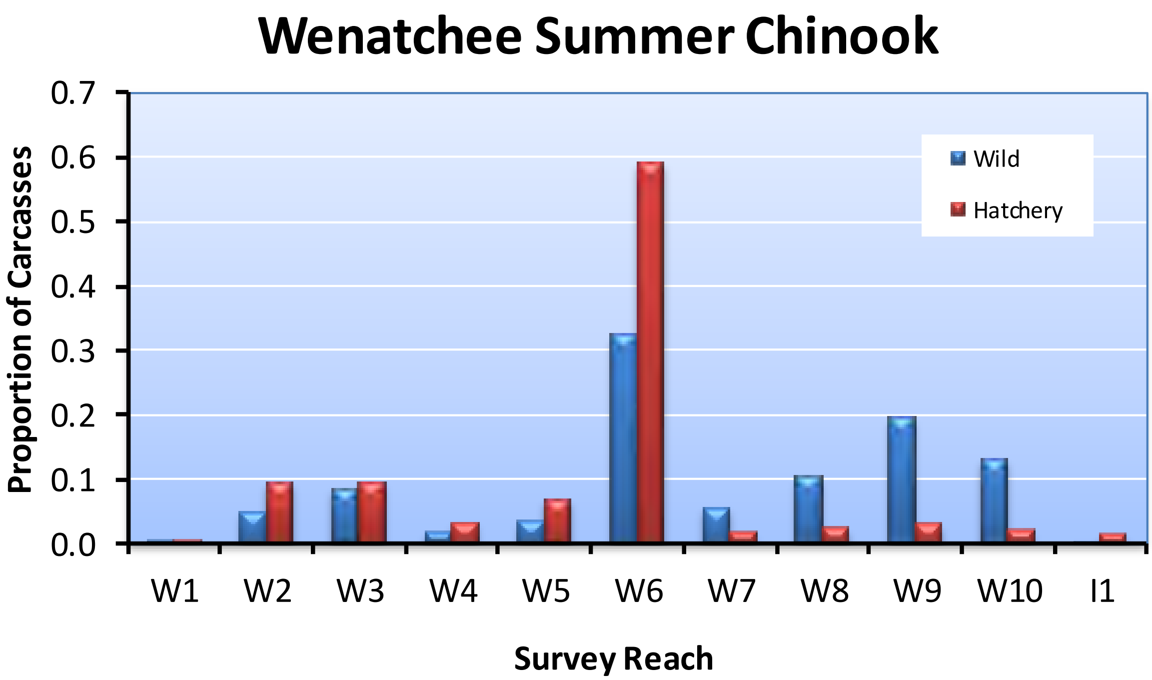


Figure 8.5. Distribution of wild and hatchery produced carcasses in different reaches in the Wenatchee River basin, 1993-2016. Reach codes are described in Table 2.10.

Sampling Rate

If spawning escapement is based on total numbers of redds, then about 22% of the total spawning escapement of summer Chinook in the Wenatchee River basin was sampled in 2016 (Table 8.20). Sampling rates among survey reaches varied from 7 to 332%.

Table 8.20. Number of redds and carcasses, total spawning escapement, and sampling rates for summer Chinook in the Wenatchee River basin, 2016.

Sampling reach	Total number of redds	Total number of carcasses	Total spawning escapement	Sampling rate
Wenatchee 1 (W1)	1	7	2	3.32
Wenatchee 2 (W2)	144	55	304	0.18
Wenatchee 3 (W3)	224	96	473	0.20
Wenatchee 4 (W4)	41	33	87	0.38
Wenatchee 5 (W5)	103	90	217	0.41
Wenatchee 6 (W6)	687	494	1,450	0.34
Wenatchee 7 (W7)	192	27	405	0.07
Wenatchee 8 (W8)	309	79	652	0.12
Wenatchee 9 (W9)	502	245	1,059	0.23
Wenatchee 10 (W10)	522	178	1,101	0.16
Icicle Creek (I1)	72	5	152	0.08
Total	***2,797***	***1,309***	***5,902***	***0.22***

Length Data

Mean lengths (POH, cm) of male and female summer Chinook carcasses sampled during surveys in the Wenatchee River basin in 2016 are provided in Table 8.21. The average size of males and females sampled in the Wenatchee River basin were 68 cm and 70 cm, respectively.

Table 8.21. Mean lengths (postorbital-to-hypural length; cm) and standard deviations (in parentheses) of male and female summer Chinook carcasses sampled in different streams/watersheds in the Wenatchee River basin, 2016.

Stream/watershed	Mean length (cm)	
	Male	Female
Wenatchee 1 (W1)	63.0 (10.2)	70.0 (0)
Wenatchee 2 (W2)	71.5 (8.3)	70.9 (5.1)
Wenatchee 3 (W3)	70.2 (10.2)	70.4 (4.8)
Wenatchee 4 (W4)	71.9 (6.7)	69.5 (2.9)
Wenatchee 5 (W5)	67.0 (8.7)	69.1 (5.0)
Wenatchee 6 (W6)	69.0 (6.9)	69.4 (4.8)
Wenatchee 7 (W7)	69.8 (10.3)	71.6 (4.4)
Wenatchee 8 (W8)	67.5 (8.4)	67.3 (4.9)
Wenatchee 9 (W9)	67.7 (8.1)	70.8 (4.0)
Wenatchee 10 (W10)	66.0 (8.2)	67.4 (5.8)
Icicle Creek (I1)	62.0 (0)	75.3 (2.6)
Total	***68.2 (8.3)***	***69.5 (4.9)***

8.7 Life History Monitoring

Life history characteristics of Wenatchee summer Chinook were assessed by examining carcasses on spawning grounds and fish collected or examined at broodstock collection sites, and by reviewing tagging data and fisheries statistics.

Migration Timing

Migration timing of hatchery and wild Wenatchee summer Chinook was determined from broodstock data and stock assessment data collected at Dryden Dam. Sampling at Dryden Dam occurs from early July through mid-October. On average, during the early part of the migration, hatchery summer Chinook arrived about two weeks later than wild Chinook (Table 8.22). This pattern carried through the migration distribution of summer Chinook at Dryden Dam. By the end of the migration, hatchery fish passed Dryden Dam about two weeks after 90% of the wild fish passed the dam.

Table 8.22. The week that 10%, 50% (median), and 90% of the wild and hatchery summer Chinook salmon passed Dryden Dam, 2007-2016. The average week is also provided. Migration timing is based on collection of summer Chinook broodstock at Dryden Dam.

Survey year	Origin	Wenatchee Summer Chinook Migration Time (week)				Sample size
		10 Percentile	50 Percentile	90 Percentile	Mean	
2007	Wild	28	31	37	31	274
	Hatchery	30	33	41	35	305
2008	Wild	29	31	40	32	219
	Hatchery	32	37	41	37	576
2009	Wild	27	29	41	31	469
	Hatchery	28	34	42	35	382
2010	Wild	30	33	35	32	403
	Hatchery	29	30	33	30	268
2011	Wild	30	31	34	32	293
	Hatchery	32	34	39	35	304
2012	Wild	30	32	39	33	247
	Hatchery	31	37	41	36	366
2013	Wild	28	30	34	31	494
	Hatchery	29	33	39	33	570
2014	Wild	29	31	37	32	512
	Hatchery	29	32	40	33	338
2015	Wild	25	30	40	31	511
	Hatchery	28	35	40	35	88
2016	Wild	28	30	40	32	407
	Hatchery	29	34	41	35	184
Average	***Wild***	***28***	***31***	***38***	***32***	***383***
	Hatchery	***30***	***34***	***40***	***34***	***338***
Median	***Wild***	***29***	***31***	***38***	***32***	***405***
	Hatchery	***29***	***34***	***41***	***35***	***322***

Age at Maturity

Because hatchery summer Chinook are released after one year of rearing and natural-origin summer Chinook migrate primarily as age-0 fish, total ages will differ between hatchery and natural-origin Chinook (see Hillman et al. 2011). Therefore, in this section, we evaluated age at maturity by comparing differences in salt (ocean) ages between the two groups.

Most of the wild and hatchery summer Chinook sampled during the period 1993-2016 in the Wenatchee River basin were salt age-3 fish (Table 8.23; Figure 8.6). Over the survey years, a higher percentage of salt age-4 wild Chinook returned to the basin than did salt age-4 hatchery Chinook. In contrast, a higher proportion of salt age-1 and 2 hatchery fish returned than did salt age-1 and 2 wild fish. Thus, a higher percentage of wild fish returned at an older age than did hatchery fish.

Table 8.23. Proportions of wild and hatchery summer Chinook of different salt (ocean) ages sampled on spawning grounds in the Wenatchee River basin, 1993-2016.

Sample year	Origin	Salt age					Sample size
		1	2	3	4	5	
1993	Wild	0.02	0.24	0.62	0.12	0.00	1,224
	Hatchery	0.03	0.91	0.03	0.03	0.00	64
1994	Wild	0.02	0.21	0.45	0.32	0.00	257
	Hatchery	0.00	0.14	0.86	0.00	0.00	21
1995	Wild	0.02	0.15	0.65	0.18	0.00	216
	Hatchery	0.00	0.00	0.05	0.95	0.00	21
1996	Wild	0.01	0.25	0.66	0.08	0.00	512
	Hatchery	0.00	0.33	0.33	0.29	0.05	21
1997	Wild	0.01	0.24	0.57	0.18	0.00	561
	Hatchery	0.05	0.20	0.67	0.08	0.00	75
1998	Wild	0.02	0.23	0.66	0.09	0.00	1,041
	Hatchery	0.03	0.49	0.38	0.10	0.00	187
1999	Wild	0.01	0.34	0.55	0.10	0.00	1,087
	Hatchery	0.01	0.15	0.79	0.05	0.00	510
2000	Wild	0.02	0.20	0.64	0.15	0.00	1,181
	Hatchery	0.07	0.11	0.66	0.15	0.00	342
2001	Wild	0.01	0.16	0.74	0.08	0.00	653
	Hatchery	0.05	0.76	0.14	0.04	0.00	181
2002	Wild	0.00	0.14	0.62	0.24	0.00	1,744
	Hatchery	0.01	0.16	0.80	0.02	0.00	646
2003	Wild	0.01	0.07	0.51	0.41	0.00	1,653
	Hatchery	0.05	0.07	0.75	0.12	0.00	530
2004	Wild	0.00	0.12	0.32	0.54	0.01	2,233
	Hatchery	0.08	0.57	0.25	0.10	0.00	566
2005	Wild	0.00	0.12	0.75	0.13	0.00	1,190
	Hatchery	0.02	0.09	0.86	0.03	0.00	450
2006	Wild	0.00	0.02	0.27	0.71	0.00	2,972
	Hatchery	0.02	0.16	0.24	0.57	0.00	299
2007	Wild	0.01	0.09	0.31	0.53	0.07	480
	Hatchery	0.00	0.15	0.75	0.07	0.03	275
2008	Wild	0.01	0.06	0.76	0.17	0.00	767
	Hatchery	0.02	0.12	0.76	0.11	0.00	329
2009	Wild	0.01	0.07	0.51	0.41	0.00	797
	Hatchery	0.10	0.36	0.49	0.05	0.00	132
2010	Wild	0.01	0.18	0.65	0.16	0.00	1,068
	Hatchery	0.00	0.49	0.47	0.03	0.00	294

Sample year	Origin	Salt age					Sample size
		1	2	3	4	5	
2011	Wild	0.01	0.11	0.60	0.29	0.00	1,533
	Hatchery	0.06	0.04	0.90	0.01	0.00	472
2012	Wild	0.00	0.04	0.48	0.48	0.00	1,017
	Hatchery	0.00	0.03	0.88	0.08	0.03	200
2013	Wild	0.00	0.07	0.58	0.34	0.01	1,277
	Hatchery	0.00	0.01	0.13	0.86	0.00	573
2014	Wild	0.00	0.05	0.70	0.25	0.00	1,437
	Hatchery	0.02	0.06	0.20	0.70	0.02	128
2015	Wild	0.00	0.09	0.40	0.51	0.00	819
	Hatchery	0.00	0.10	0.65	0.24	0.00	49
2016	Wild	0.00	0.03	0.66	0.31	0.00	1,023
	Hatchery	0.03	0.11	0.83	0.03	0.00	97
Average	***Wild***	***0.01***	***0.12***	***0.54***	***0.33***	***0.00***	***1,114***
	Hatchery	***0.03***	***0.20***	***0.59***	***0.18***	***0.00***	***269***
Median	***Wild***	***0.01***	***0.11***	***0.67***	***0.21***	***0.00***	***1,055***
	Hatchery	***0.03***	***0.29***	***0.57***	***0.11***	***0.00***	***238***

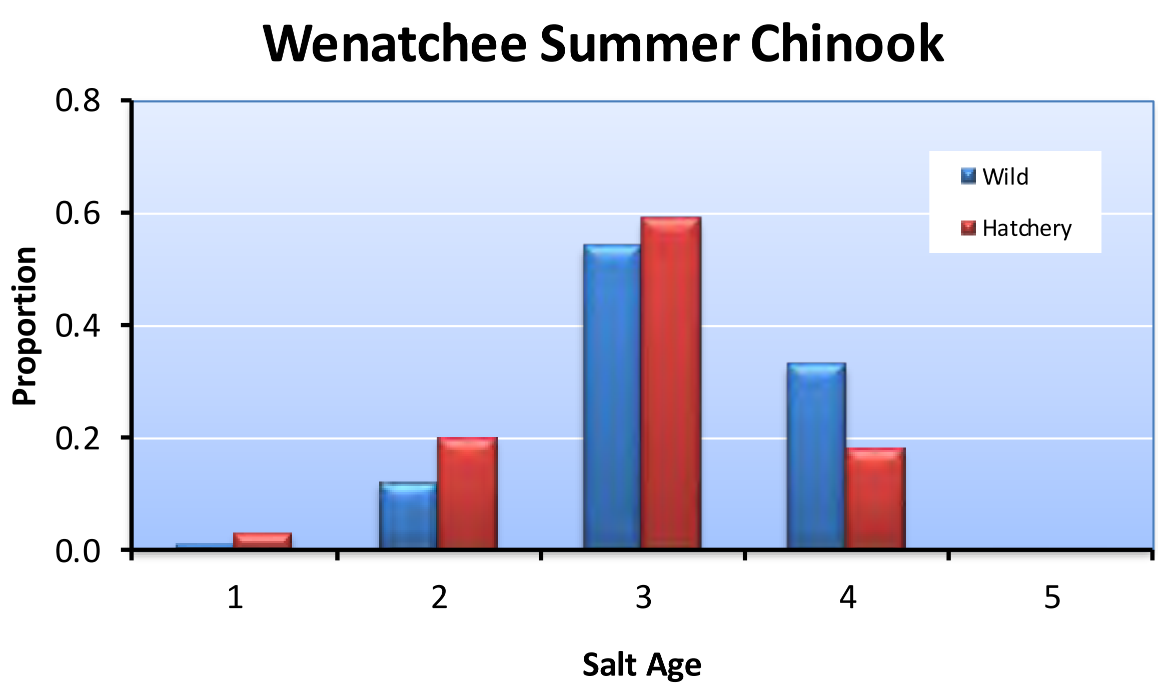


Figure 8.6. Proportions of wild and hatchery summer Chinook of different salt (ocean) ages sampled at broodstock collection sites and on spawning grounds in the Wenatchee River basin for the combined years 1993-2016.

Size at Maturity

On average, hatchery summer Chinook were about 4 cm smaller than wild summer Chinook sampled in the Wenatchee River basin (Table 8.24). This is likely because a higher percentage of hatchery fish returned as salt age-2 and 3 fish than did wild fish. In contrast, a higher percentage of wild fish returned as salt age-4 fish than did hatchery fish. Analyses for the five-year reports will compare sizes of hatchery and wild fish of the same age groups and sex.

Table 8.24. Mean lengths (POH; cm) and variability statistics for wild and hatchery summer Chinook sampled in the Wenatchee River basin, 1993-2016; SD = 1 standard deviation.

Sample year	Origin	Sample size	Summer Chinook length (POH; cm)			
			Mean	SD	Minimum	Maximum
1993[a]	Wild	1,344	73	8	33	94
	Hatchery	68	61	9	37	83
1994[a]	Wild	276	73	8	31	89
	Hatchery	25	70	8	54	85
1995[a]	Wild	225	75	7	48	87
	Hatchery	23	74	7	57	85
1996[a]	Wild	210	74	7	43	92
	Hatchery	9	66	12	52	84
1997	Wild	614	74	8	29	99
	Hatchery	79	69	10	29	83
1998	Wild	1,179	73	8	28	97
	Hatchery	188	67	10	37	87
1999	Wild	1,217	72	8	29	95
	Hatchery	518	71	8	26	94
2000	Wild	1,301	71	10	24	94
	Hatchery	369	69	11	33	91
2001	Wild	728	70	9	30	93
	Hatchery	178	63	10	28	86
2002	Wild	1,911	72	8	39	94
	Hatchery	656	71	8	34	95
2003	Wild	1,943	74	9	24	105
	Hatchery	554	69	10	26	97
2004	Wild	2,570	72	9	32	98
	Hatchery	584	59	11	25	91
2005	Wild	1,352	69	7	41	92
	Hatchery	469	69	8	39	91
2006	Wild	3,249	74	6	29	99
	Hatchery	350	71	9	35	90
2007	Wild	566	73	9	29	92
	Hatchery	269	70	7	45	87

Sample year	Origin	Sample size	Summer Chinook length (POH; cm)			
			Mean	SD	Minimum	Maximum
2008	Wild	836	69	8	29	89
	Hatchery	363	70	9	24	94
2009	Wild	872	71	8	30	94
	Hatchery	153	64	11	32	84
2010	Wild	1,147	68	8	32	92
	Hatchery	351	65	10	25	87
2011	Wild	1,698	68	8	33	101
	Hatchery	541	66	9	34	85
2012	Wild	1,116	70	7	29	91
	Hatchery	202	60	7	40	79
2013	Wild	1,277	66	9	24	95
	Hatchery	573	67	7	24	85
2014	Wild	1,600	68	7	29	98
	Hatchery	139	66	10	26	85
2015	Wild	928	68	8	39	86
	Hatchery	61	62	9	36	81
2016	Wild	1,180	69	6	43	93
	Hatchery	129	67	8	37	82
Pooled	***Wild***	***29,339***	***71***	***8***	***32***	***94***
	Hatchery	***6,851***	***67***	***9***	***35***	***87***

[a] These years include sizes reported in annual reports. The data contained in the WDFW database do not include all these data.

Contribution to Fisheries

Most of the harvest on hatchery-origin Wenatchee summer Chinook occurred in the ocean (Table 8.25). Ocean harvest has made up 47% to 100% of all hatchery Wenatchee summer Chinook harvested. Total harvest on early brood years (1990-1996 and 2007) was lower than for brood years 1997-2010.

Table 8.25. Estimated number and percent (in parentheses) of hatchery-origin Wenatchee summer Chinook captured in different fisheries, brood years 1989-2010.

Brood year	Ocean fisheries	Columbia River Fisheries			Total
		Tribal	Commercial (Zones 1-5)	Recreational (sport)	
1989	1,510 (51)	1,432 (48)	0 (0)	20 (1)	2,962
1990	30 (100)	0 (0)	0 (0)	0 (0)	30
1991	30 (63)	0 (0)	0 (0)	18 (38)	48
1992	147 (79)	39 (21)	0 (0)	0 (0)	186
1993	35 (58)	25 (42)	0 (0)	0 (0)	60
1994	641 (91)	62 (9)	2 (0)	0 (0)	705
1995	562 (98)	9 (2)	5 (1)	0 (0)	576

Brood year	Ocean fisheries	Columbia River Fisheries			Total
		Tribal	Commercial (Zones 1-5)	Recreational (sport)	
1996	200 (96)	3 (1)	0 (0)	6 (3)	209
1997	3,033 (95)	49 (2)	12 (0)	106 (3)	3,200
1998	4,991 (92)	128 (2)	16 (0)	287 (5)	5,422
1999	1,550 (84)	168 (9)	21 (1)	104 (6)	1,843
2000	7,966 (73)	1,248 (11)	447 (4)	1,224 (11)	10,885
2001	1,061 (60)	238 (13)	106 (6)	364 (21)	1,769
2002	1,527 (56)	557 (21)	189 (7)	430 (16)	2,703
2003	833 (50)	484 (29)	89 (5)	257 (15)	1,663
2004	409 (47)	218 (25)	70 (8)	167 (19)	864
2005	1,329 (58)	481 (21)	187 (8)	287 (13)	2,284
2006	3,738 (52)	1,969 (27)	406 (6)	1,142 (16)	7,255
2007	212 (60)	81 (23)	8 (2)	53 (15)	354
2008	3,746 (59)	1,042 (16)	227 (4)	1,364 (21)	6,379
2009	1,594 (61)	453 (17)	99 (4)	452 (17)	2,598
2010	1,192 (51)	653 (28)	81 (3)	403 (17)	2,329
Average	***1,652 (70)***	***425 (17)***	***89 (3)***	***304 (11)***	***2,469***
Median	***1,127 (61)***	***193 (17)***	***19 (2)***	***137 (12)***	***1,806***

Straying

Stray rates were determined by examining CWTs recovered on spawning grounds within and outside the Wenatchee River basin. Targets for strays based on return year (recovery year) within the upper Columbia River basin (Priest Rapids Dam to Chief Joseph Dam) should be less than 10% and targets for strays outside the upper Columbia River should be less than 5%. The target for brood year stay rates should be less than 5%.

Hatchery-origin Wenatchee summer Chinook have strayed into the Entiat, Chelan, Methow, and Okanogan River basins and onto the Hanford Reach (Table 8.26). In only one year did Wenatchee summer Chinook strays make up more than 10% of the spawning escapement in the Chelan Tailrace. They made up more than 10% of the spawning escapement in the Entiat River basin in five different years. They made up less than 10% of the spawning escapements in the Methow and Okanogan River basins and the Hanford Reach.

Table 8.26. Number and percent of spawning escapements within other non-target spawning streams within the upper Columbia River basin that consisted of hatchery-origin Wenatchee summer Chinook, return years 1994-2015. For example, for return year 2000, 3% of the summer Chinook escapement in the Methow River basin consisted of hatchery-origin Wenatchee summer Chinook. Percent strays should be less than 10%.

Return year	Methow		Okanogan		Chelan		Entiat		Hanford Reach	
	Number	%	Number	%	Number	%	Number	%	Number	%
1994	0	0.0	75	1.9	--	--	--	--	--	--
1995	0	0.0	0	0.0	--	--	--	--	--	--
1996	0	0.0	0	0.0	--	--	--	--	--	--
1997	0	0.0	0	0.0	--	--	--	--	--	--
1998	25	3.7	0	0.0	0	0.0	0	0.0	0	0.0
1999	20	2.0	3	0.1	0	0.0	0	0.0	13	0.0
2000	36	3.0	13	0.4	0	0.0	0	0.0	0	0.0
2001	163	5.9	57	0.5	30	3.0	0	0.0	0	0.0
2002	153	3.3	53	0.4	40	6.9	74	14.8	0	0.0
2003	80	2.0	24	0.7	44	10.5	132	19.1	26	0.0
2004	113	5.2	42	0.6	30	7.1	0	0.0	0	0.0
2005	245	9.6	67	0.8	51	9.7	49	13.4	0	0.0
2006	170	6.2	12	0.1	12	2.9	61	10.6	0	0.0
2007	127	9.3	5	0.1	9	4.8	49	20.0	20	0.1
2008	87	4.5	24	0.3	10	2.0	31	9.7	0	0.0
2009	101	5.7	13	0.2	2	0.3	12	4.8	0	0.0
2010	206	8.3	35	0.6	55	4.9	34	7.8	0	0.0
2011	258	8.8	5	0.1	78	6.1	15	3.2	0	0.0
2012	109	3.7	24	0.3	53	4.1	54	6.0	0	0.0
2013	252	7.0	57	0.7	2	0.1	8	1.1	0	0.0
2014	15	0.9	0	0.0	4	0.4	12	2.2	0	0.0
2015	75	1.9	13	0.1	4	0.3	12	2.9	0	0.0
Average	***102***	***4.1***	***24***	***0.4***	***24***	***3.5***	***30***	***6.4***	***3***	***0.0***
Median	***94***	***3.7***	***13***	***0.2***	***11***	***3.0***	***14***	***4.0***	***0***	***0.0***

Based on brood year analyses, on average, about 10% of the hatchery-origin Wenatchee summer Chinook returns have strayed into non-target populations, exceeding the target of 5% (Table 8.27). Depending on brood year, percent strays into non-target spawning areas have ranged from 0-20%. In addition, on average, about 7% have strayed into non-target hatchery programs.

Table 8.27. Number and percent of hatchery-origin Wenatchee summer Chinook that homed to target spawning areas and the target hatchery program, and number and percent that strayed to non-target spawning areas and non-target hatchery programs, by brood years 1989-2010. Percent stays should be less than 5%.

Brood year	Homing				Straying			
	Target stream		Target hatchery*		Non-target streams		Non-target hatcheries	
	Number	%	Number	%	Number	%	Number	%
1989	1,352	62.9	60	2.8	75	3.5	662	30.8
1990	74	84.1	1	1.1	0	0.0	13	14.8
1991	15	65.2	0	0.0	0	0.0	8	34.8
1992	375	84.8	7	1.6	0	0.0	60	13.6
1993	67	72.8	9	9.8	4	4.3	12	13.0
1994	890	71.8	207	16.7	61	4.9	81	6.5
1995	748	74.8	139	13.9	48	4.8	65	6.5
1996	261	70.4	42	11.3	53	14.3	15	4.0
1997	3,609	83.0	171	3.9	397	9.1	170	3.9
1998	1,790	78.5	11	0.5	416	18.2	64	2.8
1999	507	79.7	0	0.0	121	19.0	8	1.3
2000	2,745	82.5	0	0.0	545	16.4	37	1.1
2001	521	80.4	0	0.0	118	18.2	9	1.4
2002	1,521	83.4	10	0.5	284	15.6	8	0.4
2003	1,268	88.5	42	2.9	114	8.0	9	0.6
2004	497	84.2	3	0.5	72	12.2	18	3.1
2005	1,126	84.0	3	0.2	193	14.4	19	1.4
2006	2,693	79.4	8	0.2	623	18.4	67	2.0
2007	99	78.0	1	0.8	25	19.7	2	1.6
2008	3,264	84.6	61	1.6	458	11.9	77	2.0
2009	762	78.6	54	5.6	108	11.1	45	4.6
2010	164	67.5	47	19.3	12	4.9	20	8.2
Average	***1,107***	***78.1***	***40***	***4.2***	***169***	***10.4***	***67***	***7.2***
Median	***755***	***79.6***	***10***	***1.4***	***92***	***11.5***	***20***	***3.5***

* Homing to the target hatchery includes Wenatchee hatchery summer Chinook that are captured and included as broodstock in the Wenatchee Hatchery program. These hatchery fish are typically collected at Dryden and Tumwater dams.

Genetics

Genetic studies were conducted in 2011 to investigate relationships among temporally replicated collections of summer Chinook from the Wenatchee River, Methow River, and Okanogan River in the upper Columbia River basin (Kassler et al. 2011; the entire report is appended as Appendix N). A total of 2,416 summer Chinook were collected from tributaries in the upper Columbia River basin. Two collections of natural-origin summer Chinook from 1993 (prior to the supplementation program) were taken from the Wenatchee River basin (N = 139) and compared to collections of hatchery and natural-origin Chinook from 2006 and 2008 (N = 380). Two pre-supplementation collections from the Methow River (1991 and 1993) were compared to supplementation collections from 2006 and 2008 (N = 362). Three pre-supplementation collections from the Okanogan River Basin (1991, 1992, and 1993) were compared with supplementation collections from 2006 and 2008 (N = 669). A collection of natural-origin summer Chinook from the Chelan River was also analyzed (N = 70). Additionally, hatchery collections from Eastbank Hatchery (Wenatchee and Methow/Okanogan stock; N = 221) and Wells Hatchery (N = 294) were analyzed and compared to the in-river collections. Summer Chinook data (provided by the USFWS) from the Entiat River (N = 190) were used for comparison. Lastly, data from eight collections of fall Chinook (N = 2,408) were compared to the collections of summer Chinook. Samples of natural and hatchery-origin summer Chinook were analyzed and compared to determine if the supplementation programs have affected the genetic structure of these populations. The study also calculated the effective number of breeders for collection locations of natural and hatchery-origin summer Chinook from 1993 and 2008.

In general, population differentiation was not observed among the temporally replicated collection locations. A single collection from the Okanogan River (1993) was the only collection showing statistically significant differences. The effective number of breeders was not statistically different from the early collection in 1993 in comparison to the late collection in 2008. Overall, these analyses revealed a lack of differentiation among the temporal replicates from the same locations and among the collection from different locations, suggesting the populations have been homogenized or that there has been substantial gene flow among populations. Additional comparisons among summer-run and fall-run Chinook populations in the upper Columbia River were conducted to determine if there was any differentiation between Chinook with different run timing. These analyses revealed pairwise F_{ST} values that were less than 0.01 for the collections of summer Chinook to collections of fall Chinook from Hanford Reach, lower Yakima River, Priest Rapids, and Umatilla. Collections of fall Chinook from Crab Creek, Lyons Ferry Hatchery, Marion Drain, and Snake River had pairwise F_{ST} values that were higher in comparison to the collections of summer Chinook. The consensus clustering analysis did not provide good statistical support to the groupings, but did show relationships among collections based on geographic proximity. Overall the summer and fall run Chinook that have historically been spawned together were not differentiated while fall Chinook from greater geographic distances were differentiated.

It is important to note that no new information will be reported on genetics until the next five-year report (2018).

Proportionate Natural Influence

Another method for assessing the genetic risk of a supplementation program is to determine the influence of the hatchery and natural environments on the adaptation of the composite population. This is estimated by the proportion of natural-origin fish in the hatchery broodstock (pNOB) and the proportion of hatchery-origin fish in the natural spawning escapement (pHOS). We calculated Proportionate Natural Influence (PNI) by iterating Ford's (2002) equations 5 and 6 to equilibrium, using a heritability of 0.3 and a selection strength of three standard deviations. The larger the PNI value, the greater the strength of selection in the natural environment relative to that of the hatchery environment. For the natural environment to dominate selection, PNI should be greater than 0.50, and important integrated populations should have a PNI of at least 0.67 (HSRG/WDFW/NWIFC 2004).

For all brood years the PNI value has been greater than or equal to 0.67 (Table 8.28). This suggests that the natural environment has a greater influence on adaptation of Wenatchee summer Chinook than does the hatchery environment.

Table 8.28. Proportionate Natural Influence (PNI) values for the Wenatchee summer Chinook supplementation program for brood years 1989-2015. NOS = number of natural-origin Chinook on the spawning grounds; HOS = number of hatchery-origin Chinook on the spawning grounds; NOB = number of natural-origin Chinook collected for broodstock; and HOB = number of hatchery-origin Chinook included in hatchery broodstock.

Brood year	Spawners			Broodstock			PNI[a]
	NOS	HOS	pHOS	NOB	HOB	pNOB	
1989	14,331	0	0.00	290	0	1.00	1.00
1990	10,861	0	0.00	57	0	1.00	1.00
1991	10,168	0	0.00	105	0	1.00	1.00
1992	11,652	0	0.00	274	0	1.00	1.00
1993	8,868	582	0.06	406	44	0.90	0.94
1994	8,476	1,678	0.17	333	54	0.86	0.84
1995	6,862	893	0.12	363	16	0.96	0.89
1996	6,002	166	0.03	263	3	0.99	0.97
1997	5,408	505	0.09	205	13	0.94	0.92
1998	4,611	741	0.14	299	78	0.79	0.85
1999	4,101	1,375	0.25	242	236	0.51	0.68
2000	4,462	1,050	0.19	275	180	0.60	0.77
2001	9,414	1,946	0.17	210	136	0.61	0.79
2002	11,892	3,831	0.24	409	10	0.98	0.81
2003	10,025	1,775	0.15	337	7	0.98	0.87
2004	9,220	1,259	0.12	424	2	1.00	0.90
2005	6,862	1,841	0.21	397	3	0.99	0.83
2006	16,060	1,732	0.10	433	4	0.99	0.91
2007	3,173	1,417	0.31	263	3	0.99	0.77
2008	4,452	2,044	0.31	378	69	0.85	0.74
2009	7,098	1,229	0.15	452	8	0.98	0.87
2010	5,886	1,582	0.21	388	5	0.99	0.83
2011	8,150	1,700	0.17	376	7	0.98	0.86
2012	7,327	1,212	0.14	267	1	1.00	0.88
2013	7,431	2,778	0.27	234	2	0.99	0.79
2014	9,676	767	0.07	261	2	0.99	0.94
2015	4,076	254	0.06	245	0	1.00	0.95
Average	***8,020***	***1,198***	***0.14***	***303***	***33***	***0.92***	***0.87***
Median	***7,431***	***1,229***	***0.14***	***290***	***5***	***0.99***	***0.87***

[a] PNI was calculated previously using PNI approximate equation 11 (HSRG 2009; their Appendix A). All PNI values presented here were recalculated by iterating Ford's (2002) equations 5 and 6 to equilibrium using a heritability of 0.3 and a selection strength of three standard deviations. C. Busack, NOAA Fisheries, 21 March 2016, provided the model for calculating PNI.

Post-Release Survival and Travel Time

We used PIT-tagged fish to estimate survival rates and travel time (arithmetic mean days) of hatchery summer Chinook from the Wenatchee River release site to McNary Dam, and smolt to adult ratios (SARs) from release to detection at Bonneville Dam (Table 8.29).[26] Over the six brood years for which PIT-tagged hatchery fish were released, survival rates from the Wenatchee River to McNary Dam ranged from 0.619 to 0.910; SARs from release to detection at Bonneville Dam ranged from 0.001 to 0.017. Average travel time from the Wenatchee River to McNary Dam ranged from 11 to 29 days.

Most of the variation in survival rates and travel time resulted from releases of different experimental groups (Table 8.29). For example, brood year 2009 was split into three groups (control raceway group, long-term recirculating aquaculture system (RAS) group (R1), and short-term RAS group (R2)). In this case, the control group appeared to have a higher survival rate but a longer travel time from release to McNary Dam than did the two treatment groups. SARs varied little among the three groups.

Another experiment was conducted with brood years 2012 and 2013. These brood years were split into four different treatment groups (small-size fish in raceway, large-size fish in raceway, small-size fish in RAS, and large-size fish in RAS). Although the number of replicates is small, releases from the RAS had higher survival rates to McNary Dam and faster travel times. Large-size fish from the RAS had the highest survival rates and fastest travel times.

Table 8.29. Total number of Wenatchee hatchery summer Chinook released with PIT tags, their survival and travel times (mean days) to McNary Dam, and smolt-to-adult (SAR) ratios for brood years 2008-2014. Standard errors are shown in parentheses. RAS = recirculating aquaculture system; NA = not available (i.e., not all the fish from the release groups have returned to the Columbia River).

Brood year	Number of tagged fish released	Survival to McNary Dam	Travel time to McNary Dam (d)	SAR to Bonneville Dam
2008	10,035	0.847 (0.054)	28.9 (9.6)	0.017 (0.001)
2009	9,965 (Control)	0.702 (0.039)	19.3 (10.3)	0.006 (0.001)
	9,971 (R1)	0.646 (0.030)	16.4 (8.8)	0.005 (0.001)
	9,994 (R2)	0.648 (0.031)	16.0 (8.4)	0.005 (0.001)
2010	0	--	--	--
2011	5,018	0.753 (0.070)	20.9 (8.9)	0.010 (0.001)
2012 (Raceway)	5,047 (small size)	0.724 (0.066)	18.9 (9.2)	0.001 (0.001)
	4,740 (large size)	0.619 (0.061)	16.9 (8.6)	0.002 (0.001)
2012 (RAS)	5,041 (small size)	0.784 (0.060)	11.8 (5.0)	0.001 (0.000)
	5,082 (large size)	0.910 (0.077)	11.1 (4.6)	0.002 (0.001)
2013 (Raceway)	5,196 (small size)	0.692 (0.054)	19.3 (6.1)	NA
	5,158 (large size)	0.823 (0.071)	19.1 (5.6)	NA

[26] It is important to point out that because of fish size differences among rearing tanks or raceways, fish PIT tagged in one tank or raceway may not represent untagged fish rearing in other tanks or raceways.

Brood year	Number of tagged fish released	Survival to McNary Dam	Travel time to McNary Dam (d)	SAR to Bonneville Dam
2013 (RAS)	5,229 (small size)	0.788 (0.057)	18.1 (5.6)	NA
	5,201 (large size)	0.859 (0.068)	16.8 (4.8)	NA
2014	10,241 (Circular)	0.800 (0.083)	15.1 (4.9)	NA
	10,243 (Raceway)	0.735 (0.065)	17.1 (6.1)	NA

Natural and Hatchery Replacement Rates

Natural replacement rates (NRR) were calculated as the ratio of natural-origin recruits (NOR) to the parent spawning population (spawning escapement). Natural-origin recruits are naturally produced (wild) fish that survive to contribute to harvest (directly or indirectly), to broodstock, and to spawning grounds. We do not account for fish that died in route to the spawning grounds (migration mortality) or died just before spawning (pre-spawn mortality) (see Appendix B in Hillman et al. 2012). We calculated NORs with and without harvest. NORs without harvest include all returning fish that either returned to the basin or were collected as wild broodstock. NORs with harvest include all fish harvested and are based on brood year harvest rates from the hatchery program. For brood years 1989-2009, NRR for summer Chinook in the Wenatchee averaged 0.98 (range, 0.15-2.95) if harvested fish were not included in the estimate and 2.60 (range, 0.33-9.55) if harvested fish were included in the estimate (Table 8.30). NRRs for more recent brood years will be calculated as soon as all tag recoveries and sampling rates have been loaded into the database.

Hatchery replacement rates (HRR) are the hatchery adult-to-adult returns and were calculated as the ratio of hatchery-origin recruits (HOR) to the parent broodstock collected. These rates should be greater than the NRRs and greater than or equal to 5.7 (the calculated target value in Hillman et al. 2013). The target value of 5.7 includes harvest. HRRs exceeded NRRs in 16 of the 21 years of data, regardless if harvest was or was not included in the estimate (Table 8.30). Hatchery replacement rates for Wenatchee summer Chinook have exceeded the estimated target value of 5.7 in 10 of the 21 years of data.

Table 8.30. Broodstock collected, spawning escapements, natural and hatchery-origin recruits (NOR and HOR), and natural and hatchery replacement rates (NRR and HRR; with and without harvest) for summer Chinook in the Wenatchee River basin, brood years 1989-2009.

Brood year	Broodstock Collected	Spawning Escapement	Harvest not included				Harvest included			
			HOR	NOR	HRR	NRR	HOR	NOR	HRR	NRR
1989	346	14,331	2,149	9,181	6.21	0.64	5,111	21,808	14.77	1.52
1990	87	10,861	88	9,595	1.01	0.88	118	12,984	1.36	1.20
1991	128	10,168	23	5,562	0.18	0.55	71	17,167	0.55	1.69
1992	341	11,652	442	5,858	1.30	0.50	628	8,393	1.84	0.72
1993	524	9,450	92	5,385	0.18	0.57	152	8,901	0.29	0.94
1994	418	10,154	1,239	4,219	2.96	0.42	1,944	6,634	4.65	0.65
1995	398	7,755	1,000	5,329	2.51	0.69	1,576	8,459	3.96	1.09
1996	334	6,168	371	4,441	1.11	0.72	580	6,896	1.74	1.12

Brood year	Broodstock Collected	Spawning Escapement	Harvest not included				Harvest included			
			HOR	NOR	HRR	NRR	HOR	NOR	HRR	NRR
1997	240	5,913	4,347	9,761	18.11	1.65	7,547	16,743	31.45	2.83
1998	472	5,352	2,289	15,795	4.83	2.95	7,703	51,117	16.32	9.55
1999	488	5,476	636	12,081	1.30	2.21	2,479	44,253	5.08	8.08
2000	492	5,512	3,334	3,885	6.76	0.70	14,212	15,988	28.89	2.90
2001	493	11,360	648	19,209	1.31	1.69	2,417	70,621	4.90	6.22
2002	482	15,723	1,823	4,954	3.78	0.32	4,526	12,354	9.39	0.79
2003	496	11,800	1,433	1,782	2.89	0.15	3,096	3,874	6.24	0.33
2004	496	10,479	590	7,197	1.19	0.69	1,454	17,468	2.93	1.67
2005	494	8,703	1,345	5,131	2.71	0.59	3,625	13,190	7.34	1.52
2006	488	17,792	3,394	6,814	6.95	0.38	10,646	17,121	21.82	0.96
2007	419	4,590	127	10,733	0.30	2.34	481	30,064	1.15	6.55
2008	472	6,496	3,887	6,282	8.18	0.97	10,239	12,873	21.69	1.98
2009	491	8,327	969	7,434	1.97	0.89	3,567	19,667	7.26	2.36
Average	***409***	***9,432***	***1,439***	***7,649***	***3.61***	***0.98***	***3,913***	***19,837***	***9.22***	***2.60***
Median	***472***	***9,450***	***1,000***	***6,282***	***2.51***	***0.69***	***2,479***	***15,988***	***5.08***	***1.52***

Smolt-to-Adult Survivals

Smolt-to-adult survival ratios (SARs) were calculated as the number of hatchery adult recaptures divided by the number of tagged hatchery smolts released. Here, SARs were based on CWT returns. For the available brood years, SARs have ranged from 0.00037 to 0.01562 for hatchery summer Chinook in the Wenatchee River basin (Table 8.31).

Table 8.31. Smolt-to-adult ratios (SARs) for Wenatchee hatchery summer Chinook, brood years 1989-2010.

Brood year	Number of tagged smolts released[a]	Estimated adult captures[b]	SAR
1989	144,905	1,027	0.00709
1990	119,214	115	0.00096
1991	190,371	71	0.00037
1992	605,055	613	0.00101
1993	210,626	152	0.00072
1994	452,340	1,919	0.00424
1995	668,409	1,542	0.00231
1996	585,590	572	0.00098
1997	480,418	7,506	0.01562
1998	641,109	7,630	0.01190
1999	988,328	2,457	0.00249
2000	903,368	13,861	0.01534

Brood year	Number of tagged smolts released[a]	Estimated adult captures[b]	SAR
2001	596,618	2,403	0.00403
2002	805,919	4,395	0.00545
2003	639,381	3,048	0.00477
2004	875,758	1,439	0.00164
2005	631,492	3,578	0.00567
2006	931,880	10,468	0.01123
2007	453,719	481	0.00106
2008	859,401	9,934	0.01156
2009	822,986	3,538	0.00430
2010	789,056	2,570	0.00326
Average	***608,907***	***3,605***	***0.00527***
Median	***635,437***	***2,430***	***0.00414***

[a] Includes all tag codes and CWT released fish (CWT + Ad Clip fish and CWT-only fish).

[b] Includes estimated recoveries (spawning ground, hatcheries, harvest, etc.) and observed recoveries if estimated recoveries were unavailable.

8.8 ESA/HCP Compliance

Broodstock Collection

Per the 2014 broodstock collection protocol, 278 natural-origin (adipose fin present) summer Chinook adults were targeted for collection at Dryden and Tumwater dams. The actual 2014 collection totaled 281 summer Chinook (279 natural-origin and two hatchery-origin; the hatchery-origin fish were not direct collections but rather adipose-present non-wired fish with a hatchery scale pattern) in combination from Dryden and Tumwater dams. Trapping began 23 June and ended 24 September2014.

Summer Chinook and steelhead broodstock collections occurred concurrently at Dryden Dam. Thus, steelhead and spring Chinook encounters at Dryden Dam during Wenatchee summer Chinook broodstock collection were attributable to steelhead broodstock collections authorized under ESA Permit 1395 take authorizations. No steelhead or spring Chinook takes were associated with the Wenatchee summer Chinook collection. No bull trout were encountered during summer Chinook broodstock collection at Dryden Dam in 2014.

Consistent with impact minimization measures in ESA Permit 1347, all ESA-listed species handled during summer Chinook broodstock collection were subject to water-to-water transfers or anesthetized if removed from the water during handling.

Hatchery Rearing and Release

The 2014 Wenatchee summer Chinook program released an estimated 535,255 smolts, representing 107.1% of the 500,001-programmed production, and was within the 110% overage allowance identified in ESA permit 1347.

Hatchery Effluent Monitoring

Per ESA Permits 1196, 1347, 1395, 18118, 18120, and 18121, permit holders shall monitor and report hatchery effluents in compliance with applicable National Pollution Discharge Elimination Systems (NPDES) (EPA 1999) permit limitations. There were no NPDES violations reported at PUD Hatchery facilities during the period 1 January through 31 December 2016. NPDES monitoring and reporting for Chelan PUD Hatchery Programs during 2016 are provided in Appendix F.

Smolt and Emigrant Trapping

ESA-listed spring Chinook and steelhead were encountered during operation of the Lower Wenatchee Trap. ESA takes are reported in the steelhead (Section 3.8) and spring Chinook (Section 5.8) sections and are not repeated here.

Spawning Surveys

Summer Chinook spawning ground surveys conducted in the Wenatchee River basin during 2016 were consistent with ESA Section 10 Permit No. 1347. Because of the difficulty of quantifying the level of take associated with spawning ground surveys, the Permit does not specify a take level associated with these activities, even though it does authorize implementation of spawning ground surveys. Therefore, no take levels are reported. However, to minimize potential effects to established redds, wading was restricted to the extent practical, and extreme caution was used to avoid established redds when wading was required.

SECTION 9: METHOW SUMMER CHINOOK

The original goal of summer Chinook salmon supplementation in the Methow Basin was in part to use artificial production to replace adult production lost because of mortality at Wells, Rocky Reach, and Rock Island dams[27], while not reducing the natural production or long-term fitness of summer Chinook in the basin. The Rock Island Fish Hatchery Complex began operation in 1989 under funding from Chelan PUD. The Complex operated originally through the Rock Island Settlement Agreement, but since 2004 has operated under the Anadromous Fish Agreement and Habitat Conservation Plans. Beginning with broodstock collection in 2012, Grant PUD took over the summer Chinook salmon supplementation program in the Methow River basin. Grant PUD constructed a new overwinter acclimation facility adjacent to the Carlton Acclimation Pond and the first fish released from this facility was 2014. The first fish that were overwinter acclimated in the facility were released in 2015. The new facility includes eight, 30-foot diameter dual-drain circular tanks.

Presently, adult summer Chinook are collected for broodstock from the run-at-large at the west-ladder trapping facility at Wells Dam. Before 2012, the goal was to collect up to 222 natural-origin adult summer Chinook for the Methow program. In 2011, the Hatchery Committees reevaluated that amount of hatchery compensation needed to achieve NNI. Based on that evaluation, the goal of the program was revised. The current goal (beginning in 2012) is to collect up to 102 natural-origin summer Chinook for the Methow program. Broodstock collection occurs from about 1 July through 15 September with trapping occurring no more than 16 hours per day, three days a week. If natural-origin broodstock collection falls short of expectation, hatchery-origin adults can be collected to make up the difference.

Adult summer Chinook are spawned and reared at Eastbank Fish Hatchery. Juvenile summer Chinook were transferred from the hatchery to Carlton Acclimation Pond in March until overwinter acclimation was initiated with the 2013 brood year. They are now transferred to the Carlton Acclimation Facility in October or November and released from the new facility in late April to early May.

Before 2012, the production goal for the Methow summer Chinook supplementation program was to release 400,000 yearling smolts into the Methow River at ten fish per pound. Beginning with the 2012 brood, the revised goal is to release 200,000 yearling smolts at 15 fish per pound. Targets for fork length and weight are 163 mm (CV = 9.0) and 45.4 g, respectively. Over 90% of these fish are marked with CWTs. In addition, since 2009, juvenile summer Chinook have been PIT tagged annually.

9.1 Broodstock Sampling

This section focuses on results from sampling 2014-2016 Methow summer Chinook broodstock that were collected in the West Ladder of Wells Dam.

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[27] Most of the production at Carlton Acclimation Pond is initial production, which terminated in 2013, and is not necessarily tied to hydro facility mortality. The balance of the production is the result of a swap between spring and summer Chinook. That is, Chelan PUD is currently producing summer Chinook at Carlton for Douglas PUD in exchange for Douglas PUD producing spring Chinook at the Methow Fish Hatchery for Chelan PUD.

Origin of Broodstock

Broodstock collected in 2014, 2015, and 2016 consisted almost entirely of natural-origin (adipose fin present) summer Chinook (Table 9.1).

Table 9.1. Numbers of wild and hatchery summer Chinook collected for broodstock, numbers that died before spawning, and numbers of Chinook spawned for the Methow/Okanogan programs during 1989-2011. Numbers of broodstock collected from 2012 to present are only for the Methow summer Chinook Program. Unknown origin fish (i.e., undetermined by scale analysis, no CWT or fin clips, and no additional hatchery marks) were considered naturally produced. Mortality includes fish that died of natural causes typically near the end of spawning and were not needed for the program and surplus fish killed at spawning.

Brood year	Wild summer Chinook					Hatchery summer Chinook					Total number spawned
	Number collected	Prespawn loss[a]	Mortality	Number spawned	Number released	Number collected	Prespawn loss[a]	Mortality	Number spawned	Number released	
1989[b]	1,419	72	-	1,297	-	341	17	-	312	-	1,609
1990[b]	864	34	-	828	-	214	8	-	206	-	1,034
1991[b]	1,003	59	-	924	-	341	20	-	314	-	1,238
1992[b]	312	6	-	297	-	428	9	-	406	-	703
1993[b]	813	48	-	681	-	464	28	-	388	-	1,069
1994	385	33	11	341	12	266	15	7	244	1	585
1995	254	13	10	173	58	351	28	9	240	74	413
1996	316	15	11	290	0	234	2	9	223	0	513
1997	214	11	5	198	0	308	24	20	264	0	462
1998	239	28	58	153	0	348	18	119	211	0	364
1999	248	5	19	224	0	307	2	16	289	0	513
2000	184	15	5	164	0	373	17	17	339	0	503
2001	135	8	36	91	0	423	29	128	266	0	357
2002	270	2	21	247	0	285	11	33	241	0	488
2003	449	14	53	381	0	112	2	9	101	0	482
2004	541	23	12	506	0	17	0	1	16	0	522
2005	551	29	76	391	55	12	2	0	9	1	400
2006	579	50	10	500	19	12	2	0	10	0	510
2007	504	22	26	456	0	19	0	2	17	0	473
2008	418	5	9	404	0	41	0	0	41	0	445
2009	553	31	15	507	0	5	5	0	0	0	507
2010	503	13	6	484	0	8	0	0	8	0	492
2011	498	18	13	467	0	30	4	0	26	0	493
Average[c]	***380***	***19***	***22***	***332***	***8***	***175***	***9***	***21***	***141***	***4***	***473***
Median[c]	***434***	***18***	***13***	***391***	***0***	***266***	***8***	***8***	***223***	***0***	***503***
2012	125	5	0	98	22	3	0	0	1	2	99
2013	98	1	0	97	0	4	0	0	4	0	101
2014	100	4	0	96	0	0	0	0	0	0	96
2015	97	0	0	97	0	1	0	0	1	0	98
2016	106	2	1	103	0	0	0	0	0	0	103
Average[d]	***105***	***2***	***0***	***98***	***4***	***2***	***0***	***0***	***1***	***0***	***99***
Median[d]	***100***	***2***	***0***	***97***	***0***	***1***	***0***	***0***	***1***	***0***	***99***

[a] Pre-spawn loss represents the number of fish that died during the holding period before spawning. Mortality is the number of fish that were surplused following spawning.

[b] Number of fish spawned and collected during these years included fish retained from the right- and left-bank ladder traps at Wells Dam and fish collected from the volunteer channel. There was no distinction made between fish collected at trap locations and program (i.e., aggregated population used for Wells, Methow, and Okanogan summer Chinook programs).
[c] The average and median represent broodstock collected for the combined Methow and Okanogan programs. Because of bias from aggregating the spawning population from 1989-1993, averages are based on adult numbers collected from 1994-2011.
[d] The average and median represent broodstock collected only for the Methow program.

Age/Length Data

Ages of summer Chinook broodstock were determined from analysis of scales and/or CWTs. Broodstock collected from the 2014 return consisted primarily of age-4 and 5 natural-origin Chinook (95.8%). Age-3 natural-origin fish made up 4.1% of the broodstock (Table 9.2).

Broodstock collected from the 2015 return consisted primarily of age-4 and 5 natural-origin Chinook (87.8%). Age-3 natural-origin Chinook made up 12.2% of the broodstock (Table 9.2).

Broodstock collected from the 2016 return consisted primarily of age-4 and 5 natural-origin Chinook (97.8%). Age-3 natural-origin Chinook made up 1.1% of the broodstock (Table 9.2).

Table 9.2. Percent of hatchery and wild summer Chinook of different ages (total age) collected from broodstock for the Methow/Okanogan programs, 1991-2016.

Return Year	Origin	Total age				
		2	3	4	5	6
1991	Wild	0.5	6.8	35.1	55.4	2.2
	Hatchery	0.5	5.1	36.2	49.0	9.2
1992	Wild	0.0	13.0	36.2	50.7	0.0
	Hatchery	0.0	0.0	0.0	0.0	0.0
1993	Wild	0.0	3.9	75.3	20.8	0.0
	Hatchery	0.0	1.0	85.7	13.3	0.0
1994	Wild	3.1	9.7	26.3	60.3	0.6
	Hatchery	0.0	14.7	11.2	74.0	0.0
1995	Wild	0.0	4.6	15.3	75.6	4.6
	Hatchery	0.0	0.4	13.0	25.6	61.0
1996	Wild	0.0	8.4	56.7	30.4	4.6
	Hatchery	0.0	3.0	31.0	47.0	19.0
1997	Wild	0.5	9.4	53.0	35.1	2.0
	Hatchery	0.0	20.6	11.1	61.8	6.5
1998	Wild	1.1	12.1	56.3	30.5	0.0
	Hatchery	2.1	18.9	56.2	16.0	6.8
1999	Wild	4.7	5.1	53.7	36.0	0.5
	Hatchery	0.3	3.5	29.3	65.0	1.9
2000	Wild	0.6	14.0	28.7	56.1	0.6
	Hatchery	0.0	27.0	14.3	54.3	4.3
2001	Wild	0.0	23.5	58.8	11.8	5.9
	Hatchery	1.8	21.1	64.6	10.1	2.4
2002	Wild	0.4	17.4	65.6	16.6	0.0

Return Year	Origin	Total age				
		2	3	4	5	6
	Hatchery	0.0	2.4	39.4	58.3	0.0
2003	Wild	0.7	3.9	65.8	29.5	0.0
	Hatchery	0.0	5.6	18.7	70.1	5.6
2004	Wild	0.6	15.4	11.6	72.2	0.2
	Hatchery	0.0	6.7	53.3	33.3	6.7
2005	Wild	0.0	17.1	69.9	11.0	1.9
	Hatchery	0.0	10.0	40.0	50.0	0.0
2006	Wild	1.7	3.0	41.0	52.9	1.5
	Hatchery	0.0	16.7	25.0	50.0	8.3
2007	Wild	1.8	15.3	8.2	70.3	4.4
	Hatchery	0.0	0.0	21.1	57.9	21.1
2008	Wild	0.3	17.9	67.1	13.3	1.4
	Hatchery	0.0	7.2	62.7	47.7	2.4
2009	Wild	1.3	10.1	68.7	19.9	0.0
	Hatchery	0.0	0.0	16.7	83.3	0.0
2010	Wild	0.2	16.2	51.0	32.6	0.0
	Hatchery	0.0	12.5	50.0	25.0	12.5
2011	Wild	0.1	7.1	75.5	17.0	0.0
	Hatchery	0.0	30.0	20.0	40.0	0.0
2012	Wild	0.0	3.9	49.0	46.1	1.0
	Hatchery	0.0	0.0	0.0	100.0	0.0
2013	Wild	0.0	15.2	70.7	14.1	0.0
	Hatchery	0.0	0.0	50.0	50.0	0.0
2014	Wild	0.0	4.1	71.1	24.7	0.0
	Hatchery	0.0	0.0	0.0	0.0	0.0
2015	Wild	0.0	12.2	42.2	45.6	0.0
	Hatchery	0.0	0.0	100.0	0.0	0.0
2016	Wild	0.0	1.1	71.7	26.1	1.1
	Hatchery	0.0	0.0	0.0	0.0	0.0
Average	***Wild***	***0.7***	***10.4***	***50.9***	***36.7***	***1.3***
	Hatchery	***0.2***	***7.9***	***32.7***	***41.6***	***6.7***
Median	***Wild***	***0.3***	***9.9***	***55.0***	***31.6***	***0.6***
	Hatchery	***0.0***	***4.3***	***27.2***	***48.4***	***2.4***

Mean lengths of natural-origin summer Chinook of a given age differed little among return years 2014-2016 (Table 9.3). For 2015, average fork lengths for age-4 natural-origin adults were 8 cm longer than that of age-4 hatchery fish (Table 9.3). There were no hatchery-origin adults collected for the 2014 and 2016 brood. Differences in hatchery-origin and natural-origin fish were hard to assess given the small sample size of hatchery-origin fish (i.e., few hatchery fish were included in the broodstock).

Table 9.3. Mean fork length (cm) at age (total age) of hatchery and wild Methow/Okanogan summer Chinook collected from broodstock for the Methow/Okanogan programs, 1991-2016; N = sample size and SD = 1 standard deviation.

Return year	Origin	Summer Chinook fork length (cm)														
		Age-2			Age-3			Age-4			Age-5			Age-6		
		Mean	N	SD	Mean	N	SD	Mean	N	SD	Mean	N	SD	Mean	N	SD
1991	Wild	47	1	-	68	15	6	82	78	10	94	123	8	97	5	5
	Hatchery	47	1	-	49	10	6	78	71	5	91	96	8	96	18	6
1992	Wild	-	0	-	55	9	5	69	25	6	78	35	6	-	0	-
	Hatchery	-	0	-	-	0	-	-	0	-	-	0	-	-	0	-
1993	Wild	-	0	-	72	3	4	86	58	7	98	16	5	-	0	-
	Hatchery	-	0	-	42	1	-	75	84	8	88	13	6	-	0	-
1994	Wild	42	10	6	50	31	7	80	84	9	93	193	8	104	2	13
	Hatchery	-	0	-	49	38	5	76	29	7	88	191	7	-	0	-
1995	Wild	-	0	-	67	6	8	79	20	9	96	99	5	94	6	5
	Hatchery	-	0	-	52	1	-	73	32	9	89	63	9	95	150	7
1996	Wild	-	0	-	68	22	9	83	149	8	95	79	7	101	12	5
	Hatchery	-	0	-	52	7	10	77	72	7	90	109	8	100	44	6
1997	Wild	31	1	-	60	19	7	85	107	8	96	71	7	98	4	11
	Hatchery	-	0	-	45	63	5	72	34	9	92	189	7	97	20	7
1998	Wild	39	2	1	59	23	6	83	107	7	96	58	7	-	0	-
	Hatchery	43	7	6	50	64	6	74	190	7	92	54	8	98	23	5
1999	Wild	38	10	3	64	11	8	82	115	7	96	76	6	104	1	-
	Hatchery	37	1	-	53	11	9	75	92	6	91	204	6	98	6	5
2000	Wild	39	1	-	66	23	7	83	47	6	96	92	5	95	1	-
	Hatchery	-	0	-	54	100	7	78	53	8	92	201	6	99	16	6
2001	Wild	-	0	-	63	4	12	88	10	9	90	2	4	94	1	-
	Hatchery	41	9	3	55	107	9	79	327	8	93	51	7	101	12	9
2002	Wild	56	1	-	65	44	7	88	166	6	100	42	7	-	0	-
	Hatchery	-	0	-	45	6	5	76	100	7	95	148	5	-	0	-
2003	Wild	43	3	6	61	16	6	87	268	7	99	120	6	-	0	-
	Hatchery	-	0	-	55	6	9	73	20	8	91	75	7	102	6	9
2004	Wild	51	3	5	67	78	6	81	59	6	97	367	7	99	1	-
	Hatchery	-	0	-	52	1	-	70	8	5	97	5	8	109	1	-
2005	Wild	-	0	-	68	89	6	83	363	7	94	57	6	101	10	7
	Hatchery	-	0	-	55	1	-	70	4	4	89	5	4	-	0	-
2006	Wild	38	9	3	54	16	4	69	221	6	77	286	5	78	8	4
	Hatchery	-	0	-	42	2	1	62	3	2	69	6	6	76	1	-
2007	Wild	39	8	5	53	69	5	67	37	6	78	317	5	77	20	7
	Hatchery	-	0	-	-	0	-	54	4	2	75	11	5	78	4	3
2008	Wild	41	1	-	55	62	4	69	233	6	76	46	4	82	5	3

Return year	Origin	Summer Chinook fork length (cm)														
		Age-2			Age-3			Age-4			Age-5			Age-6		
		Mean	N	SD	Mean	N	SD	Mean	N	SD	Mean	N	SD	Mean	N	SD
	Hatchery	-	0	-	59	6	9	67	52	5	73	23	6	79	2	8
2009	Wild	38	7	5	54	54	5	72	367	5	79	106	5	-	0	-
	Hatchery	-	0	-	-	0	-	59	1	-	71	5	7	-	0	-
2010	Wild	43	1	-	54	78	5	71	246	5	78	157	5	-	0	-
	Hatchery	-	0	-	57	1	-	67	4	5	79	2	1	89	1	-
2011	Wild	43	2	3	66	32	8	87	338	7	97	76	5	-	0	-
	Hatchery	-	0	-	63	9	11	78	9	6	92	12	9	-	0	-
2012	Wild	-	0	-	70	10	3	84	62	5	96	54	6	-	0	-
	Hatchery	-	0	-	-	0	-	-	0	-	90	1	-	-	0	-
2013	Wild	-	0	-	72	14	5	86	65	7	97	13	5	-	0	-
	Hatchery	-	0	-	-	0	-	76	2	6	92	2	0	-	0	-
2014	Wild	-	0	-	75	4	3	88	69	6	94	24	4	-	0	-
	Hatchery	-	0	-	-	0	-	-	0	-	-	0	-	-	0	-
2015	Wild	-	0	-	71	11	4	83	38	5	94	41	6	-	0	-
	Hatchery	-	0	-	-	0	-	75	1	0	-	0	-	-	0	-
2016	Wild	-	0	-	72	1	-	84	66	6	96	24	7	102	1	-
	Hatchery	-	0	-	-	0	-	-	0	-	-	0	-	-	0	-
Average	***Wild***	***42***	***2***	***4***	***63***	***28***	***6***	***81***	***128***	***7***	***92***	***99***	***6***	***95***	***4***	***7***
	Hatchery	***42***	***1***	***5***	***52***	***17***	***7***	***72***	***45***	***6***	***87***	***58***	***6***	***94***	***11***	***6***

Sex Ratios

Male summer Chinook in the 2014 broodstock made up about 50.0% of the adults collected, resulting in an overall male to female ratio of 1.00:1.00 (Table 9.4.). In 2015, males made up about 51.0% of the adults collected, resulting in an overall male to female ratio of 1.02:1.00 (Table 9.4). In 2016, males made up about 49% of the adults collected, resulting in an overall male to female ratio of 0.96:1.00 (Table 9.4). The ratios for 2014 and 2015 broodstock were above or at the assumed 1:1 ratio goal in the broodstock protocol.

Table 9.4. Numbers of male and female wild and hatchery summer Chinook collected for broodstock at Wells Dam for the Methow/Okanogan programs, 1991-2016. Ratios of males to females are also provided.

Return year	Number of wild summer Chinook			Number of hatchery summer Chinook			Total M/F ratio
	Males (M)	Females (F)	M/F	Males (M)	Females (F)	M/F	
1989[a]	752	667	1.13:1.00	181	160	1.13:1.00	1.13:1.00
1990[a]	381	482	0.79:1.00	95	120	0.79:1.00	0.79:1.00
1991[a]	443	559	0.79:1.00	151	191	0.79:1.00	0.79:1.00
1992[a]	349	318	1.10:1.00	38	35	1.09:1.00	1.10:1.00
1993[a]	513	300	1.71:1.00	293	171	1.71:1.00	1.71:1.00
1994	205	180	1.14:1.00	165	101	1.63:1.00	1.32:1.00
1995	103	149	0.69:1.00	158	197	0.80:1.00	0.75:1.00
1996	178	138	1.29:1.00	132	102	1.29:1.00	1.29:1.00

Return year	Number of wild summer Chinook			Number of hatchery summer Chinook			Total M/F ratio
	Males (M)	Females (F)	M/F	Males (M)	Females (F)	M/F	
1997	102	112	0.91:1.00	174	134	1.30:1.00	1.12:1.00
1998	130	109	1.19:1.00	263	85	3.09:1.00	2.03:1.00
1999	138	110	1.25:1.00	161	146	1.10:1.00	1.17:1.00
2000	82	102	0.80:1.00	243	130	1.87:1.00	1.40:1.00
2001	89	46	1.93:1.00	311	112	2.78:1.00	2.53:1.00
2002	166	104	1.60:1.00	149	136	1.10:1.00	1.31:1.00
2003	255	194	1.31:1.00	61	51	1.20:1.00	1.29:1.00
2004	263	278	0.95:1.00	12	5	2.40:1.00	0.97:1.00
2005	365	186	1.96:1.00	6	6	1.00:1.00	1.93:1.00
2006	287	292	0.98:1.00	9	3	3.00:1.00	1.00:1.00
2007	228	276	0.83:1.00	11	8	1.38:1.00	0.84:1.00
2008	210	208	1.01:1.00	13	28	0.46:1.00	0.94:1.00
2009	261	292	0.89:1.00	2	3	0.67:1.00	0.89:1.00
2010	248	255	0.97:1.00	5	3	1.67:1.00	0.98:1.00
2011	236	262	0.90:1.00	23	7	3.29:1.00	0.96:1.00
2012	50	53	0.94:1.00	1	0	--	0.96:1.00
2013	49	49	1.00:1.00	3	1	3.00:1.00	1.04:1.00
2014	50	50	1.00:1.00	0	0	--	1.00:1.00
2015	49	49	1.00:1.00	1	0	--	1.02:1.00
2016	52	54	0.96:1.00	0	0	--	0.96:1.00
Total[b]	***3796***	***3548***	***1.07:1.00***	***1903***	***1258***	***1.51:1.00***	***1.19:1.00***

[a] Numbers and male to female ratios were derived from the aggregate population collected at Wells Fish Hatchery volunteer channel and left- and right-ladder traps at Wells Dam.
[b] Total values were derived from 1994-present data to exclude aggregate population bias from 1989-1993 returns.

Fecundity

Fecundities for the 2014, 2015, and 2016 summer Chinook broodstock averaged 4,685, 4,410, and 4,509 eggs per female, respectively (Table 9.5). These values are close to the overall average of 4,899 eggs per female. Mean observed fecundities for the 2014, 2015, and 2016 returns were below the expected fecundity of 4,982, 4,861, and 4,721 eggs per female assumed in the broodstock protocols, respectively.

Table 9.5. Mean fecundity of wild, hatchery, and all female summer Chinook collected for broodstock at Wells Dam for the Methow/Okanogan programs, 1989-2016; NA = not available.

Return year	Mean fecundity		
	Wild	Hatchery	Total
1989*	NA	NA	4,750
1990*	NA	NA	4,838
1991*	NA	NA	4,819
1992*	NA	NA	4,804
1993*	NA	NA	4,849

Return year	Mean fecundity		
	Wild	Hatchery	Total
1994*	NA	NA	5,907
1995*	NA	NA	4,930
1996*	NA	NA	4,870
1997	5,166	5,296	5,237
1998	5,043	4,595	4,833
1999	4,897	4,923	4,912
2000	5,122	5,206	5,170
2001	5,040	4,608	4,735
2002	5,306	5,258	5,279
2003	5,090	4,941	5,059
2004	5,130	5,118	5,130
2005	4,545	4,889	4,553
2006	4,854	4,824	4,854
2007	5,265	5,093	5,260
2008	4,814	4,588	4,787
2009	5,115	--	5,115
2010	5,124	4,717	5,116
2011	4,594	3,915	4,578
2012	4,470	--	4,470
2013	4,700	5,490	4,717
2014	4,685	--	4,685
2015	4,410	--	4,410
2016	4,509	--	4,509
Average	***4,894***	***4,897***	***4,899***
Median	***4,969***	***4,923***	***4,844***

* Individual fecundities were not assigned to females until 1997 brood.

9.2 Hatchery Rearing

Rearing History

Number of eggs taken

Based on the unfertilized egg-to-release survival standard of 81%, a total of 493,827 eggs were needed to meet the program release goal of 400,000 smolts for brood years 1989-2011. An evaluation of the program in 2011 determined that 246,913 eggs are needed to meet the revised release goal of 200,000 smolts. This revised goal began with brood year 2012. From 1989 through 2011, the egg take goal was reached in eight of those years (Table 9.6). From 2012 to present, the egg take goal was not achieved (Table 9.6).

Table 9.6. Numbers of eggs taken from summer Chinook broodstock collected at Wells Dam for the Methow/Okanogan programs, 1989-2016.

Return year	Number of eggs taken
1989	482,800
1990	464,097
1991	586,594
1992	486,260
1993	531,490
1994	595,390
1995	491,000
1996	448,000
1997	401,162
1998	389,346
1999	483,726
2000	403,268
2001	279,272
2002	466,530
2003	473,681
2004	537,210
2005	305,826
2006	509,334
2007	549,802
2008	441,778
2009	560,602
2010	505,188
2011	488,747
Average (1989-2011)	***473,091***
Median (1989-2011)	***483,726***
2012	245,245
2013	231,136
2014	223,839
2015	216,098
2016	239,025
Average (2012-present)	***231,069***
Median (2012-present)	***231,136***

Number of acclimation days

Improvements to Carlton Acclimation Pond made overwinter rearing feasible beginning with the 2013 brood Methow summer Chinook. Fish are held on well water at Eastbank Fish Hatchery before being transferred to Carlton Acclimation Pond for final acclimation on Methow River water in October (Table 9.7). Only the 1994 and 1995 broods were reared for longer durations at the Methow Fish Hatchery on Methow River water.

Table 9.7. Number of days Methow summer Chinook were acclimated at Carlton Acclimation Pond, brood years 1989-2014.

Brood year	Release year	Transfer date	Release date	Number of days
1989	1991	15-Mar	6-May	52
1990	1992	26-Feb	28-Apr	61
1991	1993	10-Mar	23-Apr	44
1992	1994	4-Mar	21-Apr	48
1993	1995	18-Mar	2-May	45
1994	1996	25-Sep	28-Apr	215
		19-Mar	28-Apr	40
1995	1997	22-Oct	8-Apr	168
		19-Mar	22-Apr	34
1996	1998	9-Mar	14-Apr	36
1997	1999	10-Mar	20-Apr	41
1998	2000	19-Mar	2-May	44
1999	2001	18-Mar	18-Apr	31
2000	2002	28-Mar	1-May	34
2001	2003	27-Mar	24-Apr	28
2002	2004	16-Mar	24-Apr	39
2003	2005	18-Mar	21-Apr	34
2004	2006	12-Mar	22-Apr	41
2005	2007	12-Mar	15-Apr – 8-May	34-57
2006	2008	4-7-Mar	16-Apr – 2 May	40-59
2007	2009	18-24-Mar	21-Apr	28-34
2008	2010	4-5, 8-9-Mar	4-21-Apr	33-50
2009	2011	25, 29, 31-Mar & 4-Apr	11-25-Apr	8-31
2010	2012	19-21, 24-Mar	23-24-Apr	31-37
2011	2013	13-21-Mar	15-23-Apr	25-41
2012	2014	19-21-Mar	7-Apr – 14 May	18-57
2013	2015	20-21-Oct	13-May	204-205
2014	2016	26 & 28-Oct	18-Apr	173 & 175

Release Information

Numbers released

The 2014 brood Methow summer Chinook program achieved 83.3% of the 200,000 goal with about 167,616 Chinook being force released from the circular ponds on the night of 18 April 2016 (Table 9.8). Forced releases at night were initiated in 2016 to improve post-release survival.

Table 9.8. Numbers of Methow summer Chinook smolts released from the hatchery, brood years 1989-2014. Beginning with the 2014 release group (brood year 2012), the release target for Methow summer Chinook is 200,000 smolts.

Brood year	Release year	CWT mark rate	Number of smolts released
1989	1991	0.8529	420,000
1990	1992	0.9485	391,650
1991	1993	0.6972	540,900
1992	1994	0.9752	402,641
1993	1995	0.4623	433,375
1994	1996	0.9851	406,560
1995	1997	0.9768	353,182
1996	1998	0.9221	298,844
1997	1999	0.9884	384,909
1998	2000	0.9429	205,269
1999	2001	0.9955	424,363
2000	2002	0.9928	336,762
2001	2003	0.9902	248,595
2002	2004	0.9913	399,975
2003	2005	0.9872	354,699
2004	2006	0.9848	400,579
2005	2007	0.9897	263,723
2006	2008	0.9783	419,734
2007	2009	0.9837	433,256
2008	2010	0.9394	397,554
2009	2011	0.9862	404,956
2010	2012	0.9962	439,000
2011	2013	0.9734	436,092
Average (1989-2011)		***0.9365***	***382,462***
Median (1989-2011)		***0.9837***	***400,579***
2012	2014	0.9987	197,391
2013	2015	0.9903	188,834
2014	2016	0.9921	167,616
Average (2012-present)		***0.9937***	***184,614***
Median (2012-present)		***0.9921***	***188,834***

Numbers tagged

The 2014 brood Methow summer Chinook were 99% CWT and adipose fin-clipped (Table 9.8).

A total of 5,064 Methow summer Chinook (brood 2015) were PIT tagged at the Carlton Acclimation Facility on 27-29 March 2017. These fish were tagged in circular ponds #1 through #8. Fish were not fed during tagging or for two days before and after tagging. Fish averaged 130 mm in length and 28 g at time of tagging.

Table 9.9 summarizes the number of hatchery summer Chinook that have been PIT-tagged and released into the Methow River.

Table 9.9. Summary of PIT-tagging activities for Methow hatchery summer Chinook, brood years 2008-2014.

Brood year	Release year	Number of fish tagged	Number of tagged fish that died	Number of tags shed	Number of tagged fish released
2008	2010	10,100	4	0	10,096
2009	2011	5,050	17	9	5,024
2010	2012	0	0	0	0
2011	2013	0	0	0	0
2012	2014	10,099	41	7	10,051
2013	2015	10,159	35	1	10,123
2014	2016	5,000	8	0	4,992

Fish size and condition at release

A forced release of yearling Chinook smolts took place on the night of 18 April 2016. Size at release from the acclimated fish was 76.7% and 50.8% of the respective target fork length and weight goals, respectively (Table 9.10). This brood year exceeded the target CV for length by 20%.

Table 9.10. Mean lengths (FL, mm), weight (g and fish/pound), and coefficient of variation (CV) of Methow summer Chinook smolts released from the hatchery, brood years 1991-2014. Size targets are provided in the last row of the table.

Brood year	Release year	Fork length (mm)		Mean weight	
		Mean	CV	Grams (g)	Fish/pound
1991	1993	152	13.6	40.3	11
1992	1994	145	16.0	37.2	12
1993	1995	154	8.6	37.1	12
1994	1996	163	8.2	48.2	9
1995	1997	141	9.6	37.0	12
1996	1998	199	13.1	105.1	4
1997	1999	153	7.6	39.5	12
1998	2000	164	8.7	51.7	9
1999	2001	153	9.3	41.5	11

Brood year	Release year	Fork length (mm)		Mean weight	
		Mean	CV	Grams (g)	Fish/pound
2000	2002	170	10.2	54.2	8
2001	2003	167	7.4	52.7	9
2002	2004	148	13.1	35.7	13
2003	2005	148	10.1	35.5	13
2004	2006	142	9.8	31.1	15
2005	2007	158	15.0	42.2	11
2006	2008	156	18.0	42.8	11
2007	2009	138	21.0	32.1	14
2008	2010	155	14.2	42.0	11
2009	2011	170	15.8	56.9	8
2010	2012	145	16.7	34.5	13
2011	2013	160	13.0	43.6	6
Average		***156***	***12.3***	***44.8***	***11***
Targets		***163***	***9.0***	***45.4***	***10***
2012	2014	158	12.1	41.6	11
2013	2015	130	12.6	27.2	17
2014	2016	125	10.8	23.0	20
Average		***138***	***11.8***	***30.6***	***16***
Targets		***163***	***9.0***	***45.4***	***13-17***

Survival Estimates

Overall survival of the 2014 brood Methow summer Chinook from green (unfertilized) egg-to-release was below the standard set for the program (Table 9.11). This was largely because of lower eyed to ponding, ponding to release, and transport to release survivals.

Table 9.11. Hatchery life-stage survival rates (%) for Methow summer Chinook, brood years 1989-2014. Survival standards or targets are provided in the last row of the table.

Brood year	Collection to spawning		Unfertilized egg-eyed	Eyed egg-ponding	30 d after ponding	100 d after ponding	Ponding to release	Transport to release	Unfertilized egg-release
	Female	Male							
1989[a]	89.8	99.5	89.9	96.7	99.7	99.4	73.3	98.5	87.0
1990[a]	93.9	99.0	84.9	97.1	81.2	80.6	97.7	99.5	84.4
1991[a]	93.1	95.5	88.2	98.0	99.4	99.1	97.5	99.6	92.2
1992[a]	96.9	99.0	87.8	98.0	99.9	99.9	90.9	98.3	82.8
1993[a]	82.2	99.4	85.4	97.6	99.8	99.5	92.0	99.4	81.5
1994	96.1	90.0	86.6	100.0	98.1	97.4	73.1	99.1	68.3
1995	91.9	96.2	98.2	84.1	96.5	96.2	92.7	89.6	71.9
1996	95.4	98.1	83.2	100.0	97.7	96.9	86.5	89.0	66.7

Brood year	Collection to spawning		Unfertilized egg-eyed	Eyed egg-ponding	30 d after ponding	100 d after ponding	Ponding to release	Transport to release	Unfertilized egg-release
	Female	Male							
1997	91.9	94.6	86.1	98.4	98.7	98.3	98.8	99.7	95.9
1998	84.0	96.2	54.1	98.0	99.4	98.9	96.6	99.9	52.7
1999	98.8	98.7	92.9	96.9	98.0	97.6	96.9	99.9	87.7
2000	90.5	96.9	89.2	98.1	98.5	98.3	94.6	94.4	83.5
2001	96.2	92.3	89.1	97.6	97.2	97.1	97.5	99.8	89.0
2002	97.1	98.1	88.3	99.9	97.7	97.5	96.7	99.9	85.7
2003	96.7	97.5	82.8	98.2	99.7	99.2	93.7	99.9	74.9
2004	93.6	98.2	84.0	97.8	99.6	99.2	98.3	98.5	74.6
2005	97.0	89.6	88.0	95.5	99.6	98.9	96.6	99.9	86.2
2006	92.9	89.5	86.3	98.3	99.6	98.7	97.2	99.5	82.4
2007	92.6	99.6	84.1	98.5	99.7	99.5	98.9	99.8	81.9
2008	99.6	97.9	91.9	99.5	99.3	98.9	98.5	99.9	90.0
2009[b]	93.6	93.5	91.0	97.7	99.7	99.2	98.8	100.0	87.9
2010[c]	96.5	100.0	91.1	100.0	96.4	96.1	95.4	99.5	86.9
2011	94.9	96.4	93.8	97.8	99.7	99.1	98.6	99.9	90.4
2012	94.3	94.2	93.1	97.8	99.4	99.0	97.0	98.3	88.3
2013	98.0	100.0	89.5	97.8	99.9	99.2	93.4	94.2	81.7
2014	96.0	96.0	94.0	95.8	99.6	99.4	87.1	88.0	78.4
Average	***94.0***	***96.4***	***87.4***	***97.5***	***98.2***	***97.8***	***93.8***	***97.8***	***82.0***
Median	***94.6***	***97.2***	***88.3***	***97.9***	***99.4***	***98.9***	***96.7***	***99.5***	***84.0***
Standard	***90.0***	***85.0***	***92.0***	***98.0***	***97.0***	***93.0***	***90.0***	***95.0***	***81.0***

[a] Survival rates were calculated from aggregate population collected at Wells Fish Hatchery volunteer channel and left- and right-ladder traps at Wells Dam.

[b] Survival rates were calculated from aggregate collections at Wells east fish ladder for the Methow and Okanogan/Similkameen programs. About 41% of the total fish collected were used to estimate survival rates.

[c] Survival rates were calculated from aggregate collections at Wells West Ladder for the Methow and Similkameen programs. About 71% of the total fish collected were used to estimate survival rates.

9.3 Disease Monitoring

Results of 2016 adult broodstock bacterial kidney disease (BKD) monitoring indicated that all females had ELISA values less than 0.120 (Table 9.12).

Table 9.12. Proportion of bacterial kidney disease (BKD) titer groups for the Methow/Okanogan summer Chinook broodstock, brood years 1997-2016. Also included are the proportions to be reared at either 0.125 fish per pound or 0.060 fish per pound.

Brood year[a]	Optical density values by titer group				Proportion at rearing densities (fish per pound, fpp)[b]	
	Very Low (≤ 0.099)	Low (0.1-0.199)	Moderate (0.2-0.449)	High (≥ 0.450)	≤ 0.125 fpp (<0.119)	≤ 0.060 fpp (>0.120)
1997	0.6267	0.1333	0.0622	0.1778	0.6844	0.3156
1998	0.9632	0.0184	0.0123	0.0061	0.9816	0.0184
1999	0.9444	0.0198	0.0238	0.0119	0.9643	0.0357
2000	0.7476	0.0952	0.0238	0.1333	0.8000	0.2000
2001	0.9801	0.0199	0.0000	0.0000	1.0000	0.0000
2002	0.9567	0.0130	0.0130	0.0173	0.9740	0.0260
2003	0.9620	0.0127	0.0169	0.0084	0.9747	0.0253
2004	0.9585	0.0151	0.0075	0.0189	0.9736	0.0264
2005	0.9884	0.0000	0.0000	0.0116	0.9884	0.0116
2006	0.9962	0.0038	0.0000	0.0000	0.9962	0.0038
2007	0.9202	0.0266	0.0152	0.0380	0.9354	0.0646
2008	1.0000	0.0000	0.0000	0.0000	1.0000	0.0000
2009	0.9891	0.0073	0.0037	0.0000	0.9927	0.0073
2010	0.9960	0.0040	0.0000	0.0000	1.0000	0.0000
2011	0.9766	0.0140	0.0000	0.0093	0.9860	0.0140
2012	0.9341	0.0440	0.0110	0.0110	0.9780	0.0220
2013	0.8776	0.1224	0.0000	0.0000	0.9388	0.0612
2014	0.9170	0.0210	0.0210	0.0420	0.9381	0.0630
2015	1.0000	0.0000	0.0000	0.0000	1.0000	0.0000
2016	1.0000	0.0000	0.0000	0.0000	1.0000	0.0000
Average	***0.9367***	***0.0285***	***0.0105***	***0.0243***	***0.9553***	***0.0447***
Median	***0.9626***	***0.0146***	***0.0056***	***0.0089***	***0.9798***	***0.0202***

[a] Individual ELISA samples were not collected before the 1997 brood.
[b] ELISA values from broodstock BKD testing dictate what density the progeny of the broodstock are reared. Progeny of broodstock with high ELISA values are reared at lower density.

9.4 Natural Juvenile Productivity

During 2016, juvenile summer Chinook were sampled at the Methow Trap located near RM 18.6. Trapping has occurred in this location since 2004.

Emigrant Estimates

Methow Trap

On the Methow River, WDFW used traps with cone diameters of 2.4 m and 1.5 m to increase trap efficiency over a greater range of river discharge. Large variation in discharge and channel configuration required the use of two trapping positions. The 1.5-m trap was deployed in the lower position at discharges less than 45.3 m^3/s. At discharges greater than 45.3 m^3/s, the 2.4-m trap was installed and operated in tandem with the 1.5 m trap.

A pooled-efficiency model estimated the total number of emigrants when the trap was operated in the low trapping position. A flow-efficiency model estimated the total number of emigrants when the trap was operated in the upper trapping position. The pooled-efficiency estimate was based on four mark-recapture release groups in 2016. The flow-efficiency estimate was based on 15 mark-recapture release groups that were conducted over the period 2007-2016.

The Methow Trap operated at night between 19 February and 5 December 2016. During that time, the trap was inoperable for 17 days because of high river discharge. During the ten-month sampling period, a total of 6,512 wild subyearling summer Chinook were captured at the Methow Trap. Based on the pooled-efficiency model and the flow efficiency model, the total number of wild subyearling summer Chinook that emigrated past the Methow Trap in 2016 was 761,769 (±4,082,084) (Table 9.13). This value contains an estimated 49,126 fish that likely emigrated past the trapping location during the 17 days in which the trap was not operating. Because 462 summer Chinook redds were observed downstream from the trap in 2015, the total number of summer Chinook emigrating from the Methow River in 2016 was expanded using the ratio of the number of redds downstream from the trap to the number upstream from the trap. This resulted in a total summer Chinook emigrant estimate of 1,219,425 (±5,164,732) fish (Table 9.13). Most of these fish emigrated during April (Figure 9.1).

Table 9.13. Numbers of redds and juvenile summer Chinook emigrants in the Methow River basin for brood years 2003-2015; NA = not available.

Brood year	Number of redds	Egg deposition	Number of emigrants upstream from trap	Total number of emigrants
2003	1,624	8,215,816	1,454,913	NA
2004*	973	4,991,490	2,016,696	NA
2005*	874	3,979,322	269,870	NA
2006	1,353	6,567,462	2,481,762	3,465,247
2007	620	3,261,200	446,860	664,396
2008	599	2,867,413	385,087	508,077
2009	692	3,539,580	838,989	1,202,030
2010	887	4,537,892	514,724	703,483
2011	941	4,307,898	1,861,614	2,292,904
2012	960	4,291,200	7,533,462	11,212,595
2013	1,551	7,316,067	473,625	709,066
2014	591	2,768,835	706,071	742,505
2015	1,231	5,428,710	761,769	1,219,425
Average	***696***	***3,409,000***	***1,518,880***	***2,271,973***

Brood year	Number of redds	Egg deposition	Number of emigrants upstream from trap	Total number of emigrants
Median	***599***	***2,867,413***	***761,769***	***972,268***

* Trap did not operate for entire migration period.

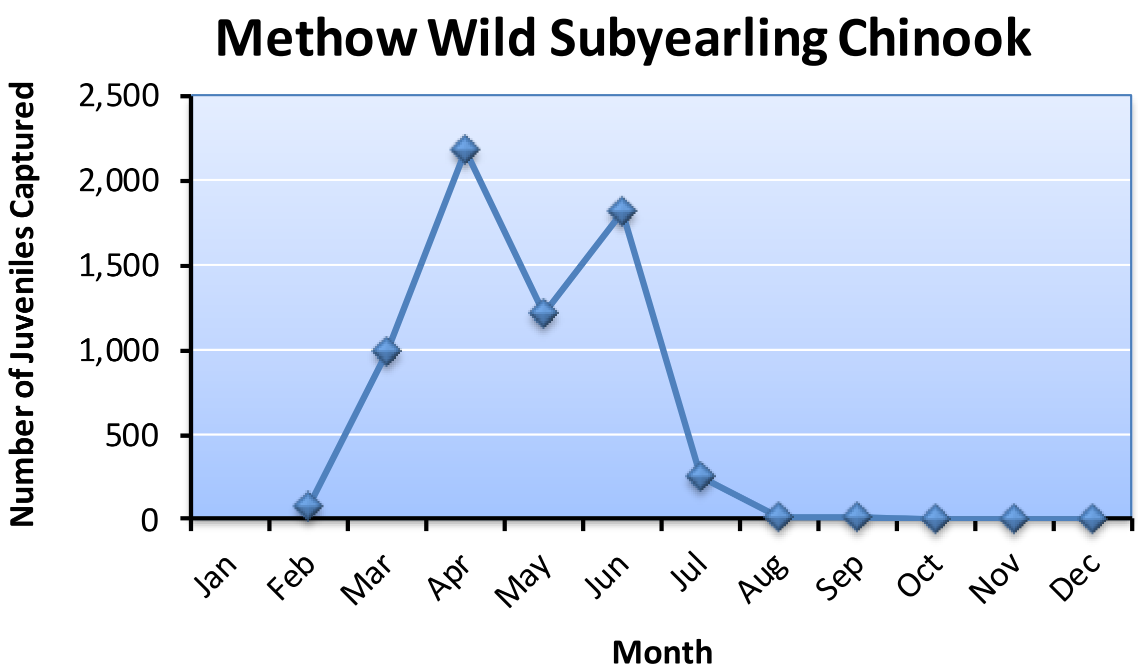

Figure 9.1. Numbers of wild subyearling Chinook captured at the Methow Trap during February to early December 2016.

Subyearling summer Chinook sampled in 2016 averaged 65.6 mm in length, 3.8 g in weight, and had a mean condition of 1.20 (Table 9.14). These size estimates were similar to the overall mean of subyearling summer Chinook sampled in previous years (overall means: 63.3 mm, 3.8 g, and condition of 1.23). Environmental conditions at the trapping location do not allow for accurate weight measurements on fry (i.e., <50 mm fork length), so this size class is underrepresented in the averages.

Table 9.14. Mean fork length (mm), weight (g), and condition factor of subyearling summer Chinook collected in the Methow Trap, 2004-2016. Numbers in parentheses indicate 1 standard deviation.

Sample year	Sample size[a]	Mean size		
		Length (mm)	Weight (g)	Condition (K)
2004	506	56.5 (17.5)	2.8 (2.8)	1.29 (0.36)
2005	326	42.6 (6.5)	1.1 (0.6)	1.34 (0.39)
2006	787	38.5 (3.0)	0.6 (0.3)	1.02 (0.28)
2007	437	73.9 (17.3)	5.8 (3.8)	1.24 (0.26)
2008	123	78.8 (16.3)	6.7 (3.9)	1.27 (0.35)
2009	162	67.4 (12.4)	4.3 (2.3)	1.31 (0.34)

Sample year	Sample size[a]	Mean size		
		Length (mm)	Weight (g)	Condition (K)
2010	142	69.7 (14.4)	4.6 (2.9)	1.26 (0.50)
2011	590	70.6 (13.5)	4.9 (2.8)	1.28 (0.31)
2012	373	61.4 (10.9)	2.9 (2.1)	1.16 (0.22)
2013	602	62.0 (11.0)	3.2 (2.1)	1.22 (0.23)
2014	707	67.1 (13.2)	3.9 (2.6)	1.16 (0.18)
2015	633	69.2 (13.6)	4.6 (2.8)	1.25 (0.22)
2016	645	65.6 (12.8)	3.8 (2.6)	1.20 (0.24)
Average	***464***	***63.3 (12.5)***	***3.8 (2.4)***	***1.23 (0.30)***
Median	***506***	***67.1 (13.2)***	***3.9 (2.6)***	***1.25 (0.28)***

[a] Sample size represents the number of fish that were measured for both length and weight.

9.5 Spawning Surveys

Surveys for Methow summer Chinook redds were conducted from late September to mid-November 2016 in the Methow River. Total redd counts (not peak counts) were conducted in the river (see Appendix O for more details).

Redd Counts

A total of 1,115 summer Chinook redds were counted in the Methow River in 2016 (Table 9.15). This is greater than the overall average of 711 redds.

Table 9.15. Total number of redds counted in the Methow River, 1989-2016.

Survey year	Total redd count
1989	149*
1990	418*
1991	153
1992	107
1993	154
1994	310
1995	357
1996	181
1997	205
1998	225
1999	448
2000	500
2001	675
2002	2,013
2003	1,624
2004	973
2005	874
2006	1,353

Survey year	Total redd count
2007	620
2008	599
2009	692
2010	887
2011	941
2012	960
2013	1,551
2014	591
2015	1,231
2016	1,115
Average	***711***
Median	***610***

* Total counts based on expanded aerial counts.

Redd Distribution

Summer Chinook redds were not evenly distributed among the seven reaches in the Methow River. Most redds (81%) were located within the lower three reaches (downstream from Twisp) (Table 9.16; Figure 9.2). Few Chinook spawned upstream from Winthrop (Reaches 6 and 7).

Table 9.16. Total number of summer Chinook redds counted in different reaches on the Methow River during September through early November 2016. Reach codes are described in Table 2.11.

Survey reach	Total redd count	Percent
Methow 1 (M1)	182	16.3
Methow 2 (M2)	309	27.7
Methow 3 (M3)	410	36.8
Methow 4 (M4)	57	5.1
Methow 5 (M5)	147	13.2
Methow 6 (M6)	1	0.1
Methow 7 (M7)	9	0.8
Totals	***1,115***	***100.0***

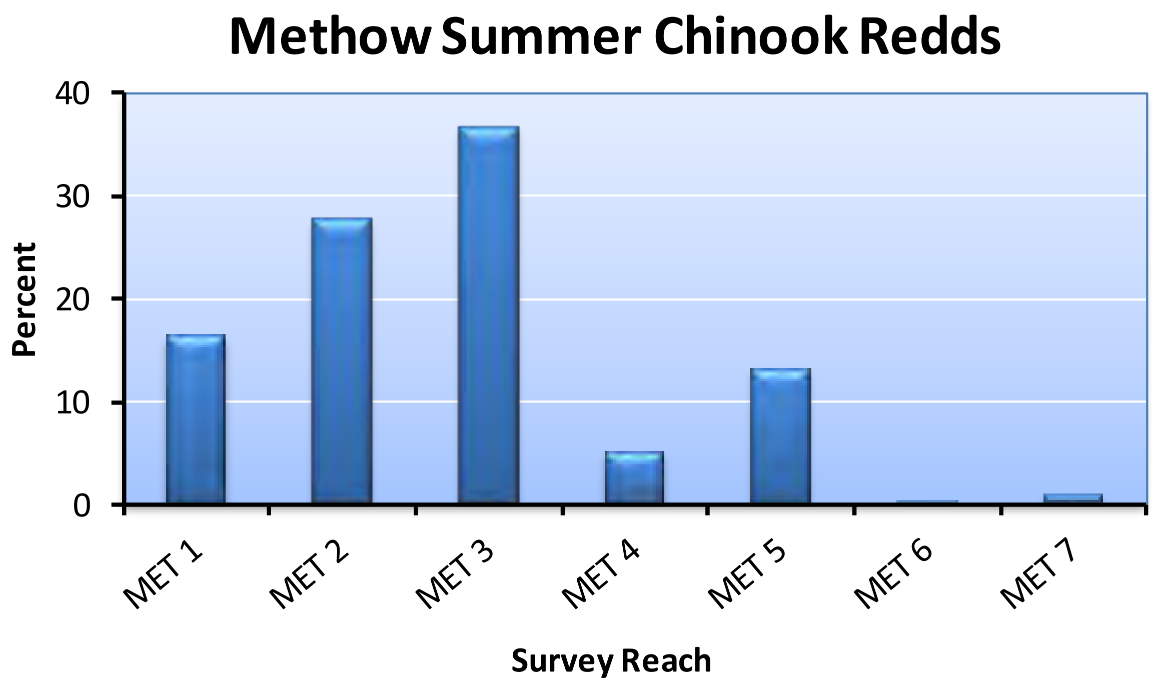

Figure 9.2. Percent of the total number of summer Chinook redds counted in different reaches on the Methow River during September through mid-November 2016. Reach codes are described in Table 2.11.

Spawn Timing

Spawning in 2016 began the last week of September, peaked in early October, and ended the third week of November (Figure 9.3). Stream temperatures in the Methow River, when spawning began, varied from 10.5-11.0°C. Peak spawning occurred during the first week of October in the upper reaches of the Methow River and one-two weeks later in the lower reaches.

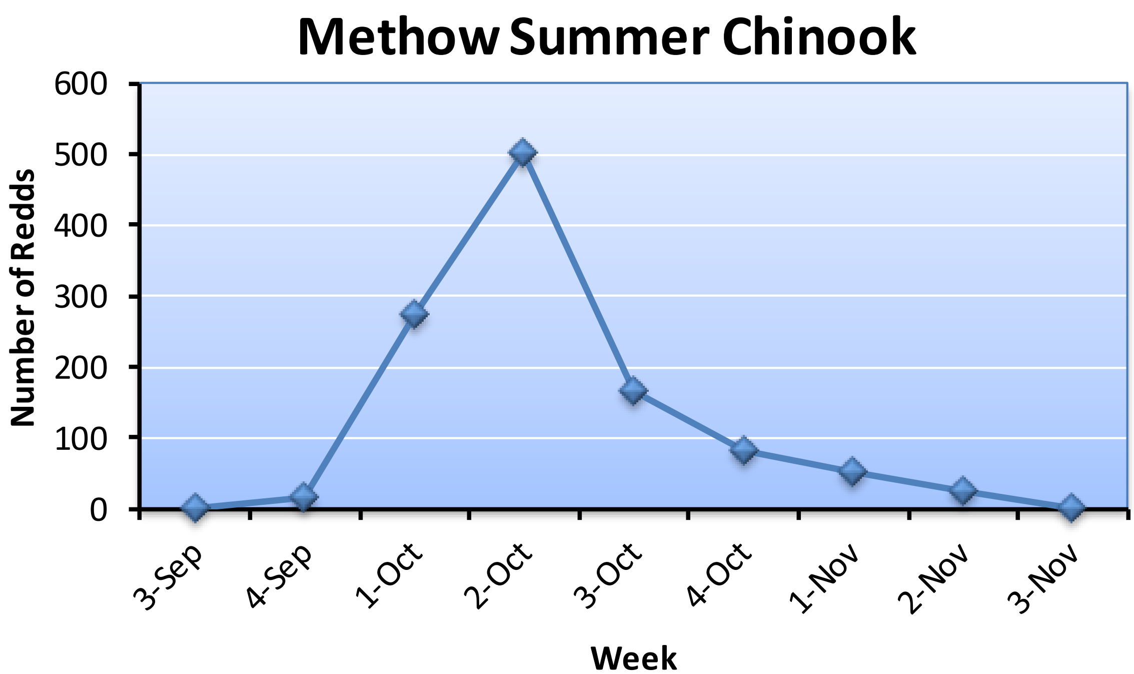

Figure 9.3. Number of new summer Chinook redds counted during different weeks in the Methow River, September through mid-November 2016.

Spawning Escapement

Spawning escapement for Methow summer Chinook was calculated as the total number of redds times the fish per redd ratio estimated from fish sampled at Wells Dam.[28] The estimated fish per redd ratio for Methow summer Chinook in 2016 was 2.01. Multiplying this ratio by the number of redds counted in the Methow River resulted in a total spawning escapement of 2,241 summer Chinook (Table 9.17).

Table 9.17. Spawning escapements for summer Chinook in the Methow River for return years 1989-2016.

Return year	Fish/Redd	Redds	Total spawning escapement
1989*	3.30	149	492
1990*	3.40	418	1,421
1991*	3.70	153	566
1992*	4.30	107	460
1993*	3.30	154	508
1994*	3.50	310	1,085
1995*	3.40	357	1,214
1996*	3.40	181	615
1997*	3.40	205	697

[28] Expansion factor = (1 + (number of males/number of females)).

Return year	Fish/Redd	Redds	Total spawning escapement
1998	3.00	225	675
1999	2.20	448	986
2000	2.40	500	1,200
2001	4.10	675	2,768
2002	2.30	2,013	4,630
2003	2.42	1,624	3,930
2004	2.25	973	2,189
2005	2.93	874	2,561
2006	2.02	1,353	2,733
2007	2.20	620	1,364
2008	3.25	599	1,947
2009	2.54	692	1,758
2010	2.81	887	2,492
2011	3.10	941	2,917
2012	3.07	960	2,947
2013	2.31	1,551	3,583
2014	2.75	591	1,625
2015	3.21	1,231	3,952
2016	2.01	1,115	2,241
Average	***2.95***	***711***	***1,913***
Median	***3.04***	***610***	***1,692***

* Spawning escapement was calculated using the “Modified Meekin Method” (i.e., 3.1 x jack multiplier).

9.6 Carcass Surveys

Surveys for Methow summer Chinook carcasses were conducted during late September to mid-November 2016 in the Methow River (see Appendix O for more details).

Number sampled

A total of 587 summer Chinook carcasses were sampled during September through mid-November in the Methow River (Table 9.18). This was greater than the overall average of 523 carcasses sampled since 1991.

Table 9.18. Numbers of summer Chinook carcasses sampled within each survey reach on the Methow River, 1991-2016. Reach codes are described in Table 2.11.

Survey year	Number of summer Chinook carcasses							
	M-1	M-2	M-3	M-4	M-5	M-6	M-7	Total
1991	0	12	8	4	2	0	0	**26**
1992	8	8	19	0	17	1	0	**53**
1993	19	25	14	2	5	0	0	**65**
1994[a]	43	33	20	5	13	0	0	**114**
1995	14	33	58	7	7	0	0	**119**

Survey year	Number of summer Chinook carcasses							
	M-1	M-2	M-3	M-4	M-5	M-6	M-7	Total
1996	6	30	46	5	2	0	0	**89**
1997	6	12	38	2	19	1	0	**78**
1998	90	84	99	17	30	0	0	**320**
1999	47	144	232	32	37	12	2	**506**
2000	62	118	105	9	99	5	0	**398**
2001	392	275	88	14	76	11	1	**857**
2002	551	318	518	164	219	34	10	**1,814**
2003	115	268	317	115	128	5	0	**948**
2004	40	173	187	82	92	2	1	**577**
2005	154	173	182	42	112	3	0	**666**
2006	121	148	110	56	144	3	1	**583**
2007	142	132	108	27	53	0	0	**462**
2008	64	128	197	33	57	3	0	**482**
2009	144	158	159	36	94	0	0	**591**
2010	105	180	184	38	63	5	1	**576**
2011	56	134	201	78	83	5	1	**558**
2012	127	154	169	75	82	14	7	**628**
2013	296	287	385	90	100	7	5	**1,170**
2014	6	14	176	53	148	73	17	**487**
2015	229	194	221	56	95	19	25	**839**
2016	82	168	216	44	70	1	5	**586**
Average	***112***	***131***	***156***	***42***	***71***	***8***	***3***	***523***
Median	***73***	***139***	***164***	***35***	***73***	***3***	***0***	***532***

[a] An additional 113 carcasses were sampled, but reach was not identified.

Carcass Distribution and Origin

Summer Chinook carcasses were not evenly distributed among reaches within the Methow River in 2016 (Table 9.18; Figure 9.4). Most of the carcasses were found in the lower three reaches (downstream from Twisp). Few carcasses were observed upstream from Winthrop (Reaches 6 and 7).

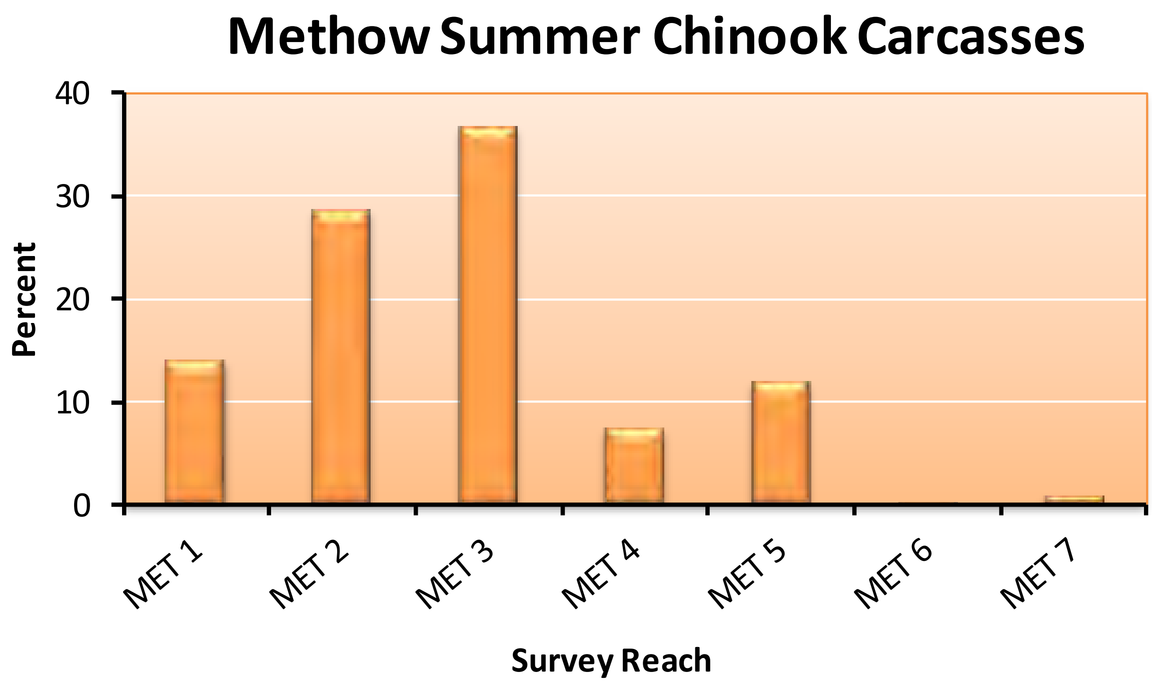

Figure 9.4. Percent of summer Chinook carcasses sampled within different reaches on the Methow River during September through mid-November 2016. Reach codes are described in Table 2.11.

Based on the available data (1991-2015), hatchery and wild summer Chinook carcasses were not distributed equally among the reaches in the Methow River (Table 9.19). A larger percentage of hatchery carcasses occurred in the lower reaches, while a larger percentage of wild summer Chinook carcasses occurred in upstream reaches (Figure 9.5).

Table 9.19. Numbers of wild and hatchery summer Chinook carcasses sampled within different reaches on the Methow River, 1991-2016.

Survey year	Origin	Survey reach							Total
		M-1	M-2	M-3	M-4	M-5	M-6	M-7	
1991	Wild	0	12	8	4	2	0	0	**26**
	Hatchery	0	0	0	0	0	0	0	**0**
1992	Wild	8	8	19	0	17	1	0	**53**
	Hatchery	0	0	0	0	0	0	0	**0**
1993	Wild	11	18	9	0	3	0	0	**41**
	Hatchery	8	7	5	2	2	0	0	**24**
1994	Wild	23	18	9	5	10	0	0	**65**
	Hatchery	20	15	11	0	3	0	0	**49**
1995	Wild	7	9	33	7	6	0	0	**62**
	Hatchery	7	24	25	0	1	0	0	**57**
1996	Wild	1	23	35	4	2	0	0	**65**
	Hatchery	5	7	11	1	0	0	0	**24**

Survey year	Origin	Survey reach							Total
		M-1	M-2	M-3	M-4	M-5	M-6	M-7	
1997	Wild	5	8	31	1	17	0	0	**62**
	Hatchery	1	4	7	1	2	1	0	**16**
1998	Wild	42	48	71	11	25	0	0	**197**
	Hatchery	48	36	28	6	5	0	0	**123**
1999	Wild	32	87	130	15	24	4	2	**294**
	Hatchery	15	57	102	17	13	8	0	**212**
2000	Wild	25	85	85	8	83	3	0	**289**
	Hatchery	37	33	20	1	16	2	0	**109**
2001	Wild	62	118	56	10	70	11	1	**328**
	Hatchery	330	157	32	4	6	0	0	**529**
2002	Wild	138	177	380	140	197	34	9	**1,075**
	Hatchery	413	141	138	24	22	0	1	**739**
2003	Wild	33	146	188	76	92	3	0	**538**
	Hatchery	82	122	129	39	36	2	0	**410**
2004	Wild	16	120	155	65	78	1	0	**435**
	Hatchery	24	53	32	17	14	1	1	**142**
2005	Wild	62	99	133	33	107	3	0	**437**
	Hatchery	92	74	49	9	5	0	0	**229**
2006	Wild	52	82	67	44	109	2	1	**357**
	Hatchery	69	66	43	12	35	1	0	**226**
2007	Wild	35	58	59	16	40	0	0	**208**
	Hatchery	107	74	49	11	13	0	0	**254**
2008	Wild	13	62	146	27	52	2	0	**302**
	Hatchery	51	66	51	6	5	1	0	**180**
2009	Wild	45	87	103	27	84	0	0	**346**
	Hatchery	99	71	56	9	10	0	0	**245**
2010	Wild	33	79	101	24	53	5	1	**296**
	Hatchery	72	101	83	14	10	0	0	**280**
2011	Wild	21	56	87	54	56	5	1	**280**
	Hatchery	35	78	114	24	27	0	0	**278**
2012	Wild	59	53	96	58	74	13	7	**360**
	Hatchery	73	101	73	17	8	1	0	**273**
2013	Wild	110	128	178	67	64	7	5	**559**
	Hatchery	186	160	208	23	36	0	0	**613**
2014	Wild	5	10	148	48	140	70	17	**438**
	Hatchery	2	4	27	5	8	3	0	**49**
2015	Wild	169	136	182	50	90	19	25	**671**
	Hatchery	60	58	39	6	5	0	0	**168**
2016	Wild	51	107	126	33	61	1	5	**384**
	Hatchery	32	61	90	11	9	0	0	**203**
Average	***Wild***	***41***	***71***	***101***	***32***	***60***	***7***	***3***	***314***

Survey year	Origin	Survey reach							Total
		M-1	M-2	M-3	M-4	M-5	M-6	M-7	
	Hatchery	*72*	*60*	*55*	*10*	*11*	*1*	*0*	*209*
Median	*Wild*	*33*	*71*	*92*	*26*	*59*	*2*	*0*	*299*
	Hatchery	*43*	*60*	*41*	*8*	*8*	*0*	*0*	*192*

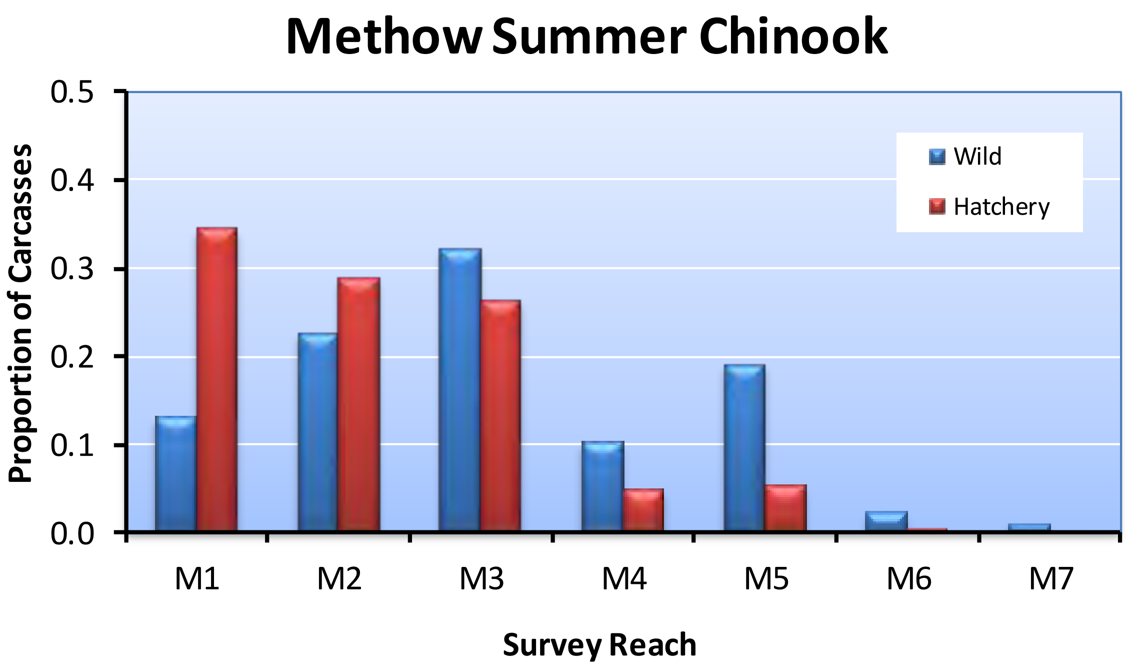

Figure 9.5. Distribution of wild and hatchery produced carcasses in different reaches on the Methow River, 1993-2016. Reach codes are described in Table 2.11.

Sampling Rate

Overall, 26% of the total spawning escapement of summer Chinook in the Methow River basin was sampled in 2016 (Table 9.20). Sampling rates among survey reaches varied from 23 to 50%.

Table 9.20. Number of redds and carcasses, total spawning escapement, and sampling rates for summer Chinook in the Methow River basin, 2016. Reach codes are described in Table 2.11.

Survey reach	Total number of redds	Total number of carcasses	Total spawning escapement	Sampling rate
Methow 1 (M1)	182	83	366	0.23
Methow 2 (M2)	309	168	621	0.27
Methow 3 (M3)	410	216	824	0.26
Methow 4 (M4)	57	44	115	0.38
Methow 5 (M5)	147	70	295	0.24
Methow 6 (M6)	1	1	2	0.50

Survey reach	Total number of redds	Total number of carcasses	Total spawning escapement	Sampling rate
Methow 7 (M7)	9	5	18	0.28
Total	***1,115***	***587***	***2,241***	***0.26***

Length Data

Mean lengths (POH, cm) of male and female summer Chinook carcasses sampled during surveys on the Methow River in 2016 are provided in Table 9.21. The average size of males and females sampled in the Methow River were 66 cm and 68 cm, respectively.

Table 9.21. Mean lengths (postorbital-to-hypural length; cm) and standard deviations (in parentheses) of male and female summer Chinook carcasses sampled in different reaches on the Methow River, 2016. Reach codes are described in Table 2.11.

Stream/watershed	Mean length (cm)	
	Male	Female
Methow 1 (M1)	65.3 (6.0)	67.9 (5.2)
Methow 2 (M2)	64.4 (8.7)	67.9 (5.4)
Methow 3 (M3)	67.2 (7.6)	68.5 (4.1)
Methow 4 (M4)	65.2 (9.1)	66.8 (4.6)
Methow 5 (M5)	68.3 (5.6)	69.2 (4.9)
Methow 6 (M6)	--	67.0 (-)
Methow 7 (M7)	67.3 (2.1)	64.0 (2.8)
Total	***65.5 (8.0)***	***68.3 (4.7)***

9.7 Life History Monitoring

Life history characteristics of Methow summer Chinook were assessed by examining carcasses on spawning grounds and fish collected or examined at broodstock collection sites, and by reviewing tagging data and fisheries statistics.

Migration Timing

Migration timing of hatchery and wild Methow/Okanogan summer Chinook was determined from broodstock data collected at Wells Dam. Counting of summer/fall Chinook at Wells Dam occurs from 29 June to 15 November. Broodstock collection at the Dam occurs from early July (week 27) to mid-September (week 37) (Table 2.1). Based on broodstock sampling in 2016, hatchery summer Chinook arrived at Wells Dam earlier than wild summer Chinook (Table 9.22). This was true throughout most of the migration period. In contrast, there was little difference in migration timing between wild and hatchery summer Chinook when data were pooled for the 2007-2016 survey period.

Table 9.22. The week that 10%, 50% (median), and 90% of the wild and hatchery summer Chinook salmon passed Wells Dam, 2007-2016. The average week is also provided. Migration timing is based on collection of summer Chinook broodstock at Wells Dam.

Survey year	Origin	Methow/Okanogan Summer Chinook Migration Time (week)				Sample size
		10 Percentile	50 Percentile	90 Percentile	Mean	
2007	Wild	27	30	34	30	485
	Hatchery	27	30	33	30	433
2008	Wild	28	30	34	30	542
	Hatchery	28	30	36	31	884
2009	Wild	27	29	34	30	585
	Hatchery	27	29	33	29	708
2010	Wild	27	29	33	29	377
	Hatchery	27	29	32	29	801
2011	Wild	30	32	36	32	516
	Hatchery	30	32	35	33	1223
2012	Wild	28	30	34	31	192
	Hatchery	28	31	34	31	591
2013	Wild	27	30	33	30	229
	Hatchery	27	30	33	30	282
2014	Wild	27	31	40	32	316
	Hatchery	27	30	35	30	208
2015	Wild	26	28	30	28	217
	Hatchery	27	28	31	29	164
2016	Wild	26	29	39	30	314
	Hatchery	25	28	34	29	251
Average	***Wild***	***27***	***30***	***35***	***30***	***377***
	Hatchery	***27***	***30***	***34***	***30***	***555***
Median	***Wild***	***27***	***30***	***34***	***30***	***347***
	Hatchery	***27***	***30***	***34***	***30***	***512***

Age at Maturity

Because hatchery summer Chinook are released after one year of rearing and natural-origin summer Chinook migrate primarily as age-0 fish, total ages will differ between hatchery and natural-origin Chinook (see Hillman et al. 2011). Therefore, in this section, we evaluated age at maturity by comparing differences in salt (ocean) ages between the two groups.

Most of the wild and hatchery summer Chinook sampled during the period 1993-2016 in the Methow River were salt age-3 fish (Table 9.23; Figure 9.6). A higher percentage of salt age-4 wild Chinook returned to the basin than did salt age-4 hatchery Chinook. In contrast, a higher proportion of salt age-1 and 2 hatchery fish returned than did salt age-1 and 2 wild fish. Thus, a higher percentage of wild fish returned at an older age than did hatchery fish.

Table 9.23. Proportions of wild and hatchery summer Chinook of different salt (ocean) ages sampled on spawning grounds in the Methow River, 1993-2015.

Sample year	Origin	Salt age						Sample size
		1	2	3	4	5	6	
1993	Wild	0.05	0.08	0.76	0.11	0.00	0.00	38
	Hatchery	0.00	1.00	0.00	0.00	0.00	0.00	20
1994	Wild	0.03	0.26	0.51	0.20	0.00	0.00	101
	Hatchery	0.00	0.07	0.93	0.00	0.00	0.00	111
1995	Wild	0.00	0.09	0.70	0.20	0.00	0.00	54
	Hatchery	0.02	0.04	0.44	0.51	0.00	0.00	55
1996	Wild	0.04	0.30	0.54	0.13	0.00	0.00	56
	Hatchery	0.00	0.05	0.50	0.41	0.05	0.00	22
1997	Wild	0.00	0.22	0.51	0.27	0.00	0.00	55
	Hatchery	0.13	0.06	0.56	0.25	0.00	0.00	16
1998	Wild	0.09	0.38	0.45	0.09	0.00	0.00	188
	Hatchery	0.02	0.52	0.41	0.04	0.00	0.00	123
1999	Wild	0.01	0.51	0.43	0.05	0.00	0.00	252
	Hatchery	0.00	0.07	0.90	0.03	0.00	0.00	210
2000	Wild	0.01	0.09	0.75	0.16	0.00	0.00	257
	Hatchery	0.10	0.16	0.62	0.11	0.00	0.00	97
2001	Wild	0.02	0.20	0.72	0.07	0.00	0.00	292
	Hatchery	0.10	0.60	0.26	0.04	0.00	0.00	526
2002	Wild	0.01	0.17	0.61	0.21	0.00	0.00	1,003
	Hatchery	0.01	0.41	0.57	0.01	0.00	0.00	734
2003	Wild	0.01	0.11	0.50	0.37	0.00	0.00	478
	Hatchery	0.02	0.03	0.90	0.04	0.00	0.00	399
2004	Wild	0.00	0.09	0.35	0.56	0.00	0.00	394
	Hatchery	0.07	0.28	0.30	0.35	0.00	0.00	141
2005	Wild	0.11	0.74	0.14	0.01	0.00	0.00	410
	Hatchery	0.06	0.26	0.65	0.02	0.00	0.00	220
2006	Wild	0.00	0.02	0.33	0.64	0.00	0.00	356
	Hatchery	0.01	0.19	0.50	0.30	0.00	0.00	164
2007	Wild	0.03	0.09	0.24	0.59	0.05	0.00	208
	Hatchery	0.07	0.09	0.75	0.09	0.01	0.00	213
2008	Wild	0.01	0.14	0.71	0.13	0.01	0.00	298
	Hatchery	0.10	0.45	0.30	0.15	0.00	0.00	138
2009	Wild	0.00	0.11	0.41	0.48	0.00	0.00	317
	Hatchery	0.17	0.26	0.53	0.04	0.00	0.00	242
2010	Wild	0.01	0.16	0.59	0.24	0.00	0.00	269
	Hatchery	0.01	0.69	0.29	0.02	0.00	0.00	247

Sample year	Origin	Salt age						Sample size
		1	2	3	4	5	6	
2011	Wild	0.02	0.09	0.60	0.30	0.00	0.00	255
	Hatchery	0.16	0.10	0.74	0.01	0.00	0.00	261
2012	Wild	0.03	0.24	0.53	0.21	0.00	0.00	315
	Hatchery	0.09	0.71	0.16	0.04	0.00	0.00	243
2013	Wild	0.02	0.25	0.62	0.11	0.00	0.00	533
	Hatchery	0.02	0.18	0.79	0.01	0.00	0.00	570
2014	Wild	0.01	0.12	0.69	0.18	0.00	0.00	412
	Hatchery	0.06	0.43	0.47	0.04	0.00	0.00	47
2015	Wild	0.00	0.20	0.45	0.35	0.00	0.00	588
	Hatchery	0.02	0.61	0.35	0.02	0.00	0.00	136
2016	Wild	0.0	0.02	0.77	0.20	0.00	0.00	350
	Hatchery	0.02	0.14	0.84	0.00	0.00	0.00	175
Average	***Wild***	***0.02***	***0.19***	***0.53***	***0.26***	***0.00***	***0.00***	***312***
	Hatchery	***0.05***	***0.32***	***0.57***	***0.06***	***0.00***	***0.00***	***213***
Median	***Wild***	***0.01***	***0.16***	***0.59***	***0.25***	***0.00***	***0.00***	***295***
	Hatchery	***0.05***	***0.24***	***0.65***	***0.06***	***0.00***	***0.00***	***170***

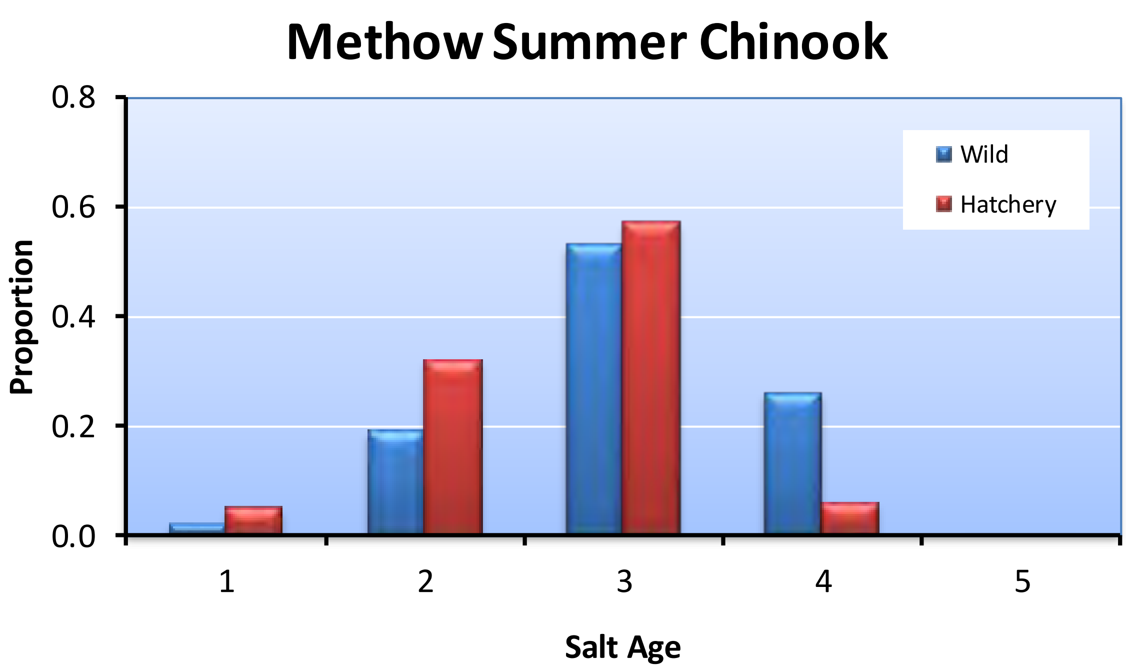

Figure 9.6. Proportions of wild and hatchery summer Chinook of different salt (ocean) ages sampled at broodstock collection sites and on spawning grounds in the Methow River for the combined years 1993-2016.

Size at Maturity

On average, hatchery summer Chinook were about 5 cm smaller than wild summer Chinook sampled in the Methow River basin (Table 9.24). This is likely because a higher percentage of wild fish returned as salt age-4 fish than did hatchery fish. Future analyses will compare sizes of hatchery and wild fish of the same age groups and sex.

Table 9.24. Mean lengths (POH; cm) and variability statistics for wild and hatchery summer Chinook sampled in the Methow River basin, 1993-2015; SD = 1 standard deviation.

Survey year	Origin	Sample size	Summer Chinook length (POH; cm)			
			Mean	SD	Minimum	Maximum
1993[a]	Wild	41	74	9	51	89
	Hatchery	24	62	8	36	80
1994[a]	Wild	112	69	8	35	87
	Hatchery	114	67	5	43	77
1995	Wild	62	74	6	52	88
	Hatchery	56	73	7	46	85
1996	Wild	64	70	11	34	91
	Hatchery	23	72	7	58	85
1997	Wild	62	76	9	35	90
	Hatchery	16	68	15	33	87
1998	Wild	196	67	10	38	97
	Hatchery	123	63	10	37	87
1999	Wild	292	66	8	43	99
	Hatchery	212	66	7	26	89
2000	Wild	288	74	8	37	89
	Hatchery	109	68	12	24	87
2001	Wild	328	67	10	29	86
	Hatchery	529	63	10	31	87
2002	Wild	1,075	70	8	37	94
	Hatchery	739	67	9	33	87
2003	Wild	538	71	8	35	88
	Hatchery	410	69	8	35	89
2004	Wild	435	73	7	38	89
	Hatchery	142	65	12	34	85
2005	Wild	437	69	8	45	86
	Hatchery	229	64	9	36	79
2006	Wild	438	73	7	35	92
	Hatchery	149	69	8	38	91
2007	Wild	249	72	11	33	89
	Hatchery	219	69	9	22	84
2008	Wild	384	69	8	30	90

Survey year	Origin	Sample size	Summer Chinook length (POH; cm)			
			Mean	SD	Minimum	Maximum
	Hatchery	210	63	15	23	86
2009	Wild	363	71	9	32	88
	Hatchery	228	63	12	30	83
2010	Wild	296	69	8	33	90
	Hatchery	280	62	9	39	81
2011	Wild	280	70	9	31	89
	Hatchery	278	64	11	26	82
2012	Wild	355	68	8	36	85
	Hatchery	273	59	9	21	81
2013	Wild	559	65	9	31	89
	Hatchery	613	66	8	27	83
2014	Wild	438	67	7	31	88
	Hatchery	49	60	10	35	76
2015	Wild	588	66	8	38	87
	Hatchery	136	59	8	38	79
2016	Wild	384	68	6	46	84
	Hatchery	203	66	7	37	83
Pooled	***Wild***	***8,264***	***70***	***8***	***37***	***89***
	Hatchery	***5,364***	***65***	***9***	***34***	***84***

[a] These years include sizes reported in annual reports. The data contained in the WDFW database do not include all these data.

Contribution to Fisheries

Most of the harvest on hatchery-origin Methow summer Chinook occurred in the Ocean (Table 9.25). Ocean harvest has made up 13% to 99% of all hatchery-origin Methow summer Chinook harvested. Brood years 1989, 1998, 2006, 2008, and 2010 provided the largest harvests, while brood years 1996 and 1999 provided the lowest.

Table 9.25. Estimated number and percent (in parentheses) of hatchery-origin Methow summer Chinook captured in different fisheries, brood years 1989-2010.

Brood year	Ocean fisheries	Columbia River Fisheries			Total
		Tribal	Commercial (Zones 1-5)	Recreational (sport)	
1989	1,043 (52)	884 (44)	0 (0)	66 (3)	1,993
1990	55 (57)	41 (43)	0 (0)	0 (0)	96
1991	12 (20)	49 (80)	0 (0)	0 (0)	61
1992	17 (55)	14 (45)	0 (0)	0 (0)	31
1993	29 (58)	17 (34)	4 (8)	0 (0)	50
1994	153 (81)	34 (18)	1 (1)	1 (1)	189
1995	77 (99)	0 (0)	1 (1)	0 (0)	78
1996	12 (92)	1 (8)	0 (0)	0 (0)	13

Brood year	Ocean fisheries	Columbia River Fisheries			Total
		Tribal	Commercial (Zones 1-5)	Recreational (sport)	
1997	219 (89)	7 (3)	0 (0)	21 (9)	247
1998	1,752 (83)	101 (5)	14 (1)	234 (11)	2,101
1999	2 (13)	13 (87)	0 (0)	0 (0)	15
2000	366 (71)	88 (17)	27 (5)	33 (6)	514
2001	326 (52)	97 (15)	43 (7)	160 (26)	626
2002	271 (48)	96 (17)	61 (11)	137 (24)	565
2003	58 (58)	17 (17)	7 (7)	18 (18)	100
2004	133 (49)	55 (20)	16 (6)	68 (25)	272
2005	298 (54)	137 (25)	50 (9)	66 (12)	551
2006	1,128 (48)	811 (34)	100 (4)	314 (13)	2,353
2007	205 (60)	69 (20)	16 (5)	54 (16)	344
2008	1,231 (52)	366 (15)	65 (3)	717 (30)	2,379
2009	318 (42)	203 (27)	28 (4)	209 (28)	758
2010	526 (50)	282 (27)	26 (2)	217 (105)	1,051
Average	***374 (58)***	***154 (27)***	***21 (3)***	***105 (11)***	***654***
Median	***212 (55)***	***62 (20)***	***11 (3)***	***44 (10)***	***308***

Straying

Stray rates were determined by examining CWTs recovered on spawning grounds within and outside the Methow River basin. Targets for strays based on return year (recovery year) within the upper Columbia River basin (Priest Rapids Dam to Chief Joseph Dam) should be less than 10% and targets for strays outside the upper Columbia River should be less than 5%. The target for brood year stay rates should be less than 5%.

Few hatchery-origin Methow summer Chinook have strayed into basins outside the Methow (Table 9.26). Although hatchery-origin Methow summer Chinook have strayed into the Wenatchee River basin, Okanogan River basin, Entiat River basin, Chelan tailrace, and Hanford Reach, on average, they have made up less than 1% of the spawning escapement within those areas.

Table 9.26. Number and percent of spawning escapements within other non-target basins that consisted of hatchery-origin Methow summer Chinook, return years 1994-2015. For example, for return year 2002, 0.4% of the summer Chinook escapement in the Okanogan River basin consisted of hatchery-origin Methow summer Chinook. Percent strays should be less than 10%.

Return year	Wenatchee		Okanogan		Chelan		Entiat		Hanford Reach	
	Number	%	Number	%	Number	%	Number	%	Number	%
1994	0	0.0	72	1.8	-	-	-	-	-	-
1995	0	0.0	9	0.3	-	-	-	-	-	-
1996	0	0.0	0	0.0	-	-	-	-	-	-
1997	0	0.0	0	0.0	-	-	-	-	-	-
1998	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0

Return year	Wenatchee		Okanogan		Chelan		Entiat		Hanford Reach	
	Number	%	Number	%	Number	%	Number	%	Number	%
1999	0	0.0	9	0.2	0	0.0	0	0.0	7	0.0
2000	0	0.0	3	0.1	0	0.0	0	0.0	0	0.0
2001	0	0.0	0	0.0	0	0.0	0	0.0	7	0.0
2002	0	0.0	54	0.4	0	0.0	0	0.0	0	0.0
2003	0	0.0	1	0.0	6	1.4	0	0.0	0	0.0
2004	0	0.0	7	0.1	3	0.7	0	0.0	0	0.0
2005	0	0.0	24	0.3	0	0.0	0	0.0	0	0.0
2006	0	0.0	12	0.1	0	0.0	0	0.0	0	0.0
2007	0	0.0	17	0.4	2	1.1	3	1.2	0	0.0
2008	0	0.0	12	0.2	0	0.0	0	0.0	0	0.0
2009	0	0.0	14	0.2	0	0.0	0	0.0	0	0.0
2010	6	0.1	44	0.7	22	2.0	0	0.0	0	0.0
2011	0	0.0	45	0.5	8	0.6	0	0.0	0	0.0
2012	0	0.0	31	0.4	0	0.0	0	0.0	0	0.0
2013	0	0.0	10	0.1	0	0.0	0	0.0	0	0.0
2014	0	0.0	17	0.1	0	0.0	0	0.0	0	0.0
2015	0	0.0	40	0.3	4	0.3	0	0.0	0	0.0
Average	***0***	***0.0***	***19***	***0.3***	***3***	***0.3***	***0***	***0.1***	***1***	***0.0***
Median	***0***	***0.0***	***12***	***0.2***	***0***	***0.0***	***0***	***0.0***	***0***	***0.0***

Based on brood year analyses, on average, about 3.9% of the returns have strayed into non-target populations, falling within the acceptable level of less than 5% (Table 9.27). Depending on brood year, percent strays into non-target spawning areas have ranged from 0-17.1%. Few (<1% on average) have strayed into non-target hatchery programs.

Table 9.27. Number and percent of hatchery-origin Methow summer Chinook that homed to target spawning areas and the target hatchery program, and number and percent that strayed to non-target spawning areas and non-target hatchery programs, by brood years 1989-2010. Percent stays should be less than 5%.

Brood year	Homing				Straying			
	Target stream		Target hatchery*		Non-target streams		Non-target hatcheries	
	Number	%	Number	%	Number	%	Number	%
1989	773	55.7	459	33.0	81	5.8	76	5.5
1990	199	70.6	81	28.7	0	0.0	2	0.7
1991	82	65.6	43	34.4	0	0.0	0	0.0
1992	68	63.0	40	37.0	0	0.0	0	0.0
1993	54	65.9	22	26.8	6	7.3	0	0.0
1994	419	79.7	94	17.9	13	2.5	0	0.0
1995	126	81.8	28	18.2	0	0.0	0	0.0

Brood year	Homing				Straying			
	Target stream		Target hatchery*		Non-target streams		Non-target hatcheries	
	Number	%	Number	%	Number	%	Number	%
1996	57	93.4	4	6.6	0	0.0	0	0.0
1997	379	93.8	7	1.7	18	4.5	0	0.0
1998	1,653	94.7	32	1.8	60	3.4	0	0.0
1999	18	100.0	0	0.0	0	0.0	0	0.0
2000	239	93.0	4	1.6	14	5.4	0	0.0
2001	272	88.3	6	1.9	29	9.4	1	0.3
2002	315	94.6	4	1.2	14	4.2	0	0.0
2003	131	99.2	1	0.8	0	0.0	0	0.0
2004	194	85.5	6	2.6	27	11.9	0	0.0
2005	373	90.5	13	3.2	23	5.6	3	0.7
2006	1,317	91.4	15	1.0	109	7.6	0	0.0
2007	134	98.5	2	1.5	0	0.0	0	0.0
2008	1,886	97.8	15	0.8	25	1.3	3	0.2
2009	185	93.0	14	7.0	0	0.0	0	0.0
2010	203	80.6	6	2.4	43	17.1	0	0.0
Average	***413***	***85.3***	***41***	***10.5***	***21***	***3.9***	***4***	***0.3***
Median	***201***	***91.0***	***14***	***2.5***	***14***	***3.0***	***0***	***0.0***

* Homing to the target hatchery includes Methow hatchery summer Chinook that are captured and included as broodstock in the Methow Hatchery program. These hatchery fish are typically collected at Wells Dam.

Genetics

Genetic studies were conducted to investigate relationships among temporally replicated collections of summer Chinook from the Wenatchee River, Methow River, and Okanogan River in the upper Columbia River basin (Kassler et al. 2011; the entire report is appended as Appendix N). A total of 2,416 summer Chinook were collected from tributaries in the upper Columbia River basin. Two collections of natural-origin summer Chinook from 1993 (prior to the supplementation program) were taken from the Wenatchee River basin (N = 139) and compared to collections of hatchery and natural-origin Chinook from 2006 and 2008 (N = 380). Two pre-supplementation collections from the Methow River (1991 and 1993) were compared to supplementation collections from 2006 and 2008 (N = 362). Three pre-supplementation collections from the Okanogan River Basin (1991, 1992, and 1993) were compared with supplementation collections from 2006 and 2008 (N = 669). A collection of natural-origin summer Chinook from the Chelan River was also analyzed (N = 70). Additionally, hatchery collections from Eastbank Hatchery (Wenatchee and Methow/Okanogan stock; N = 221) and Wells Hatchery (N = 294) were analyzed and compared to the in-river collections. Summer Chinook data (provided by the USFWS) from the Entiat River (N = 190) were used for comparison. Lastly, data from eight collections of fall Chinook (N = 2,408) were compared to the collections of summer Chinook. Samples of natural and hatchery-origin summer Chinook were analyzed and compared to determine if the supplementation programs have affected the genetic structure of these populations. The study also calculated the effective number of breeders for collection locations of natural and hatchery-origin summer Chinook from 1993 and 2008.

In general, population differentiation was not observed among the temporally replicated collection locations. A single collection from the Okanogan River (1993) was the only collection showing statistically significant differences. The effective number of breeders was not statistically different from the early collection in 1993 in comparison to the late collection in 2008. Overall, these analyses revealed a lack of differentiation among the temporal replicates from the same locations and among the collection from different locations, suggesting the populations have been homogenized or that there has been substantial gene flow among populations. Additional comparisons among summer-run and fall-run Chinook populations in the upper Columbia River were conducted to determine if there was any differentiation between Chinook with different run timing. These analyses revealed pairwise F_{ST} values that were less than 0.01 for the collections of summer Chinook to collections of fall Chinook from Hanford Reach, lower Yakima River, Priest Rapids, and Umatilla. Collections of fall Chinook from Crab Creek, Lyons Ferry Hatchery, Marion Drain, and Snake River had pairwise F_{ST} values that were higher in comparison to the collections of summer Chinook. The consensus clustering analysis did not provide good statistical support to the groupings, but did show relationships among collections based on geographic proximity. Overall the summer and fall run Chinook that have historically been spawned together were not differentiated while fall Chinook from greater geographic distances were differentiated.

Proportionate Natural Influence

Another method for assessing the genetic risk of a supplementation program is to determine the influence of the hatchery and natural environments on the adaptation of the composite population. This is estimated by the proportion of natural-origin fish in the hatchery broodstock (pNOB) and the proportion of hatchery-origin fish in the natural spawning escapement (pHOS). We calculated Proportionate Natural Influence (PNI) by iterating Ford's (2002) equations 5 and 6 to equilibrium, using a heritability of 0.3 and a selection strength of three standard deviations. The larger the PNI value, the greater the strength of selection in the natural environment relative to that of the hatchery environment. For the natural environment to dominate selection, PNI should be greater than 0.50, and important integrated populations should have a PNI of at least 0.67 (HSRG/WDFW/NWIFC 2004).

For brood years 1993-2003, the PNI values were generally less than 0.67 (Table 9.28). However, since brood year 2003, PNI has generally been greater than 0.67; brood year 2015 had a PNI value of 0.83.

Table 9.28. Proportionate Natural Influence (PNI) values for the Methow summer Chinook supplementation program for brood years 1989-2015. NOS = number of natural-origin Chinook on the spawning grounds; HOS = number of hatchery-origin Chinook on the spawning grounds; NOB = number of natural-origin Chinook collected for broodstock; and HOB = number of hatchery-origin Chinook included in hatchery broodstock.

Brood year	Spawners			Broodstock			PNI[a]
	NOS	HOS	pHOS	NOB	HOB	pNOB	
1989	492	0	0.00	1,297	312	0.81	1.00
1990	1,421	0	0.00	828	206	0.80	1.00
1991	566	0	0.00	924	314	0.75	1.00

Brood year	Spawners			Broodstock			PNI[a]
	NOS	HOS	pHOS	NOB	HOB	pNOB	
1992	460	0	0.00	297	406	0.42	1.00
1993	314	194	0.38	681	388	0.64	0.64
1994	596	489	0.45	341	244	0.58	0.58
1995	596	618	0.51	173	240	0.42	0.47
1996	435	180	0.29	287	155	0.65	0.70
1997	529	168	0.24	197	265	0.43	0.66
1998	436	239	0.35	153	211	0.42	0.56
1999	573	413	0.42	224	289	0.44	0.53
2000	861	339	0.28	164	337	0.33	0.56
2001	1,122	1,646	0.59	12	345	0.03	0.09
2002	2,572	2,058	0.44	247	241	0.51	0.55
2003	2,307	1,623	0.41	381	101	0.79	0.67
2004	1,622	567	0.26	506	16	0.97	0.79
2005	1,672	889	0.35	391	9	0.98	0.74
2006	1,675	1,058	0.39	500	10	0.98	0.72
2007	660	704	0.52	456	17	0.96	0.66
2008	1,194	753	0.39	359	86	0.81	0.68
2009	1,042	716	0.41	503	4	0.99	0.72
2010	1,326	1,166	0.47	484	8	0.98	0.68
2011	1,503	1,414	0.48	467	26	0.95	0.67
2012	1,593	1,354	0.46	98	1	0.99	0.69
2013	1,693	1,890	0.53	97	4	0.96	0.65
2014	1,451	174	0.11	96	0	1.00	0.90
2015	3,138	814	0.21	103	0	1.00	0.83
Average	***1,180***	***721***	***0.33***	***380***	***157***	***0.73***	***0.69***
Median	***1,122***	***618***	***0.39***	***341***	***155***	***0.80***	***0.68***

[a] PNI was calculated previously using PNI approximate equation 11 (HSRG 2009; their Appendix A). All PNI values presented here were recalculated by iterating Ford's (2002) equations 5 and 6 to equilibrium using a heritability of 0.3 and a selection strength of three standard deviations. C. Busack, NOAA Fisheries, 21 March 2016, provided the model for calculating PNI.

Post-Release Survival and Travel Time

We used PIT-tagged fish to estimate survival rates and travel time (arithmetic mean days) of hatchery summer Chinook from the Methow River release site to McNary Dam, and smolt to adult ratios (SARs) from release to detection at Bonneville Dam (Table 9.29).[29] Over the five brood years for which PIT-tagged hatchery fish were released, survival rates from the Methow River to McNary Dam ranged from 0.485 to 0.747; SARs from release to detection at Bonneville Dam ranged from 0.000 to 0.016. Average travel time from the Methow River to McNary Dam ranged from 17 to 55 days.

[29] It is important to point out that because of fish size differences among rearing tanks or raceways, fish PIT tagged in one tank or raceway may not represent untagged fish rearing in other tanks or raceways.

Table 9.29. Total number of Methow hatchery summer Chinook released with PIT tags, their survival and travel times (mean days) to McNary Dam, and smolt-to-adult (SAR) ratios for brood years 2008-2014. Standard errors are shown in parentheses. NA = not available (i.e., not all the fish from the release groups have returned to the Columbia River).

Brood year	Number of tagged fish released	Survival to McNary Dam	Travel time to McNary Dam (d)	SAR to Bonneville Dam
2008	10,094	0.747 (0.055)	39.1 (13.0)	0.016 (0.001)
2009	5,020	0.485 (0.037)	30.2 (11.1)	0.002 (0.001)
2010	0	--	--	--
2011	0	--	--	--
2012	9,801	0.545 (0.046)	17.0 (8.1)	0.000 (0.000)
2013	9,825	0.560 (0.101)	54.5 (8.3)	NA
2014	4,992	0.624 (0.053)	24.5 (8.1)	NA

Natural and Hatchery Replacement Rates

Natural replacement rates (NRR) were calculated as the ratio of natural-origin recruits (NOR) to the parent spawning population (spawning escapement). Natural-origin recruits are naturally produced (wild) fish that survive to contribute to harvest (directly or indirectly), to broodstock, and to spawning grounds. We do not account for fish that died in route to the spawning grounds (migration mortality) or died just before spawning (pre-spawn mortality) (see Appendix B in Hillman et al. 2012). We calculated NORs with and without harvest. NORs without harvest include all returning fish that either returned to the basin or were collected as wild broodstock. NORs with harvest include all fish harvested and are based on a brood year harvest rates from the hatchery program. For brood years 1989-2009, NRR for summer Chinook in the Methow averaged 1.11 (range, 0.10-4.90) if harvested fish were not included in the estimate and 2.13 (range, 0.18-10.84) if harvested fish were included in the estimate (Table 9.30). NRRs for more recent brood years will be calculated as soon as all tag recoveries and sampling rates have been loaded into the database.

Hatchery replacement rates (HRR) are the hatchery adult-to-adult returns and were calculated as the ratio of hatchery-origin recruits (HOR) to the parent broodstock collected. These rates should be greater than the NRRs and greater than or equal to 3.0 (the calculated target value in Hillman et al. 2013). The target value of 3.0 includes harvest. HRRs exceeded NRRs in 13 out of the 21 years of data, regardless if harvest was or was not included in the estimate (Table 9.30). Hatchery replacement rates for Methow summer Chinook have exceeded the estimated target value of 3.0 in ten of the 20 years of data.

Table 9.30. Broodstock collected, spawning escapements, natural and hatchery-origin recruits (NOR and HOR), and natural and hatchery replacement rates (NRR and HRR; with and without harvest) for wild summer Chinook in the Methow River basin, brood years 1989-2009.

Brood year	Broodstock Collected	Spawning Escapement	Harvest not included				Harvest included			
			HOR	NOR	HRR	NRR	HOR	NOR	HRR	NRR
1989	202	492	1,389	631	6.88	1.28	3,382	1,532	16.74	3.11
1990	202	1,421	282	978	1.40	0.69	378	1,318	1.87	0.93
1991	266	566	125	287	0.47	0.51	186	429	0.70	0.76
1992	214	460	108	614	0.50	1.33	139	792	0.65	1.72
1993	234	508	82	430	0.35	0.85	132	701	0.56	1.38
1994	260	1,085	526	542	2.02	0.50	715	738	2.75	0.68
1995	242	1,214	154	1,201	0.64	0.99	232	1,809	0.96	1.49
1996	220	615	61	445	0.28	0.72	74	541	0.34	0.88
1997	209	697	404	1,493	1.93	2.14	651	2,315	3.11	3.32
1998	235	675	1,745	3,307	7.43	4.90	3,846	6,601	16.37	9.78
1999	222	986	18	2,862	0.08	2.90	33	5,251	0.15	5.33
2000	222	1,200	257	800	1.16	0.67	771	2,286	3.47	1.91
2001	223	2,768	308	2,574	1.38	0.93	934	6,435	4.19	2.32
2002	222	4,630	333	924	1.50	0.20	898	2,504	4.05	0.54
2003	224	3,930	132	352	0.59	0.09	232	619	1.04	0.16
2004	223	2,189	227	1,540	1.02	0.70	499	3,392	2.24	1.55
2005	225	2,561	412	1,120	1.83	0.44	963	2,489	4.28	0.97
2006	236	2,733	1,441	1,706	6.11	0.62	3,794	3,842	16.08	1.41
2007	209	1,364	136	1,509	0.65	1.11	480	3,992	2.30	2.93
2008	184	1,947	1,929	1,501	10.48	0.77	4,308	2,575	23.41	1.32
2009	223	1,758	199	1,542	0.89	0.88	957	4,047	4.29	2.30
Average	***224***	***1,609***	***489***	***1,255***	***2.27***	***1.11***	***1,124***	***2,581***	***5.22***	***2.13***
Median	***223***	***1,214***	***257***	***1,120***	***1.16***	***0.77***	***651***	***2,315***	***2.75***	***1.49***

Smolt-to-Adult Survivals

Smolt-to-adult survival ratios (SARs) were calculated as the number of hatchery adult recaptures divided by the number of tagged hatchery smolts released. Here, SARs were based on CWT returns. For the available brood years, SARs have ranged from 0.00008 to 0.01883 for hatchery summer Chinook in the Methow River basin (Table 9.31).

Table 9.31. Smolt-to-adult ratios (SARs) for Methow summer Chinook, brood years 1989-2010.

Brood year	Number of tagged smolts released[a]	Estimated adult captures[b]	SAR
1989	358,237	2,871	0.008010
1990	371,483	361	0.000970
1991	377,097	130	0.000340

Brood year	Number of tagged smolts released[a]	Estimated adult captures[b]	SAR
1992	392,636	138	0.000350
1993	200,345	62	0.000310
1994	400,488	710	0.001770
1995	344,974	229	0.000660
1996	289,880	73	0.000250
1997	380,430	647	0.001700
1998	202,559	3,812	0.018820
1999	422,473	33	0.000080
2000	334,337	770	0.002300
2001	246,159	930	0.003780
2002	310,846	895	0.002880
2003	353,495	232	0.000660
2004	394,490	496	0.001260
2005	262,496	961	0.003660
2006	417,795	3,786	0.009060
2007	426,188	479	0.001120
2008	373,234	4,088	0.010950
2009	450,237	952	0.002110
2010	428,458	1,289	0.003008
Average	***351,743***	***1,088***	***0.00337***
Median	***372,359***	***679***	***0.00174***

[a] Includes all tag codes and CWT released fish (CWT + Ad Clip fish and CWT-only fish).

[b] Includes estimated recoveries (spawning ground, hatcheries, harvest, etc.) and observed recoveries if estimated recoveries were unavailable.

9.8 ESA/HCP Compliance

Broodstock Collection

Summer Chinook adults collected at Wells Dam are used primarily for the Methow supplementation programs. On an as needed basis, adults collected at Wells Dam may be used to augment adult collections for the Okanogan summer Chinook supplementation program. Per the 2014 broodstock collection protocol, 100 natural-origin (adipose fin present) adults were targeted for collection between 1 July and 15 September at the West Ladder of Wells Dam for the Methow summer Chinook program. Actual collections occurred between 1 July and 3 September and totaled 100 summer Chinook. ESA Permit 1347 provides authorization to collect Methow and Okanogan summer Chinook at Wells Dam three days per week and up to 16 hours per day from July through November. During 2014, broodstock collection activities were accomplished within the allowable trapping days authorized under ESA Permit 1347.

Collection of Methow summer Chinook broodstock at Wells Dam occurred concurrently with collection of summer steelhead for the Wells steelhead program authorized under ESA Section 10 Permit 1395. Encounters with steelhead and spring Chinook during Methow summer Chinook broodstock collections did not result in takes that were outside those authorized in Permit 1347 and in Permit 1395 for the Wells Steelhead program. Steelhead encountered during summer Chinook collections that were not required for steelhead broodstock were passed at the trap site and were not physically handled. Any spring Chinook encountered during summer Chinook broodstock activities were also passed without handling. No chinook were collected at Wells Dam for the 2014 Okanogan summer Chinook program.

Hatchery Rearing and Release

The 2014 brood Methow summer Chinook reared throughout their juvenile life-stages at Eastbank Fish Hatchery and the Carlton Acclimation Pond without incident (see Section 9.2). The 2014 brood smolt release totaled 167,616 summer Chinook, representing 83.8% of the 200,000-production objective and was compliant with the 10% overage allowable in ESA Section 10 Permit 1347. Lower than anticipated fecundity (94% of the biological assumption used in the 2014 broodstock collection protocols) was the largest factor in not meeting the full program, followed by lower than expected overwinter survival (87.1%).

Hatchery Effluent Monitoring

Per ESA Permits 1196, 1347, 1395, 18118, 18120, and 18121, permit holders shall monitor and report hatchery effluents in compliance with applicable National Pollution Discharge Elimination Systems (NPDES) (EPA 1999) permit limitations. There were no NPDES violations reported at PUD Hatchery facilities during the period 1 January through 31 December 2016. NPDES monitoring and reporting for PUD Hatchery Programs during 2016 are provided in Appendix F.

Spawning Surveys

Summer Chinook spawning ground surveys conducted in the Methow River basin during 2016 were consistent with ESA Section 10 Permit No. 1347. Because of the difficulty of quantifying the level of take associated with spawning ground surveys, the Permit does not specify a take level associated with these activities, even though it does authorize implementation of spawning ground surveys. Therefore, no take levels are reported. However, to minimize potential effects to established redds, wading was restricted to the extent practical, and extreme caution was used to avoid established redds when wading was required.

SECTION 10: OKANOGAN/SIMILKAMEEN SUMMER CHINOOK

The goal of summer Chinook salmon supplementation in the Okanogan Basin is to use artificial production to replace adult production lost because of mortality at Wells, Rocky Reach, and Rock Island dams, while not reducing the natural production or long-term fitness of summer Chinook in the basin. The Rock Island Fish Hatchery Complex began operation in 1989 under funding from Chelan PUD. The Complex operated originally through the Rock Island Settlement Agreement, but since 2004 has operated under the Anadromous Fish Agreement and Habitat Conservation Plans.

Before 2012, adult summer Chinook were collected for broodstock from the run-at-large at the east ladder trapping facility at Wells Dam. Since then, the Colville Tribes collect broodstock using purse seines in the Okanogan and Columbia rivers. The goal was to collect up to 334 adult summer Chinook for the Okanogan program. Broodstock collection occurred from about 7 July through 15 September with trapping occurring no more than 16 hours per day, three days a week. If natural-origin broodstock collection fell short of expectation, hatchery-origin adults could be collected to make up the difference.

Before 2012, adult summer Chinook were spawned and reared at Eastbank Fish Hatchery. Juvenile summer Chinook were transferred from the hatchery to Similkameen Acclimation Pond in October. In addition, since 2005, about 20% (100,000) of the juveniles were transferred to Bonaparte Pond. Chinook were released from the ponds in April to early May.

Prior to 2012, the production goal for the Okanogan summer Chinook supplementation program was to release 576,000 yearling smolts into the Similkameen and Okanogan rivers at ten fish per pound. Beginning with the 2012 brood, the revised production goal is to release 166,569 yearling smolts into the rivers. Targets for fork length and weight are 176 mm (CV = 9.0) and 45.4 g, respectively. Over 90% of these fish are marked with CWTs. In addition, since 2009, juvenile summer Chinook have been PIT tagged annually.

The Colville Tribes began monitoring the Okanogan/Similkameen summer Chinook program in 2013. Their monitoring results are published in annual reports to Bonneville Power Administration (BPA). The purpose of retaining this section is to provide readers with monitoring data collected with Chelan PUD funding through brood year 2012. Thus, this section tracks the status and life histories of summer Chinook up to and including brood year 2012. Results from monitoring brood year 2013 and beyond will be included in annual reports to BPA.

10.1 Broodstock Sampling

Summer Chinook broodstock for the Okanogan/Similkameen and Methow programs was typically collected at the East and West Ladders of Wells Dam. In 2012, broodstock was also collected at the mouth of the Okanogan River via purse seine. In 2012, a total of 81 summer Chinook (79 wild Chinook and two hatchery Chinook)[30] were spawned for the Okanogan program. Refer to Section

[30] It is important to point out that some summer Chinook were used for both the Methow and Okanogan programs in 2012 because of the availability of ripe adults at the time of spawning. In addition, some eyed-eggs were split between the two programs

9.1 for information on the origin, age and length, sex ratios, and fecundity of summer Chinook broodstock collected at Wells Dam before 2013.

10.2 Hatchery Rearing

In this section, we describe the hatchery rearing of the Okanogan summer Chinook program through brood year 2012. The Colville Tribes began operating the program in 2013. Information on rearing history since brood year 2012 can be found in annual reports prepared by the Colville Tribes and submitted to BPA.

Rearing History

Number of eggs taken

Based on the unfertilized egg-to-release survival standard of 81%, a total of 711,111 eggs were required to meet the program release goal of 576,000 smolts through the 2011 brood year. An evaluation of the program in 2012 determined that 205,134 eggs were needed to meet the revised release goal of 166,569 smolts. This revised goal began with brood year 2012. From 1989 through 2012, the egg take goal was reached in 13 of those years (Table 10.1).

Table 10.1. Numbers of eggs taken from summer Chinook broodstock for the Okanogan program during 1989-2012. From 1989-2011, broodstock were collected at Wells Dam. In 2012, broodstock were collected in purse seines in the Okanogan River.

Return year	Number of eggs taken
1989	724,200
1990	696,144
1991	879,892
1992	729,389
1993	797,234
1994	893,086
1995	736,500
1996	672,000
1997	601,744
1998	584,018
1999	725,589
2000	645,403
2001	418,907
2002	718,599
2003	710,521
2004	805,814
2005	452,928
2006	757,350
2007	824,703
2008	662,668
2009	840,902
2010	726,979

Return year	Number of eggs taken
2011	683,419
Average (1989-2011)	***708,173***
Median (1989-2011)	***724,200***
2012	201,295
Average (2012)	***201,295***
Median (2012)	***201,295***

Number of acclimation days

Summer Chinook were released volitionally from Similkameen Pond as yearling smolts. Transfer dates, release dates, and the number of acclimation days for Okanogan summer Chinook are shown in Table 10.2.

Table 10.2. Number of days Okanogan summer Chinook broods were acclimated at Similkameen and Bonaparte ponds, brood years 1989-2012.

Brood year	Release year	Rearing facility	Transfer date	Release date	Number of days
1989	1991	Similkameen	29-Oct	7-May	190
1990	1992	Similkameen	5-Nov	25-Apr	171
1991	1993	Similkameen	1-Nov	9-Apr	159
1992	1994	Similkameen	2-Nov	1-Apr	150
			26-Feb	1-Apr	34
1993	1995	Similkameen	24-Oct	1-Apr	159
			24-Feb	1-Apr	36
1994	1996	Similkameen	30-Oct	6-Apr	158
			14-Mar	6-Apr	23
1995	1997	Similkameen	1-Oct	1-Apr	182
1996	1998	Similkameen	10-Oct	15-Mar	156
1997	1999	Similkameen	7-Oct	19-Apr	194
1998	2000	Similkameen	5-Oct	19-Apr	196
1999	2001	Similkameen	5-Oct	18-Apr	195
2000	2002	Similkameen	10-Oct	8-Apr	180
2001	2003	Similkameen	1-Oct	29-Apr	210
2002	2004	Similkameen	9-Nov	23-Apr	165
2003	2005	Similkameen	19-Oct	28-Apr	191
2004	2006	Similkameen	26-Oct	23-Apr	179
2005	2007	Bonaparte	6-Nov	11-Apr	156
		Similkameen	25-Oct	18-Apr – 9-May	179-200

Brood year	Release year	Rearing facility	Transfer date	Release date	Number of days
2006	2008	Similkameen	15-17-Oct	16-Apr – 7-May	182-205
2007	2009	Bonaparte	3-4-Nov	10-22-Apr	157-170
		Similkameen	20-24-Oct	14-Apr – 9-May	172-201
2008	2010	Bonaparte	2-4-Nov	19-Apr – 5-May	167-185
		Similkameen	26-28-Oct	19-Apr – 14-May	176-201
2009	2011	Bonaparte	8-9-Nov	12-Apr	155-156
		Similkameen	25-27-Oct	13-Apr – 5-May	169-193
2010	2012	Bonaparte	No program	No program	No program
		Similkameen	25-27 Oct	16-Apr – 7-May	173-196
2011	2013	Bonaparte	No program	No program	No program
		Similkameen	23-26 Oct	16-Apr – 8-May	175-197
2012	2014	Bonaparte	No program	No program	No program
		Similkameen	28-30 Oct	15 Apr – 5 May	167-189

Release Information

Numbers released

The 2012 Okanogan summer Chinook program achieved 68.4% of the 166,569 target goal with about 114,000 fish being released volitionally into the Similkameen River (Table 10.3).

Table 10.3. Numbers of Okanogan summer Chinook smolts released from the Similkameen and Bonaparte ponds, brood years 1989-2012; NA = not available. For brood years 1998-2012, the release target was 576,000 smolts. Since brood year 2013, the release target for Okanogan summer Chinook is 114,000 smolts.

Brood year	Release year	Rearing facility	CWT mark rate	Number of smolts released
1989	1991	Similkameen	0.5732	352,600
1990	1992	Similkameen	0.6800	540,000
1991	1993	Similkameen	0.5335	675,500
1992	1994	Similkameen	0.9819	548,182
1993	1995	Similkameen	0.6470	586,000
1994	1996	Similkameen	0.4176	536,299
1995	1997	Similkameen	0.9785	587,000
1996	1998	Similkameen	0.9769	507,913
1997	1999	Similkameen	0.9711	589,591
1998	2000	Similkameen	0.9825	293,191
1999	2001	Similkameen	0.9689	630,463
2000	2002	Similkameen	0.9928	532,453
2001	2003	Similkameen	0.9877	26,642

Brood year	Release year	Rearing facility	CWT mark rate	Number of smolts released
2002	2004	Similkameen	0.9204	388,589
2003	2005	Similkameen	0.9929	579,019
2004	2006	Similkameen	0.9425	703,359
2005	2007	Bonaparte	0	0 (assumed)
		Similkameen	0.9862	275,919
2006	2008	Similkameen	0.9878	604,035
2007	2009	Bonaparte	0.9920	102,099
		Similkameen	0.9914	513,039
2008	2010	Bonaparte	0.9947	175,729
		Similkameen	0.9947	343,628
2009	2011	Bonaparte	0.9981	151,382
		Similkameen	0.9953	524,521
2010	2012	Similkameen	0.9886	617,950
2011	2013	Similkameen	0.9956	627,978
Average (1989-2011)		***Bonaparte***	***0.7462***	***143,070***
		Similkameen	***0.8907***	***503,647***
Median (1989-2011)		***Bonaparte***	***0.9819***	***540,000***
		Similkameen	***0.9934***	***151,382***
2012	2014	Bonaparte	No program	No program
		Similkameen	0.9939	114,000
Average (2012-present)		***Bonaparte***	***No program***	***No program***
		Similkameen	***0.9939***	***114,000***
Median (2012-present)		***Bonaparte***	***No program***	***No program***
		Similkameen	***0.9939***	***114,000***

Numbers tagged

The 2012 brood Okanogan summer Chinook from the Similkameen facility were 99.4% CWT and adipose fin-clipped (Table 10.3). Table 10.4 summarizes the number of hatchery summer Chinook that have been PIT-tagged and released into the Okanogan River basin. No fish from the 2012 brood year were PIT tagged.

Table 10.4. Summary of PIT-tagging activities for Okanogan hatchery summer Chinook, brood years 2008-2011.

Brood year	Release year	Number of fish tagged	Number of tagged fish that died	Number of tags shed	Number of tagged fish released
2008	2010	5,700 (high density)	1,169	0	4,531
		5,700 (low density)	1,407	0	4,293
2009	2011	5,100	11	0	5,089
2010	2012	0	0	0	0

Brood year	Release year	Number of fish tagged	Number of tagged fish that died	Number of tags shed	Number of tagged fish released
2011	2013	5,100	64	0	5,036

Fish size and condition at release

Size at release of the Similkameen population was 73.3% and 56.8% of the fork length and weight targets, respectively. The CV for fork length exceeded the target by 18.9% (Table 10.5). There was no Bonaparte program for the 2014 release year.

Table 10.5. Mean lengths (FL, mm), weight (g and fish/pound), and coefficient of variation (CV) of Okanogan summer Chinook smolts released from the hatchery, brood years 1989-2012. Size targets are provided in the last row of the table.

Brood year	Release year	Fork length (mm)		Mean weight	
		Mean	CV	Grams (g)	Fish/pound
1989	1991	-	-	41.3	11
1990	1992	143	9.5	37.8	12
1991	1993	125	15.5	22.4	20
1992	1994	120	15.4	20.7	22
1993	1995	132	-	23.2	20
1994	1996	136	16.0	29.6	15
1995	1997	137	8.2	32.8	14
1996	1998	127	12.8	26.2	17
1997	1999	144	9.9	36.0	13
1998	2000	148	5.9	41.0	11
1999	2001	141	15.7	35.4	13
2000	2002	121	13.4	20.4	22
2001	2003	132	8.2	25.7	18
2002	2004	119	13.4	20.8	22
2003	2005	133	10.6	28.9	16
2004	2006	132	9.9	29.8	15
2005	2007	132	9.6	25.9	18
2006	2008	120	12.3	20.9	22
2007	2009	124	12.6	21.9	21
2008	2010	140	12.3	35.1	13
2009	2011	132	11.6	24.7	18
2010	2012	125	10.1	23.2	20
2011	2013	132	9.5	27.9	16
2012	2014	129	7.3	25.8	18
Average		***131***	***11.4***	***28.2***	***17***
Median		***132***	***11.1***	***26.1***	***18***
Targets		***176***	***9.0***	***45.4***	***10***

Survival Estimates

Overall survival of Okanogan summer Chinook from green (unfertilized) egg to release was above the standard set for the program (Table 10.6). Low survival can be attributed to high mortality after ponding through release because of external fungus. Currently, it is unknown if gamete viability is sex biased or is uniform between sexes and more influenced by between-year environmental variations.

Table 10.6. Hatchery life-stage survival rates (%) for Okanogan summer Chinook, brood years 1989-2012. Survival standards or targets are provided in the last row of the table.

Brood year	Rearing facility	Collection to spawning		Unfertilized egg-eyed	Eyed egg-ponding	30 d after ponding	100 d after ponding	Ponding to release	Transport to release	Unfertilized egg-release
		Female	Male							
1989[a]	Similkameen	89.8	99.5	89.9	96.7	99.7	99.4	73.3	57.4	48.7
1990[a]	Similkameen	93.9	99.0	84.9	97.1	81.2	80.6	97.7	98.6	77.6
1991[a]	Similkameen	93.1	95.5	88.2	97.1	99.4	99.1	98.4	97.1	76.8
1992[a]	Similkameen	96.9	99.0	87.0	98.0	99.9	99.9	91.7	92.6	75.2
1993[a]	Similkameen	82.2	99.4	85.4	97.6	99.8	99.5	92.0	90.2	73.5
1994	Similkameen	96.1	90.0	86.6	100.0	98.1	97.4	73.1	89.8	60.1
1995	Similkameen	91.9	96.2	98.2	84.1	96.5	96.2	92.7	98.2	79.7
1996	Similkameen	95.4	98.1	83.2	100.0	97.7	96.9	86.5	92.5	75.6
1997	Similkameen	91.9	94.6	86.1	98.4	98.7	98.3	98.8	99.4	98.0
1998	Similkameen	84.0	96.2	54.1	98.0	99.4	98.9	96.6	99.6	50.2
1999	Similkameen	98.8	98.7	92.9	96.9	98.0	97.6	96.9	99.0	86.9
2000	Similkameen	90.5	96.9	89.2	98.5	98.2	98.0	93.6	97.2	82.5
2001	Similkameen	96.2	92.3	89.1	97.6	99.7	99.5	7.4	11.9	6.4
2002	Similkameen	97.1	98.1	89.8	98.0	99.7	99.5	51.6	52.2	54.1
2003	Similkameen	96.7	97.5	86.8	97.6	99.3	98.5	98.0	98.8	81.5
2004	Similkameen	93.6	98.2	84.0	97.6	99.6	99.3	97.8	98.8	80.2
	Bonaparte	93.6	98.2	84.0	97.6	99.6	99.3	97.9	98.9	80.3
2005	Similkameen	97.0	89.6	88.0	99.5	99.5	99.0	93.5	94.6	81.8
	Bonaparte	97.0	89.6	88.0	99.5	99.5	99.0	0.0	0.0	0.0
2006	Similkameen	92.9	89.5	86.3	98.3	99.6	99.3	94.1	95.5	79.8
2007	Similkameen	92.6	99.6	80.8	99.1	99.5	99.1	97.0	98.1	77.7
	Bonaparte	92.6	99.6	80.8	99.1	99.5	99.1	95.6	96.7	76.6
2008	Similkameen	97.9	99.6	91.2	96.8	99.7	99.3	89.8	90.5	79.3
	Bonaparte	97.9	99.6	91.2	96.8	99.7	99.3	86.9	87.8	76.7
2009[b]	Similkameen	93.6	93.5	91.0	98.2	99.7	99.5	97.8	98.6	87.4
	Bonaparte	93.6	93.5	91.0	98.2	99.7	99.5	74.8	75.3	66.8
2010	Similkameen	96.5	100.0	91.2	99.9	97.4	97.1	93.3	96.3	85.0
2011	Similkameen	100.0	90.2	95.9	98.3	99.8	99.1	97.8	98.8	92.2
2012	Similkameen	100.0	100.0	85.1	98.6	99.7	99.3	70.6	71.2	59.3
Mean	***Similkameen***	***94.1***	***96.3***	***86.9***	***97.6***	***98.3***	***97.9***	***86.7***	***88.2***	***72.9***
	Bonaparte	***94.9***	***96.1***	***87.0***	***98.2***	***99.6***	***99.2***	***71.0***	***71.7***	***60.1***
Median	***Similkameen***	***94.7***	***97.8***	***87.5***	***98.0***	***99.5***	***99.1***	***93.6***	***96.7***	***78.5***
	Bonaparte	***93.6***	***98.2***	***88.0***	***98.2***	***99.6***	***99.3***	***86.9***	***87.8***	***76.6***
Standard		***90.0***	***85.0***	***92.0***	***98.0***	***97.0***	***93.0***	***90.0***	***95.0***	***81.0***

[a] Survival rates were calculated from the aggregate population collected at Wells Fish Hatchery volunteer channel and left- and right-ladder traps at Wells Dam.

[b] Survival rates were calculated from aggregate collections at Wells east fish ladder for the Methow and Okanogan/Similkameen programs. About 59% of the total fish collected were used to estimate survival rates.

10.3 Disease Monitoring

Results of adult broodstock bacterial kidney disease (BKD) monitoring for Methow/Okanogan summer Chinook are shown in Table 9.12 in Section 9.3.

10.4 Spawning Surveys

Surveys for Okanogan/Similkameen summer Chinook redds were conducted from late September to mid-November in the Okanogan and Similkameen rivers. Total redd counts (not peak counts) were conducted in the rivers.

Redd Counts

During the survey period 1989 through 2016, the number of summer Chinook redds in the Okanogan River basin averaged 2,179 and ranged from 110 to 6,025 (Table 10.7).

Table 10.7. Total number of redds counted in the Okanogan River basin, 1989-2016. The Colville Tribes provided data for survey years 2013 to present.

Survey year	Number of summer Chinook redds		
	Okanogan River	Similkameen River	Total count
1989	151	370	521
1990	99	147	246
1991	64	91	155
1992	53	57	110
1993	162	288	450
1994	375*	777	1,152
1995	267*	616	883
1996	116	419	535
1997	158	486	644
1998	88	276	364
1999	369	1,275	1,644
2000	549	993	1,542
2001	1,108	1,540	2,648
2002	2,667	3,358	6,025
2003	1,035	378	1,413
2004	1,327	1,660	2,987
2005	1,611	1,423	3,034
2006	2,592	1,666	4,258
2007	1,301	707	2,008
2008	1,146	1,000	2,146
2009	1,672	1,298	2,970

Survey year	Number of summer Chinook redds		
	Okanogan River	Similkameen River	Total count
2010	1,011	1,107	2,118
2011	1,714	1,409	3,123
2012	1,613	1,066	2,679
2013	2,267	1,280	3,547
2014	2,231	2,022	4,253
2015	2,379	1,897	4,276
2016	3,486	1,790	5,276
Average	***1,129***	***1,050***	***2,179***
Median	***1,072***	***1,033***	***2,063***

* Reach-expanded aerial counts.

Spawning Escapement

Spawning escapement for Okanogan/Similkameen summer Chinook was calculated as the total number of redds times the fish per redd ratio estimated from fish sampled at Wells Dam.[31] During the survey period 1989 through 2016, the summer Chinook spawning escapement within the Okanogan River basin averaged 5,870 and ranged from 473 to 13,857 (Table 10.8).

Table 10.8. Spawning escapements for summer Chinook in the Okanogan and Similkameen rivers for return years 1989-2016. The Colville Tribes provided data for return years 2013 to present.

Return year	Fish/Redd	Spawning escapement		
		Okanogan	Similkameen	Total
1989*	3.30	498	1,221	1,719
1990*	3.40	337	500	837
1991*	3.70	237	337	574
1992*	4.30	228	245	473
1993*	3.30	535	950	1,485
1994*	3.50	1,313	2,720	4,033
1995*	3.40	908	2,094	3,002
1996*	3.40	394	1,425	1,819
1997*	3.40	537	1,652	2,189
1998	3.00	264	828	1,092
1999	2.20	812	2,805	3,617
2000	2.40	1,318	2,383	3,701
2001	4.10	4,543	6,314	10,857
2002	2.30	6,134	7,723	13,857
2003	2.42	2,505	915	3,420
2004	2.25	2,986	3,735	6,721
2005	2.93	4,720	4,169	8,889

[31] Expansion factor = (1 + (number of males/number of females)).

Return year	Fish/Redd	Spawning escapement		
		Okanogan	Similkameen	Total
2006	2.02	5,236	3,365	8,601
2007	2.20	2,862	1,555	4,417
2008	3.25	3,725	3,250	6,975
2009	2.54	4,247	3,297	7,544
2010	2.81	2,841	3,111	5,952
2011	3.10	5,313	4,368	9,681
2012	3.07	4,952	3,273	8,225
2013	2.31	5,237	2,957	8,194
2014	2.86	6,381	5,783	12,164
2015	3.21	7,637	6,089	13,726
2016	2.01	7,007	3,598	10,605
Average	***2.95***	***2,990***	***2,881***	***5,870***
Median	***3.04***	***2,852***	***2,881***	***5,185***

* Spawning escapement was calculated using the "Modified Meekin Method" (i.e., 3.1 x jack multiplier).

10.5 Carcass Surveys

Surveys for summer Chinook carcasses were conducted during late September to mid-November in the Okanogan and Similkameen rivers.

Number sampled

During the survey period 1993 through 2016, the number of summer Chinook carcasses sampled in the Okanogan River basin averaged 1,727 and ranged from 115 to 5,276 (Table 10.9). In all years, most were sampled in the upper Okanogan River and lower Similkameen River (Table 10.9).

Table 10.9. Numbers of summer Chinook carcasses sampled within each survey reach in the Okanogan River basin, 1993-2016. Reach codes are described in Table 2.11. The Colville Tribes provided data for survey years 2013 to present.

Survey year	Number of summer Chinook carcasses								
	Okanogan						Similkameen		Total
	O-1	O-2	O-3	O-4	O-5	O-6	S-1	S-2	
1993[a]	0	2	3	0	23	13	73	1	115
1994[b]	0	4	4	0	27	5	318	60	418
1995	0	0	2	0	30	0	239	15	286
1996	0	0	0	2	5	2	226	0	235
1997	0	0	2	0	9	3	225	1	240
1998	0	1	8	1	7	7	340	4	368
1999	0	0	3	2	23	53	766	48	895
2000	0	2	20	15	47	16	727	41	868
2001	0	26	75	10	127	112	1,141	105	1,596

Survey year	Number of summer Chinook carcasses								
	Okanogan						Similkameen		Total
	O-1	O-2	O-3	O-4	O-5	O-6	S-1	S-2	
2002	10	32	83	35	204	572	1,265	259	2,460
2003[c]	0	0	28	0	17	243	596	381	1,265
2004	0	4	31	24	146	283	1,392	298	2,178
2005	0	8	93	37	371	434	731	276	1,950
2006	4	3	31	16	120	291	508	106	1,079
2007	2	0	55	1	453	519	658	29	1,717
2008	4	10	40	36	248	665	859	157	2,019
2009	2	7	31	32	348	500	703	150	1,773
2010	3	10	30	42	241	352	627	148	1,453
2011	0	0	55	14	361	478	753	114	1,775
2012	1	0	56	15	256	537	495	54	1,414
2013	3	2	158	46	397	1,661	1,254	26	3,547
2014	11	57	191	111	851	1,010	1,737	285	4,253
2015	36	113	284	79	1,008	859	1,611	286	4,276
2016	2	57	52	130	907	2,338	1,645	145	5,276
Average	***3***	***14***	***56***	***27***	***259***	***456***	***787***	***125***	***1,727***
Median	***0***	***3***	***31***	***15***	***175***	***322***	***715***	***106***	***1,525***

[a] 25 additional carcasses were sampled on the Similkameen and 46 on the Okanogan without any reach designation.
[b] One additional carcasses was sampled on the Similkameen without any reach designation.
[c] 793 carcasses were sampled on the Similkameen before initiation of spawning (pre-spawn mortality) and an additional 40 carcasses were sampled on the Okanogan. The cause of the high mortality (*Ichthyophthirius multifilis* and *Flavobacterium columnarae*) was exacerbated by high river temperatures.

Carcass Distribution and Origin

Based on the available data (1991-2015), most fish, regardless of origin, were found in Reach 1 on the Similkameen River (Driscoll Channel to Oroville Bridge) (Table 10.10). However, a slightly larger percentage of hatchery fish were found in reaches on the Similkameen River than were wild fish (Figure 10.1). In contrast, a larger percentage of wild fish were found in reaches on the Okanogan River.

Table 10.10. Numbers of wild and hatchery summer Chinook carcasses sampled within different reaches in the Okanogan River basin, 1993-2015.

Survey year	Origin	Survey reach								Total
		O-1	O-2	O-3	O-4	O-5	O-6	S-1	S-2	
1993	Wild	0	0	3	0	13	4	48	1	69
	Hatchery	0	2	0	0	10	9	25	0	46
1994	Wild	0	0	1	0	7	1	113	22	144
	Hatchery	0	4	3	0	20	4	205	38	274
1995	Wild	0	0	1	0	10	0	66	4	81
	Hatchery	0	0	1	0	20	0	173	11	205
1996	Wild	0	0	0	1	3	1	53	0	58

Survey year	Origin	Survey reach								Total
		O-1	O-2	O-3	O-4	O-5	O-6	S-1	S-2	
	Hatchery	0	0	0	1	2	1	173	0	177
1997	Wild	0	0	1	0	0	3	83	0	87
	Hatchery	0	0	1	0	9	0	142	1	153
1998	Wild	0	1	3	1	6	5	162	4	182
	Hatchery	0	0	5	0	1	2	178	0	186
1999	Wild	0	0	0	0	9	23	293	9	334
	Hatchery	0	0	3	2	14	30	473	39	561
2000	Wild	0	0	8	8	24	11	189	4	244
	Hatchery	0	2	12	7	23	5	538	37	624
2001	Wild	0	10	23	5	67	42	390	54	591
	Hatchery	0	16	52	5	60	70	751	51	1,005
2002	Wild	6	14	20	10	81	212	340	72	755
	Hatchery	4	18	63	25	123	360	925	187	1,705
2003	Wild	0	0	13	0	12	152	231	124	532
	Hatchery	0	0	15	0	5	91	365	257	733
2004	Wild	0	2	19	19	108	225	1,125	260	1,758
	Hatchery	0	2	12	5	38	58	267	38	420
2005	Wild	0	5	51	21	256	364	531	176	1,404
	Hatchery	0	3	42	16	115	70	200	100	546
2006	Wild	2	2	22	10	105	247	370	73	831
	Hatchery	2	1	9	6	15	44	138	33	248
2007	Wild	1	0	30	1	284	322	405	20	1,063
	Hatchery	1	0	25	0	169	197	253	9	654
2008	Wild	2	1	14	11	107	324	347	41	847
	Hatchery	2	9	26	25	141	341	512	116	1,172
2009	Wild	2	3	13	14	189	347	330	75	973
	Hatchery	0	4	18	18	159	153	373	75	800
2010	Wild	1	5	19	18	154	180	329	69	775
	Hatchery	2	5	11	24	87	172	296	79	676
2011	Wild	0	0	21	4	201	362	216	19	823
	Hatchery	0	0	34	10	160	116	537	95	952
2012	Wild	0	0	18	9	133	427	206	23	816
	Hatchery	1	0	38	6	123	110	288	31	597
2013	Wild	0	0	23	7	37	360	216	4	647
	Hatchery	0	0	7	2	15	72	164	3	263
2014	Wild	0	1	62	47	233	717	648	426	2,134
	Hatchery	0	1	17	7	42	66	122	63	318
2015	Wild	0	5	39	9	209	931	1,186	176	2,555
	Hatchery	0	5	22	2	74	63	516	56	738
Average	***Wild***	***1***	***2***	***18***	***8***	***98***	***229***	***342***	***72***	***770***
	Hatchery	***1***	***3***	***18***	***7***	***62***	***88***	***331***	***57***	***568***

Survey year	Origin	Survey reach								Total
		O-1	O-2	O-3	O-4	O-5	O-6	S-1	S-2	
Median	*Wild*	*0*	*0*	*18*	*7*	*81*	*212*	*293*	*23*	*755*
	Hatchery	*0*	*1*	*12*	*5*	*38*	*66*	*267*	*38*	*561*

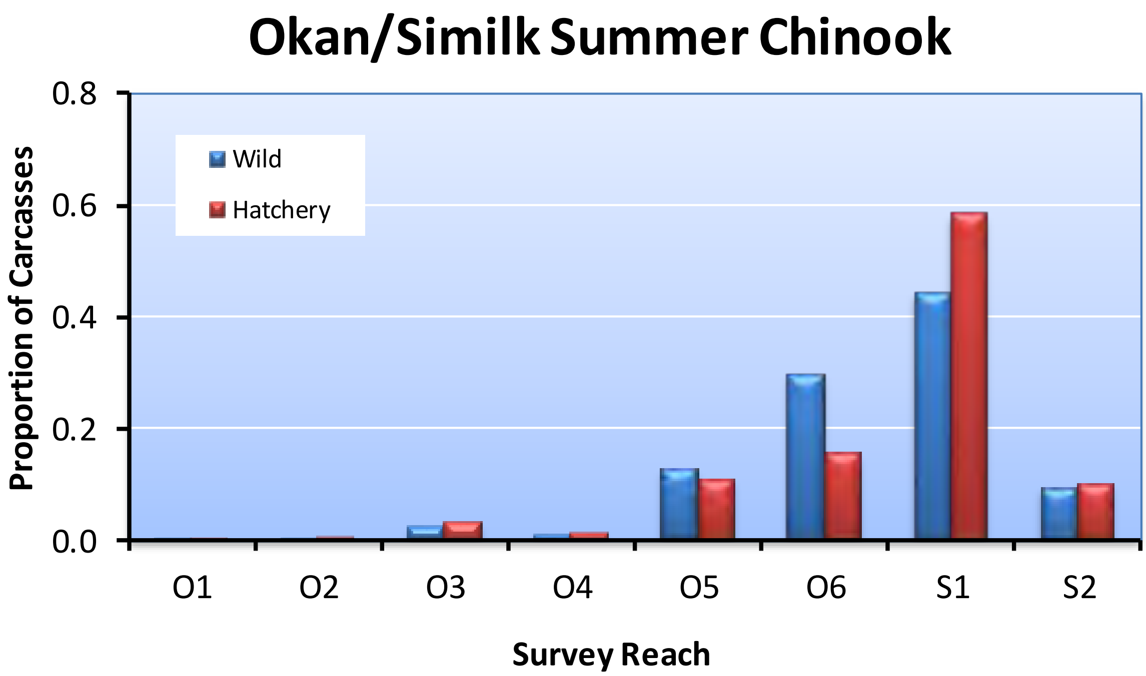

Figure 10.1. Distribution of wild and hatchery produced carcasses in different reaches in the Okanogan River basin, 1993-2015. Reach codes are described in Table 2.11.

10.6 Life History Monitoring

Life history characteristics of Okanogan/Similkameen summer Chinook were assessed by examining carcasses on spawning grounds and fish collected or examined at broodstock collection sites, and by reviewing tagging data and fisheries statistics.

Migration Timing

Migration timing for Okanogan/Similkameen summer Chinook is described in Section 9.6.

Age at Maturity

Because hatchery summer Chinook are released after one year of rearing and natural-origin summer Chinook migrate primarily as age-0 fish, total ages will differ between hatchery and natural-origin Chinook (see Hillman et al. 2011). Therefore, in this section, we evaluated age at maturity by comparing differences in salt (ocean) ages between the two groups.

Most of the wild and hatchery summer Chinook sampled during the period 1993-2015 in the Okanogan River basin were salt age-3 fish (Table 10.11; Figure 10.2). A higher percentage of salt age-4 wild Chinook returned to the basin than did salt age-4 hatchery Chinook. In contrast, a higher proportion of salt age-1 and 2 hatchery fish returned than did salt age-1 and 2 wild fish. Thus, a higher percentage of wild fish returned at an older age than did hatchery fish.

Table 10.11. Proportions of wild and hatchery summer Chinook of different salt (ocean) ages sampled on spawning grounds in the Okanogan River basin, 1993-2015.

Sample year	Origin	Salt age					Sample size
		1	2	3	4	5	
1993	Wild	0.00	0.21	0.70	0.10	0.00	63
	Hatchery	0.00	0.98	0.02	0.00	0.00	44
1994	Wild	0.02	0.13	0.54	0.31	0.00	134
	Hatchery	0.02	0.09	0.89	0.00	0.00	290
1995	Wild	0.00	0.19	0.59	0.22	0.00	68
	Hatchery	0.01	0.15	0.36	0.49	0.00	200
1996	Wild	0.03	0.28	0.61	0.08	0.00	36
	Hatchery	0.02	0.22	0.56	0.20	0.01	174
1997	Wild	0.04	0.27	0.53	0.15	0.00	73
	Hatchery	0.00	0.02	0.87	0.11	0.00	148
1998	Wild	0.02	0.35	0.52	0.11	0.00	151
	Hatchery	0.05	0.50	0.23	0.22	0.00	185
1999	Wild	0.00	0.20	0.64	0.16	0.00	268
	Hatchery	0.00	0.12	0.85	0.02	0.00	552
2000	Wild	0.03	0.15	0.62	0.20	0.00	216
	Hatchery	0.12	0.02	0.76	0.10	0.00	545
2001	Wild	0.02	0.18	0.76	0.04	0.00	531
	Hatchery	0.05	0.88	0.02	0.05	0.00	1,005
2002	Wild	0.02	0.15	0.62	0.21	0.00	692
	Hatchery	0.01	0.19	0.80	0.01	0.00	1,681
2003	Wild	0.03	0.18	0.63	0.17	0.00	477
	Hatchery	0.03	0.06	0.79	0.12	0.00	653
2004	Wild	0.01	0.17	0.26	0.55	0.00	1,528
	Hatchery	0.01	0.32	0.45	0.23	0.00	382
2005	Wild	0.00	0.12	0.79	0.08	0.01	1,281
	Hatchery	0.02	0.06	0.77	0.15	0.00	530
2006	Wild	0.00	0.02	0.53	0.45	0.00	830
	Hatchery	0.05	0.18	0.24	0.53	0.00	139
2007	Wild	0.02	0.07	0.12	0.78	0.02	1,061
	Hatchery	0.22	0.30	0.42	0.05	0.01	559
2008	Wild	0.01	0.32	0.63	0.04	0.01	846

Sample year	Origin	Salt age					Sample size
		1	2	3	4	5	
	Hatchery	0.02	0.60	0.36	0.02	0.00	1,108
2009	Wild	0.01	0.03	0.81	0.15	0.00	926
	Hatchery	0.05	0.05	0.86	0.03	0.00	783
2010	Wild	0.00	0.16	0.45	0.39	0.00	708
	Hatchery	0.02	0.65	0.27	0.06	0.00	619
2011	Wild	0.01	0.07	0.82	0.10	0.00	787
	Hatchery[a]	0.16	0.08	0.76	0.00	0.00	873
2012	Wild	0.02	0.23	0.41	0.34	0.00	750
	Hatchery	0.05	0.55	0.35	0.05	0.00	532
2013	Wild	0.01	0.17	0.75	0.07	0.00	520
	Hatchery	0.03	0.21	0.74	0.02	0.00	252
2014	Wild	0.02	0.08	0.76	0.14	0.00	1892
	Hatchery	0.18	0.26	0.55	0.02	0.00	300
2015	Wild	0.00	0.40	0.34	0.25	0.00	2,167
	Hatchery	0.03	0.68	0.26	0.02	0.00	549
Average	***Wild***	***0.01***	***0.17***	***0.55***	***0.26***	***0.00***	***695***
	Hatchery	***0.05***	***0.32***	***0.56***	***0.07***	***0.00***	***527***
Median	***Wild***	***0.01***	***0.16***	***0.67***	***0.17***	***0.00***	***692***
	Hatchery	***0.04***	***0.23***	***0.64***	***0.09***	***0.00***	***532***

[a] There was one salt age-6 hatchery fish that was not included in this table.

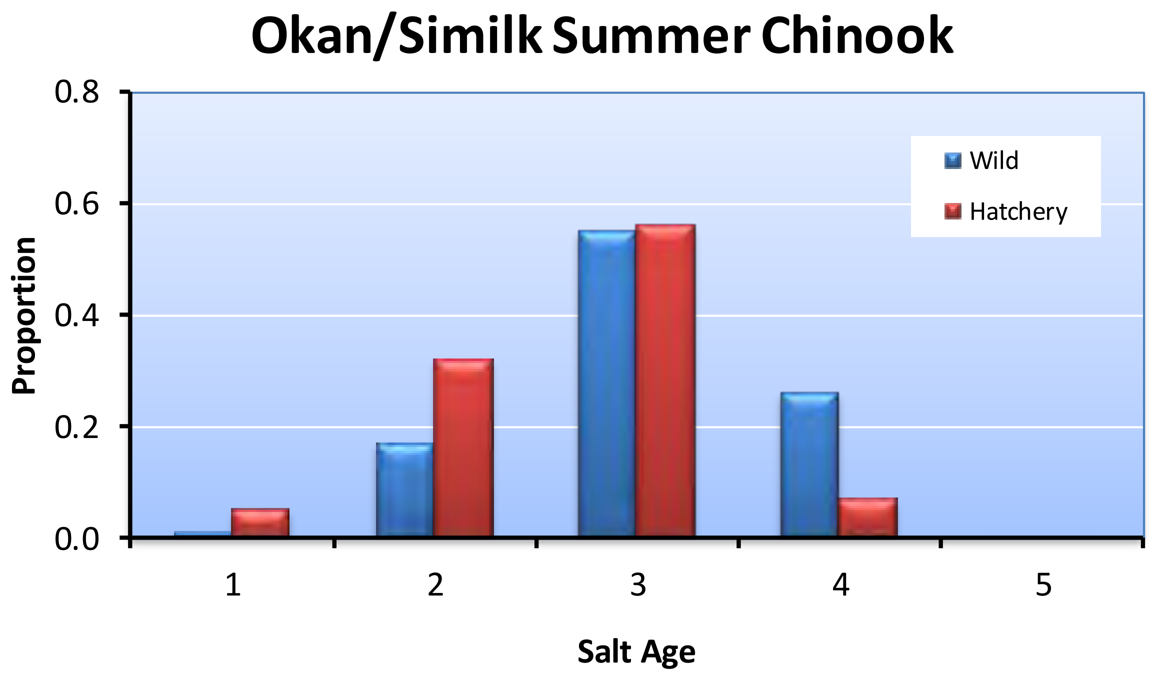

Figure 10.2. Proportions of wild and hatchery summer Chinook of different salt (ocean) ages sampled at broodstock collection sites and on spawning grounds in the Okanogan River basin for the combined years 1993-2015.

Size at Maturity

For the period 1993 through 2015, on average, hatchery summer Chinook were about 2 cm smaller than wild summer Chinook sampled in the Okanogan River basin (Table 10.12). This is likely because a higher percentage of wild fish returned as salt age-4 fish than did hatchery fish.

Table 10.12. Mean lengths (POH; cm) and variability statistics for wild and hatchery summer Chinook sampled in the Okanogan River basin, 1993-2015; SD = 1 standard deviation.

Sample year	Origin	Sample size	Summer Chinook length (POH; cm)			
			Mean	SD	Minimum	Maximum
1993[a]	Wild	69	73	7	52	90
	Hatchery	59	62	6	47	75
1994	Wild	136	71	7	40	86
	Hatchery	268	69	8	30	84
1995	Wild	81	75	6	54	87
	Hatchery	201	73	8	39	87
1996	Wild	22	68	14	22	85
	Hatchery	26	75	8	60	88
1997	Wild	87	70	7	44	84
	Hatchery	148	74	6	48	88

Sample year	Origin	Sample size	Summer Chinook length (POH; cm)			
			Mean	SD	Minimum	Maximum
1998	Wild	182	70	8	45	94
	Hatchery	186	65	12	30	87
1999	Wild	333	73	7	56	91
	Hatchery	559	71	7	23	84
2000	Wild	241	70	10	32	86
	Hatchery	624	69	12	24	92
2001	Wild	578	67	9	26	86
	Hatchery	997	61	8	32	90
2002	Wild	755	69	9	28	91
	Hatchery	1705	70	8	33	87
2003	Wild	532	68	9	30	93
	Hatchery	733	69	10	26	90
2004	Wild	1756	71	10	33	94
	Hatchery	417	66	9	41	92
2005	Wild	1403	66	7	41	99
	Hatchery	546	68	8	31	85
2006	Wild	831	72	6	31	91
	Hatchery	248	71	9	33	87
2007	Wild	1063	75	9	27	99
	Hatchery	654	64	13	30	87
2008	Wild	847	65	9	29	86
	Hatchery	1172	65	8	32	89
2009	Wild	973	70	7	28	89
	Hatchery	799	70	9	35	86
2010	Wild	775	71	9	43	90
	Hatchery	676	64	10	22	87
2011	Wild	823	68	7	29	89
	Hatchery	952	66	11	26	86
2012	Wild	816	67	10	27	93
	Hatchery	597	63	9	23	86
2013	Wild	642	67	8	23	87
	Hatchery	267	71	8	36	88
2014	Wild	2,134	68	8	30	83
	Hatchery	318	64	13	30	89
2015	Wild	2,572	60	9	24	87
	Hatchery	720	58	8	23	78
Pooled	***Wild***	***17,651***	***69***	***8***	***22***	***99***
	Hatchery	***12,872***	***67***	***9***	***22***	***92***

[a] This year includes sizes reported in the annual report. The data contained in the WDFW database do not include all these data.

Contribution to Fisheries

Most of the harvest on hatchery-origin Okanogan/Similkameen summer Chinook occurred in the Ocean (Table 10.13). Ocean harvest has made up 37-100% of all hatchery-origin Okanogan/Similkameen summer Chinook harvested. Brood year 2008 provided the largest harvest, while brood years 1993 and 1996 provided the lowest.

Table 10.13. Estimated number and percent (in parentheses) of hatchery-origin Okanogan/Similkameen summer Chinook captured in different fisheries, brood years 1989-2010.

Brood year	Ocean fisheries	Columbia River Fisheries			Total
		Tribal	Commercial (Zones 1-5)	Recreational (sport)	
1989	2,371 (80)	553 (19)	0 (0)	42 (1)	2,966
1990	355 (89)	34 (8)	0 (0)	12 (3)	401
1991	220 (86)	37 (14)	0 (0)	0 (0)	257
1992	422 (91)	28 (6)	2 (0)	10 (2)	462
1993	24 (80)	6 (20)	0 (0)	0 (0)	30
1994	372 (92)	23 (6)	2 (0)	7 (2)	406
1995	643 (93)	9 (1)	12 (2)	25 (4)	698
1996	6 (100)	0 (0)	0 (0)	0 (0)	6
1997	6,618 (92)	136 (2)	36 (0)	416 (6)	7,206
1998	4,395 (90)	251 (5)	45 (1)	219 (4)	4,910
1999	1,357 (68)	224 (11)	31 (2)	384 (19)	1,996
2000	3,139 (69)	533 (12)	222 (5)	665 (15)	4,559
2001	184 (58)	81 (25)	31 (10)	23 (7)	319
2002	706 (56)	200 (16)	90 (7)	258 (21)	1,254
2003	711 (38)	568 (30)	130 (7)	466 (25)	1,875
2004	3,156 (39)	2,162 (26)	694 (8)	2,165 (26)	8,177
2005	470 (46)	306 (30)	79 (8)	167 (16)	1,022
2006	3,136 (37)	3,352 (40)	469 (6)	1,419 (17)	8,376
2007	1,549 (45)	951 (27)	67 (2)	905 (26)	3,477
2008	4,237 (41)	1,963 (19)	218 (2)	3,958 (38)	10,376
2009	2,009 (46)	980 (23)	207 (5)	1,138 (26)	4,334
2010	3,213 (50)	1,845 (29)	247 (4)	1,063 (17)	6,368
Average	***1,786 (68)***	***647 (17)***	***117 (3)***	***606 (13)***	***3,157***
Median	***1,034 (69)***	***238 (18)***	***41 (2)***	***239 (11)***	***1,936***

Straying

Stray rates were determined by examining CWTs recovered on spawning grounds within and outside the Okanogan River basin. Targets for strays based on return year (recovery year) within the upper Columbia River basin (Priest Rapids Dam to Chief Joseph Dam) should be less than

10% and targets for strays outside the upper Columbia River should be less than 5%. The target for brood year stay rates should be less than 5%.

Few hatchery-origin Okanogan summer Chinook have strayed into basins outside the Okanogan (Table 10.14). Although hatchery-origin Okanogan summer Chinook have strayed into other spawning areas, they usually made up less than 10% of the spawning escapement within those areas. The Chelan tailrace has received the largest number of Okanogan strays.

Table 10.14. Number and percent of spawning escapements within other non-target basins that consisted of hatchery-origin Okanogan summer Chinook, return years 1994-2015. For example, for return year 2002, 1% of the summer Chinook spawning escapement in the Entiat Basin consisted of hatchery-origin Okanogan summer Chinook. Percent strays should be less than 10%.

Return year	Wenatchee		Methow		Chelan		Entiat		Hanford Reach	
	Number	%	Number	%	Number	%	Number	%	Number	%
1994	0	0.0	0	0.0	-	-	-	-	-	-
1995	0	0.0	0	0.0	-	-	-	-	-	-
1996	0	0.0	0	0.0	-	-	-	-	-	-
1997	0	0.0	0	0.0	-	-	-	-	-	-
1998	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
1999	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
2000	0	0.0	6	0.5	30	4.5	0	0.0	3	0.0
2001	12	0.1	0	0.0	10	1.0	0	0.0	0	0.0
2002	0	0.0	3	0.1	4	0.7	5	1.0	0	0.0
2003	0	0.0	8	0.2	22	5.3	14	2.0	0	0.0
2004	0	0.0	0	0.0	5	1.2	0	0.0	0	0.0
2005	5	0.1	27	1.1	36	6.9	7	1.9	8	0.0
2006	0	0.0	5	0.2	4	1.0	7	1.3	0	0.0
2007	0	0.0	3	0.2	4	2.1	0	0.0	0	0.0
2008	0	0.0	9	0.5	46	9.3	4	1.3	0	0.0
2009	15	0.2	3	0.2	11	1.8	18	7.2	0	0.0
2010	6	0.1	0	0.0	33	3.0	0	0.0	0	0.0
2011	0	0.0	0	0.0	46	3.6	0	0.0	0	0.0
2012	7	0.1	5	0.2	19	1.5	0	0.0	0	0.0
2013	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
2014	0	0.0	4	0.2	8	0.7	0	0.0	0	0.0
2015	4	0.1	5	0.1	4	0.3	0	0.0	0	0.0
Average	**2**	**0.0**	**4**	**0.2**	**16**	**2.4**	**3**	**0.8**	**1**	**0.0**
Median	**0**	**0.0**	**2**	**0.1**	**9**	**1.4**	**0**	**0.0**	**0**	**0.0**

On average, about 1% of the brood year returns have strayed into non-target populations, falling within the acceptable level of less than 5% (Table 10.15). Depending on brood year, percent strays into non-target spawning areas have ranged from 0-4.4%. Few (<1% on average) have strayed into non-target hatchery programs.

Table 10.15. Number and percent of hatchery-origin Okanogan summer Chinook that homed to target spawning areas and the target hatchery, and number and percent that strayed to non-target spawning areas and non-target hatchery programs, by brood years 1989-2010. Percent stays should be less than 5%.

Brood year	Homing				Straying			
	Target stream		Target hatchery*		Non-target streams		Non-target hatcheries	
	Number	%	Number	%	Number	%	Number	%
1989	3,132	69.7	1,328	29.6	2	0.0	31	0.7
1990	729	71.4	291	28.5	0	0.0	1	0.1
1991	1,125	71.3	453	28.7	0	0.0	0	0.0
1992	1,264	68.5	572	31.0	8	0.4	1	0.1
1993	54	62.1	32	36.8	0	0.0	1	1.1
1994	924	80.8	203	17.7	16	1.4	1	0.1
1995	1,883	85.4	271	12.3	50	2.3	0	0.0
1996	27	100.0	0	0.0	0	0.0	0	0.0
1997	11,629	97.1	309	2.6	34	0.3	3	0.0
1998	2,727	95.3	102	3.6	31	1.1	2	0.1
1999	828	96.7	18	2.1	10	1.2	0	0.0
2000	2,091	93.6	29	1.3	99	4.4	15	0.7
2001	105	98.1	2	1.9	0	0.0	0	0.0
2002	702	96.2	17	2.3	11	1.5	0	0.0
2003	1,580	96.2	47	2.9	16	1.0	0	0.0
2004	4,947	94.4	206	3.9	85	1.6	2	0.0
2005	606	93.2	22	3.4	22	3.4	0	0.0
2006	5,220	97.6	60	1.1	68	1.3	0	0.0
2007	1,396	97.8	21	1.5	10	0.7	0	0.0
2008	3,600	97.2	78	2.1	23	0.6	4	0.1
2009	1,006	85.9	152	13.0	12	1.0	1	0.1
2010	909	61.3	566	38.1	9	0.6	0	0.0
Average	**2,117**	**86.8**	**217**	**12.0**	**23**	**1.0**	**3**	**0.1**
Median	**1,195**	**94.0**	**90**	**3.5**	**12**	**0.9**	**1**	**0.0**

* Homing to the target hatchery includes Okanogan/Similkameen hatchery summer Chinook that are captured and included as broodstock in the Okanogan/Similkameen Hatchery program. These hatchery fish were typically collected at Wells Dam.

Genetics

Genetic studies were conducted to investigate relationships among temporally replicated collections of summer Chinook from the Wenatchee River, Methow River, and Okanogan River in the upper Columbia River basin (Kassler et al. 2011; the entire report is appended as Appendix N). A total of 2,416 summer Chinook were collected from tributaries in the upper Columbia River basin. Two collections of natural-origin summer Chinook from 1993 (prior to the supplementation program) were taken from the Wenatchee River basin (N = 139) and compared to collections of hatchery and natural-origin Chinook from 2006 and 2008 (N = 380). Two pre-supplementation collections from the Methow River (1991 and 1993) were compared to supplementation collections from 2006 and 2008 (N = 362). Three pre-supplementation collections from the Okanogan River Basin (1991, 1992, and 1993) were compared with supplementation collections from 2006 and 2008 (N = 669). A collection of natural-origin summer Chinook from the Chelan River was also analyzed (N = 70). Additionally, hatchery collections from Eastbank Hatchery (Wenatchee and Methow/Okanogan stock; N = 221) and Wells Hatchery (N = 294) were analyzed and compared to the in-river collections. Summer Chinook data (provided by the USFWS) from the Entiat River (N = 190) were used for comparison. Lastly, data from eight collections of fall Chinook (N = 2,408) were compared to the collections of summer Chinook. Samples of natural and hatchery-origin summer Chinook were analyzed and compared to determine if the supplementation programs have affected the genetic structure of these populations. The study also calculated the effective number of breeders for collection locations of natural and hatchery-origin summer Chinook from 1993 and 2008.

In general, population differentiation was not observed among the temporally replicated collection locations. A single collection from the Okanogan River (1993) was the only collection showing statistically significant differences. The effective number of breeders was not statistically different from the early collection in 1993 in comparison to the late collection in 2008. Overall, these analyses revealed a lack of differentiation among the temporal replicates from the same locations and among the collection from different locations, suggesting the populations have been homogenized or that there has been substantial gene flow among populations. Additional comparisons among summer-run and fall-run Chinook populations in the upper Columbia River were conducted to determine if there was any differentiation between Chinook with different run timing. These analyses revealed pairwise F_{ST} values that were less than 0.01 for the collections of summer Chinook to collections of fall Chinook from Hanford Reach, lower Yakima River, Priest Rapids, and Umatilla. Collections of fall Chinook from Crab Creek, Lyons Ferry Hatchery, Marion Drain, and Snake River had pairwise F_{ST} values that were higher in comparison to the collections of summer Chinook. The consensus clustering analysis did not provide good statistical support to the groupings, but did show relationships among collections based on geographic proximity. Overall the summer and fall run Chinook that have historically been spawned together were not differentiated while fall Chinook from greater geographic distances were differentiated.

Proportionate Natural Influence

Another method for assessing the genetic risk of a supplementation program is to determine the influence of the hatchery and natural environments on the adaptation of the composite population. This is estimated by the proportion of natural-origin fish in the hatchery broodstock (pNOB) and the proportion of hatchery-origin fish in the natural spawning escapement (pHOS). We calculated Proportionate Natural Influence (PNI) by iterating Ford's (2002) equations 5 and 6 to equilibrium, using a heritability of 0.3 and a selection strength of three standard deviations. The larger the PNI value, the greater the strength of selection in the natural environment relative to that of the hatchery environment. For the natural environment to dominate selection, PNI should be greater than 0.50, and important integrated populations should have a PNI of at least 0.67 (HSRG/WDFW/NWIFC 2004).

For brood years 1993-2003, the PNI values were less than 0.67 (Table 10.16). However, since brood year 2003, PNI has generally been greater than 0.67, save 2008 and 2011. PNI results reported here end with brood year 2012. Beginning with brood year 2013, the Colville

Confederated Tribes report PNI values for Okanogan summer Chinook in their annual reports to BPA.

Table 10.16. Proportionate Natural Influence (PNI) values for the Okanogan/Similkameen summer Chinook supplementation program for brood years 1989-2012. NOS = number of natural-origin Chinook on the spawning grounds; HOS = number of hatchery-origin Chinook on the spawning grounds; NOB = number of natural-origin Chinook collected for broodstock; and HOB = number of hatchery-origin Chinook included in hatchery broodstock.

Brood year	Spawners			Broodstock			PNI[a]
	NOS	HOS	pHOS	NOB	HOB	pNOB	
1989	1,719	0	0	1,297	312	0.81	1.00
1990	837	0	0	828	206	0.80	1.00
1991	574	0	0	924	314	0.75	1.00
1992	473	0	0	297	406	0.42	1.00
1993	915	570	0.38	681	388	0.64	0.64
1994	1,323	2,710	0.67	341	244	0.58	0.48
1995	979	2,023	0.67	173	240	0.42	0.40
1996	568	1,251	0.69	287	155	0.65	0.50
1997	862	1,327	0.61	197	265	0.43	0.43
1998	600	492	0.45	153	211	0.42	0.50
1999	1,274	2,343	0.65	224	289	0.44	0.42
2000	1,174	2,527	0.68	164	337	0.33	0.35
2001	4,306	6,551	0.6	12	345	0.03	0.09
2002	4,346	9,511	0.69	247	241	0.51	0.44
2003	1,933	1,487	0.43	381	101	0.79	0.66
2004	5,309	1,412	0.21	506	16	0.97	0.83
2005	6,441	2,448	0.28	391	9	0.98	0.78
2006	5,507	3,094	0.36	500	10	0.98	0.74
2007	2,983	1,434	0.32	456	17	0.96	0.76
2008	2,998	3,977	0.57	359	86	0.81	0.60
2009	4,204	3,340	0.44	503	4	0.99	0.70
2010	3,189	2,763	0.46	484	8	0.98	0.69
2011	4,642	5,039	0.52	467	26	0.95	0.65
2012	4,494	3,731	0.45	79	2	0.98	0.69
Average	***2,569***	***2,418***	***0.42***	***415***	***176***	***0.69***	***0.64***
Median	***1,826***	***2,183***	***0.45***	***370***	***209***	***0.77***	***0.66***

[a] PNI was calculated previously using PNI approximate equation 11 (HSRG 2009; their Appendix A). All PNI values presented here were recalculated by iterating Ford's (2002) equations 5 and 6 to equilibrium using a heritability of 0.3 and a selection strength of three standard deviations. C. Busack, NOAA Fisheries, 21 March 2016, provided the model for calculating PNI.

Post-Release Survival and Travel Time

We used PIT-tagged fish to estimate survival rates and travel times (arithmetic mean days) of hatchery summer Chinook from the Similkameen River release site to McNary Dam, and smolt to adult ratios (SARs) from release to detection at Bonneville Dam (Table 10.17).[32] Over the three brood years for which PIT-tagged hatchery fish were released, survival rates from the Similkameen River to McNary Dam ranged from 0.432 to 0.720; SARs from release to detection at Bonneville Dam ranged from 0.016 to 0.031. Average travel time from the Similkameen River to McNary Dam ranged from 41 to 44 days. Although there is only one year in which low densities were compared to high densities (brood year 2008), there was little difference in survival rates and travel times between the two groups (Table 10.17).

Table 10.17. Total number of Okanogan hatchery summer Chinook released with PIT tags, their survival and travel times (mean days) to McNary Dam, and smolt-to-adult (SAR) ratios for brood years 2008-2011. Standard errors are shown in parentheses. NA = not available (i.e., not all the fish from the release groups have returned to the Columbia River).

Brood year	Number of tagged fish released	Survival to McNary Dam	Travel time to McNary Dam (d)	SAR to Bonneville Dam
2008	4,531 (high density)	0.445 (0.061)	44.0 (10.2)	0.028 (0.002)
	4,293 (low density)	0.432 (0.050)	41.4 (9.7)	0.030 (0.003)
2009	5,089	0.720 (0.102)	41.5 (10.1)	0.016 (0.002)
2010	0	--	--	--
2011	5,036	0.683 (0.064)	41.9 (12.3)	0.031 (0.002)

Natural and Hatchery Replacement Rates

Natural replacement rates (NRR) were calculated as the ratio of natural-origin recruits (NOR) to the parent spawning population (spawning escapement). Natural-origin recruits are naturally produced (wild) fish that survive to contribute to harvest (directly or indirectly), to broodstock, and to spawning grounds. We do not account for fish that died in route to the spawning grounds (migration mortality) or died just before spawning (pre-spawn mortality) (see Appendix B in Hillman et al. 2012). We calculated NORs with and without harvest. NORs without harvest include all returning fish that either returned to the basin or were collected as wild broodstock. NORs with harvest include all fish harvested and are based on brood year harvest rates from the hatchery program. For brood years 1989-2009, NRR for summer Chinook in the Okanogan averaged 1.01 (range, 0.16-3.82) if harvested fish were not included in the estimate and 2.41 (range, 0.32-10.26) if harvested fish were included in the estimate (Table 10.18). NRRs for more recent brood years will be calculated as soon as all tag recoveries and sampling rates have been loaded into the database.

Hatchery replacement rates (HRR) are the hatchery adult-to-adult returns and were calculated as the ratio of hatchery-origin recruits (HOR) to the parent broodstock collected. These rates should be greater than the NRRs and greater than or equal to 8.6 (the calculated target value in Hillman et al. 2013). The target value of 8.6 includes harvest. HRRs exceeded NRRs in 18 of the 21 years of data, regardless if harvest was or was not included in the estimate (Table 10.18). Hatchery

[32] It is important to point out that because of fish size differences among rearing tanks or raceways, fish PIT tagged in one tank or raceway may not represent untagged fish rearing in other tanks or raceways.

replacement rates for Okanogan summer Chinook have exceeded the estimated target value of 8.6 in 10 of the 21 years of data.

Table 10.18. Broodstock collected, spawning escapements, natural and hatchery-origin recruits (NOR and HOR), and natural and hatchery replacement rates (NRR and HRR; with and without harvest) for wild summer Chinook in the Okanogan River basin, brood years 1989-2009.

Brood year	Broodstock Collected	Spawning Escapement	Harvest not included				Harvest included			
			HOR	NOR	HRR	NRR	HOR	NOR	HRR	NRR
1989	304	1,719	4,493	2,146	14.78	1.25	7,459	3,577	24.54	2.08
1990	288	837	1,021	1,477	3.55	1.76	1,422	2,063	4.94	2.46
1991	364	574	1,578	629	4.34	1.10	1,835	728	5.04	1.27
1992	304	473	1,845	752	6.07	1.59	2,307	942	7.59	1.99
1993	328	1,485	87	1,003	0.27	0.68	117	1,348	0.36	0.91
1994	302	4,033	1,144	2,168	3.79	0.54	1,548	2,946	5.13	0.73
1995	385	3,002	2,204	959	5.72	0.32	2,893	1,267	7.51	0.42
1996	330	1,819	27	466	0.08	0.26	33	574	0.10	0.32
1997	313	2,189	12,005	4,363	38.35	1.99	19,211	6,959	61.38	3.18
1998	352	1,092	2,919	4,166	8.29	3.82	7,829	11,199	22.24	10.26
1999	333	3,617	856	6,641	2.57	1.84	2,852	22,211	8.56	6.14
2000	334	3,701	2,234	1,716	6.69	0.46	6,793	5,232	20.34	1.41
2001	335	10,857	107	8,946	0.32	0.82	426	35,784	1.27	3.30
2002	333	13,857	730	6,061	2.19	0.44	1,984	16,470	5.96	1.19
2003	337	3,420	1,643	562	4.88	0.16	3,518	1,201	10.44	0.35
2004	335	6,721	5,240	3,112	15.64	0.46	13,417	7,959	40.05	1.18
2005	338	8,889	650	6,173	1.92	0.69	1,672	15,951	4.95	1.79
2006	355	8,601	5,348	2,422	15.06	0.28	13,724	6,242	38.66	0.73
2007	314	4,417	1,427	6,334	4.54	1.43	4,899	21,841	15.60	4.94
2008	276	6,975	3,705	2,674	13.42	0.38	14,081	10,445	51.02	1.50
2009	335	7,544	1,171	6,937	3.50	0.92	5,505	34,342	16.43	4.55
Average	***328***	***4,563***	***2,402***	***3,319***	***7.43***	***1.01***	***5,406***	***9,966***	***16.77***	***2.41***
Median	***333***	***3,617***	***1,578***	***2,422***	***4.54***	***0.69***	***2,893***	***6,242***	***8.56***	***1.50***

Smolt-to-Adult Survivals

Smolt-to-adult survival ratios (SARs) were calculated as the number of hatchery adult recaptures divided by the number of tagged hatchery smolts released. Here, SARs were based on CWT returns. For the available brood years, SARs have ranged from 0.00007 to 0.03239 for hatchery summer Chinook in the Okanogan River basin (Table 10.19).

Table 10.19. Smolt-to-adult ratios (SARs) for Okanogan/Similkameen summer Chinook, brood years 1989-2010.

Brood year	Number of tagged smolts released[a]	Estimated adult captures[b]	SAR
1989	202,125	4,293	0.02124
1990	367,207	972	0.00265
1991	360,380	975	0.00271
1992	537,190	2,282	0.00425
1993	379,139	117	0.00031
1994	217,818	1,528	0.00702
1995	574,197	2,851	0.00497
1996	487,776	32	0.00007
1997	572,531	18,543	0.03239
1998	287,948	7,641	0.02654
1999	610,868	2,776	0.00454
2000	528,639	6,765	0.01280
2001	26,315	424	0.01611
2002	245,997	1,969	0.00800
2003	574,908	3,484	0.00606
2004	676,222	12,892	0.01906
2005	273,512	1,662	0.00608
2006	597,276	13,622	0.02281
2007	610,379	4,881	0.00800
2008	516,533	14,026	0.02715
2009	522,295	5,497	0.01052
2010	610,927	7,805	0.01278
Average	***444,554***	***5,229***	***0.01164***
Median	***519,414***	***3,168***	***0.00800***

[a] Includes all tag codes and CWT released fish (CWT + Ad Clip fish and CWT-only fish).

[b] Includes estimated recoveries (spawning ground, hatcheries, harvest, etc.) and observed recoveries if estimated recoveries were unavailable.

10.7 ESA/HCP Compliance

Broodstock Collection

Because summer Chinook adults collected at Wells Dam are used for both the Methow and Okanogan supplementation programs, please refer to Section 9.7 for information on ESA compliance during broodstock collection. Direct and/or indirect take of ESA-listed species during broodstock collection for the Okanogan summer Chinook outside of Wells Dam is covered by permits held by the Colville Tribes. For 2014, no summer Chinook were collected at Wells Dam for the Okanogan summer Chinook program.

Hatchery Rearing and Release

Activities associated with the spawning, rearing, and release of Okanogan summer Chinook that could result in either direct or incidental take of listed species is covered under ESA permits held by the Colville Tribes.

Hatchery Effluent Monitoring

Per ESA Permits 1196, 1347, 1395, 18118, 18120, and 18121, permit holders shall monitor and report hatchery effluents in compliance with applicable National Pollution Discharge Elimination Systems (NPDES) (EPA 1999) permit limitations. There were no NPDES violations reported at PUD Hatchery facilities during the period 1 January through 31 December 2016. NPDES monitoring and reporting for PUD Hatchery Programs during 2016 are provided in Appendix F. NPDES reporting for Okanogan summer Chinook only covers the Similkameen acclimation facility and only during the time fish are present.

SECTION 11: CHELAN FALLS SUMMER CHINOOK

Although the Chelan Falls summer Chinook program (formerly the Turtle Rock program) is an augmentation program, the production of 200,000 fish is No Net Impact (NNI) compensation for passage mortalities associated with Rocky Reach Dam. In addition, the conversion of the subyearling program to a 400,000-yearling program is compensation for lost spawning habitat as a result of the construction of Rocky Reach Dam. In 2011, as part of the periodic recalculation of NNI for Rocky Reach Dam, the previous 200,000 NNI program was reduced to 176,000 fish. This reduced the combined Chelan Falls summer Chinook production from 600,000 to 576,000 beginning with the 2012 brood.

Before 2012, broodstock were collected at Wells Dam and consisted of volunteers to the Wells Fish Hatchery. Summer Chinook were spawned at Wells Fish Hatchery and fertilized eggs were then transferred to Eastbank Fish Hatchery for hatching and rearing. In 2012, adults were collected at Wells Fish Hatchery and then transferred to Eastbank Fish Hatchery for spawning, hatching, and rearing. Beginning in 2013, broodstock collection was initiated at the Eastbank Fish Hatchery Outfall. With returns to the Outfall diminishing, a pilot broodstock collection program was initiated in 2016 at the outlet structure of the water conveyance canal for the Chelan Tailrace Pump Station. Because the pilot collection program was successful, future broodstock for the Chelan Falls Program will be collected at the outlet structure of the water conveyance canal.

The original program consisted of both subyearling (normal and accelerated groups) and yearling releases. Subyearlings were transferred to Turtle Rock Fish Hatchery for acclimation in May. These fish were released in June after about 30 days of acclimation on Columbia River water. The goal of this program was to release 1,620,000 subyearling summer Chinook (810,000 normal and 810,000 accelerated subyearlings) into the Columbia River at 40 fish per pound. Targets for fork length and weight were 112 mm (CV = 9.0) and 11.4 g, respectively. Over 50% of both subyearling groups were marked with CWTs. In 2010, the subyearling program was converted to a 400,000-yearling program.

The goal of the yearling program was to release 200,000 summer Chinook smolts into the Columbia River from Turtle Rock Fish Hatchery at 10 fish per pound. Targets for fork length and weight were 176 mm (CV = 9.0) and 45.4 g, respectively. Beginning with the 2006 brood year, yearling summer Chinook were acclimated at both Turtle Rock Fish Hatchery and the Chelan River net pens. With the conversion of the subyearling program to a yearling program and the reduction of the NNI component to 176,000, the current goal is to release 576,000 yearling summer Chinook smolts (176,000 from the NNI program plus 400,000 from the converted subyearling program). Beginning in 2012, the 576,000 yearlings are acclimated overwinter at facilities at Chelan Hatchery on Chelan River water. In 2012, the Turtle Rock program officially became the Chelan Falls summer Chinook program.

Over 90% of yearling summer Chinook have been marked with CWTs and all are ad-clipped. In addition, juvenile summer Chinook were PIT tagged within each of the circular and standard raceways.

11.1 Broodstock Sampling

Before 2013, broodstock for the program were collected as part of the Wells summer Chinook volunteer program. Refer to Snow et al. (2012) for information related to adults collected for those programs. Beginning in 2013, broodstock collection for the Chelan Falls program was piloted at the Eastbank Hatchery Outfall and at the outlet structure of the water conveyance canal for the Chelan Tailrace Pump Station. This section focuses on results from sampling broodstock from 2013 to present.

Origin of Broodstock

Broodstock collected in 2013-2016 consisted entirely of hatchery-origin summer Chinook (Table 11.1). A total of 85 hatchery-origin Chinook collected from Chief Joseph Fish Hatchery were surplused from the 2015 brood year.

Table 11.1. Numbers of wild and hatchery summer Chinook collected for broodstock, numbers that died before spawning, and numbers of Chinook spawned for the Chelan Falls summer Chinook program during 2013-2016. Unknown origin fish (i.e., undetermined by scale analysis, no CWT or fin clips, and no additional hatchery marks) were considered naturally produced. Mortality includes fish that died of natural causes typically near the end of spawning and were not needed for the program and surplus fish killed at spawning.

Brood year	Wild summer Chinook					Hatchery summer Chinook					Total number spawned
	Number collected	Prespawn loss[a]	Mortality	Number spawned	Number released	Number collected	Prespawn loss[a]	Mortality	Number spawned	Number released	
2013	-	-	-	-	-	318	4	0	314	0	314
2014	-	-	-	-	-	331	19	15	297	0	297
2015	-	-	-	-	-	351	17	14[b]	320	0	320
2016	-	-	-	-	-	350	5	1	344	0	344
Average	-	-	-	-	-	***338***	***11***	***8***	***319***	***0***	***319***
Median	-	-	-	-	-	***341***	***11***	***8***	***317***	***0***	***317***

[a] Pre-spawn loss represents the number of fish that died during the holding period before spawning. Mortality is the number of fish that were surplused following spawning.
[b] There was an additional 85 fish surplused that were excess from collections at Chief Joseph Fish Hatchery and were not included in mortality estimates.

Age/Length Data

Ages of summer Chinook broodstock were determined from analysis of scales and/or CWTs. Broodstock collected from the 2014 return consisted primarily of age-4 and 5 hatchery-origin Chinook (99%). Age-3 hatchery-origin fish made up 1% of the broodstock (Table 11.2).

Broodstock collected from the 2015 return consisted primarily of age-4 and 5 hatchery-origin Chinook (97.3%). Age-3 hatchery-origin Chinook made up 2.3% of the broodstock. Age-6 hatchery-origin Chinook made up 0.3% of the broodstock (Table 11.2).

Broodstock collected from the 2016 return consisted primarily of age-4 and 5 natural-origin Chinook (98.7%). Age-3 natural-origin Chinook made up 0.6% of the broodstock (Table 11.2).

Table 11.2. Percent of hatchery and wild summer Chinook of different ages (total age) collected from broodstock for the Chelan Falls summer Chinook program, 2013-2016.

Return Year	Origin	Total age				
		2	3	4	5	6
2013	Wild	--	--	--	--	--
	Hatchery	0.0	0.0	37.0	62.0	1.0
2014	Wild	--	--	--	--	--
	Hatchery	0.0	0.0	37.0	62.0	1.0
2015	Wild	--	--	--	--	--
	Hatchery	0.0	2.3	53.8	43.5	0.3
2016	Wild	--	--	--	--	--
	Hatchery	0.0	0.0	35.4	64.0	0.7
Average	***Wild***	**--**	**--**	**--**	**--**	**--**
	Hatchery	***0***	***0.6***	***40.8***	***57.9***	***0.8***
Median	***Wild***	**--**	**--**	**--**	**--**	**--**
	Hatchery	***0***	***0***	***37***	***62***	***0.85***

Mean lengths of hatchery-origin summer Chinook of a given age differed little among return years 2013-2016 (Table 11.3).

Table 11.3. Mean fork length (cm) at age (total age) of hatchery and wild summer Chinook collected from broodstock for the Chelan Falls program, 2013-2016; N = sample size and SD = 1 standard deviation.

Return year	Origin	Summer Chinook fork length (cm)														
		Age-2			Age-3			Age-4			Age-5			Age-6		
		Mean	N	SD	Mean	N	SD	Mean	N	SD	Mean	N	SD	Mean	N	SD
2013	Wild	-	0	-	-	0	-	-	0	-	-	0	-	-	0	-
	Hatchery	-	0	-	-	0	-	77	99	6	91	196	5	-	0	-
2014	Wild	-	0	-	-	0	-	-	0	-	-	0	-	-	0	-
	Hatchery	-	0	-	-	0	-	78	114	6	90	191	5	95	3	6
2015	Wild	-	0	-	-	0	-	-	0	-	-	0	-	-	0	-
	Hatchery	-	0	-	70	7	3	78	162	5	87	131	6	107	1	-
2016	Wild	-	0	-	-	0	-	-	0	-	-	0	-	-	0	-
	Hatchery	-	0	-	-	0	-	77	104	5	88	188	6	89	2	8
Average	***Wild***	**-**	***0***	**-**	**-**	***0***	**-**	**-**	***0***	**-**	**-**	***0***	**-**	**-**	***0***	**-**
	Hatchery	**-**	***0***	**-**	***70***	***2***	***3***	***78***	***120***	***6***	***89***	***177***	***6***	***97***	***2***	***7***

Sex Ratios

Male summer Chinook in the 2014 broodstock made up about 50.8% of the adults collected, resulting in an overall male to female ratio of 1.03:1.00 (Table 11.4.). In 2015, males made up about 46.0% of the adults collected, resulting in an overall male to female ratio of 0.85:1.00 (Table 11.4). In 2016, males made up about 50.6% of the adults collected, resulting in an overall male to female ratio of 1.02:1.00 (Table 11.4). The ratios for 2014 and 2016 broodstock were above the assumed 1:1 ratio goal in the broodstock protocol. The ratios for 2015 broodstock were below the assumed 1:1 ratio goal in the broodstock protocol.

Table 11.4. Numbers of male and female wild and hatchery summer Chinook collected for broodstock at for the Chelan Falls program, 2013-2016. Ratios of males to females are also provided.

Return year	Number of wild summer Chinook			Number of hatchery summer Chinook			Total M/F ratio
	Males (M)	Females (F)	M/F	Males (M)	Females (F)	M/F	
2013	-	-	-	160	158	1.01:1.00	1.01:1.00
2014	-	-	-	168	163	1.03:1.00	1.03:1.00
2015	-	-	-	149	175	0.85:1.00	0.85:1.00
2016	-	-	-	177	173	1.02:1.00	1.02:1.00
Total	**-**	**-**	**-**	***654***	***669***	***0.98:1.00***	***0.98:1.00***

Fecundity

Fecundities for the 2014, 2015, and 2016 summer Chinook broodstock averaged 4,275, 3,597, and 4,008 eggs per female, respectively (Table 11.5). These values are close to the overall average of 4,086 eggs per female. Mean observed fecundities for the 2014-2016 returns were below the expected fecundity of 4,475, 4,372, and 4,372 eggs per female assumed in the broodstock protocol, respectively.

Table 11.5. Mean fecundity of wild, hatchery, and all female summer Chinook collected for broodstock for the Chelan Falls program, 2013-2016; NA = not available.

Return year	Mean fecundity		
	Wild	Hatchery	Total
2013	-	4,462	4,462
2014	-	4,275	4,275
2015	-	3,597	3,597
2016	-	4,008	4,008
Average	**-**	***4,086***	***4,086***
Median	**-**	***4,142***	***4,142***

* Individual fecundities were not assigned to females until 1997 brood.

11.2 Hatchery Rearing

Rearing History

Number of eggs taken

Based on the unfertilized egg-to-release standard of 81%, a total of 688,995 eggs were needed to meet the program goal of 576,000 smolts for brood years 2012 and 2013. An evaluation of the program in 2014 concluded that 696,493 eggs were needed to attain the 576,000 smolts. From 2013-2016, the egg take goal has not been reached (Table 11.6).

Table 11.6. Numbers of eggs taken from summer Chinook broodstock for the Chelan Falls program, 2013-2016.

Return year	Number of eggs taken
2013	696,131
2014	618,092
2015	573,144
2016	680,448
Average	***641,954***
Median	***649,270***

Number of acclimation days

Rearing of the 2014 brood Chelan Falls summer Chinook was similar to previous years with fish being held on well water at Eastbank Hatchery until transfer to the Chelan Falls Acclimation Facility for overwinter acclimation. This was the fourth year that the whole program was transferred to the Chelan Falls Acclimation Facility for final overwinter acclimation on Chelan River water. Transfer occurred on 2-4 November 2014. Fish were volitionally released from 15-18 April 2016 after 163-168 days of acclimation (Table 11.7).

Table 11.7. Number of days Chelan summer Chinook were acclimated at Chelan Falls Acclimation Facility, brood years 2013-2014.

Brood year	Release year	Transfer date	Release date	Number of days
2013	2015	3-6 Nov	15 Apr	160-163
2014	2016	2-4-Nov	15-18-Apr	163-168

Release Information

Numbers released

The subyearling Turtle Rock summer Chinook program was discontinued in 2010; however, releases of subyearling Chinook in past years are shown in Tables 11.8 and 11.9. Production from the subyearling programs was converted to the yearling program.

The 2014 yearling summer Chinook program achieved 80.8% of the 576,000 goal with about 465,450 fish being released from the Chelan River Acclimation Ponds (Table 11.10).

Table 11.8. Numbers of Turtle Rock summer Chinook subyearlings released from the hatchery, brood years 1995-2009. The release target for Turtle Rock summer Chinook subyearlings was 810,000 fish.

Brood year	Release year	CWT mark rate	Number of subyearlings released
1995	1996	0.1873	1,074,600
1996	1997	0.9653	385,215
1997	1998	0.9780	508,060
1998	1999	0.6453	301,777
1999	2000	0.9748	369,026

Brood year	Release year	CWT mark rate	Number of subyearlings released
2000	2001	0.3678	604,892
2001	2002	0.9871	214,059
2002	2003	0.3070	656,399
2003	2004	0.4138	491,480
2004	2005	0.4591	411,707
2005	2006	0.4337	490,074
2006	2007	0.3388	538,392
2007	2008	0.4385	439,806
2008	2009	0.6355	309,003
2009	2010	NA	713,130
Average		***0.6111***	***500,508***
Median		***0.4488***	***490.074***

Table 11.9. Numbers of Turtle Rock summer Chinook accelerated subyearlings released from the hatchery, brood years 1995-2008. The release target for Turtle Rock summer Chinook accelerated subyearlings was 810,000 fish.

Brood year	Release year	CWT mark rate	Number of subyearlings released
1995	1996	0.9834	169,000
1996	1997	0.4163	477,300
1997	1998	0.3767	521,480
1998	1999	0.6033	307,571
1999	2000	0.9556	347,946
2000	2001	0.4331	449,329
2001	2002	0.4086	480,584
2002	2003	0.5492	364,461
2003	2004	0.6414	289,696
2004	2005	0.5471	364,453
2005	2006	0.9783	457,340
2006	2007	0.5510	342,273
2007	2008	0.4745	392,024
2008	2009	0.5295	372,320
Average		***0.6034***	***381,127***
Median		***0.5482***	***368,391***

Table 11.10. Numbers of Turtle Rock/Chelan Falls summer Chinook yearling smolts released from the hatchery, brood years 1995-2014. The release target for Turtle Rock summer Chinook was 200,000 smolts for the period before brood year 2010. The current release target is 600,000 smolts.

Brood year	Release year	Acclimation facility	CWT mark rate	Number of smolts released
1995	1997	Turtle Rock	0.9688	150,000
1996	1998	Turtle Rock	0.9582	202,727
1997	1999	Turtle Rock	0.9800	202,989
1998	2000	Turtle Rock	0.9337	217,797
1999	2001	Turtle Rock	0.9824	285,707
2000	2002	Turtle Rock	0.9941	279,969
2001	2003	Turtle Rock	0.9824	203,279
2002	2004	Turtle Rock	0.9799	195,851
2003	2005	Turtle Rock	0.9258	215,366
2004	2006	Turtle Rock	0.9578	206,734
2005	2007	Chelan	0.9810	204,644
2006	2008	Chelan	0.9752	99,271
		Turtle Rock	0.9752	43,943
2007	2009	Chelan Falls	0.9426	112,604
		Turtle Rock	0.9426	61,003
2008	2010	Chelan Falls	0.9818	200,999
		Turtle Rock	0.9818	252,762
2009	2011	Chelan Falls[a]	-	190,449
		Turtle Rock	0.9721	250,667
Average (1995-2009)		***Chelan Falls***	***0.9665***	***137,625***
		Turtle Rock	***0.9745***	***233,429***
Median (1995-2009)		***Chelan Falls***	***0.9737***	***205,007***
		Turtle Rock	***0.9781***	***190,449***
2010	2012	Chelan Falls	0.9702	563,824
2011	2013	Chelan Falls	0.9859	582,460
2012	2014	Chelan Falls	0.9879	566,188
2013	2015	Chelan Falls	0.9917	599,584
2014	2016	Chelan Falls	0.9901	465,450
Average (2010-present)		***Chelan Falls***	***0.9852***	***555,501***
Median (2010-present)		***Chelan Falls***	***0.9879***	***566,188***

[a] No CWT mark rate was provided because of the early release of this group.

Numbers tagged

Brood year 2014 yearling Chinook were 99.0% CWT and 99.4% adipose fin-clipped.

In 2017, a total of 10,103 Chelan River summer Chinook (brood 2015) were tagged at Chelan Falls Hatchery on 13-16 March (Table 11). These were tagged and released into water-reuse circular ponds. Fish were not fed during tagging or for two days before and after tagging. Fish averaged 133-137 mm in length and 25-26 g at time of tagging.

Table 11.11 summarizes the number of yearling summer Chinook that have been PIT-tagged and released from the Turtle Rock/Chelan Falls Program.

Table 11.11. Summary of PIT-tagging activities for Turtle Rock/Chelan Falls yearling summer Chinook, brood years 2007-2014; fpp = fish per pound.

Brood year	Release year	Raceway/Program	Number of fish tagged	Number of tagged fish that died	Number of tags shed	Number of tagged fish released
2007	2009	Circular Reuse	10,104	128	1	9,975
		Standard	10,102	162	3	9,937
2008	2010	Circular Reuse	11,102	20	0	11,082
		Standard	11,100	28	2	11,070
2009	2011	Turtle Rock	5,051	106	0	4,945
		Chelan Net Pens	5,050	2	0	5,048
2010	2012	Chelan Falls	4,200	10	0	4,186
2011	2013	Chelan Falls	4,101	26	0	4,075
2012	2014	Chelan Falls (small)	2,500	17	0	4,983
		Chelan Falls (large)	5,000	40	0	4,960
2013	2015	Chelan Falls (small)	5,000	41	0	4,959
		Chelan Falls (large)	5,000	37	0	4,963
2014	2016	Chelan Falls (18 fpp)	2,500	5	0	2,495
		Chelan Falls (22 fpp)	2,500	19	0	2,481
		Chelan Falls (10 fpp)	2,500	22	0	2,478
		Chelan Falls (13 fpp)	2,500	140	0	2,360

Fish size and condition at release

Although the subyearling summer Chinook program was discontinued, sizes of subyearlings released from Turtle Rock Hatchery before 2010 are shown in Tables 11.12 and 11.13.

Table 11.12. Mean lengths (FL, mm), weight (g and fish/pound), and coefficient of variation (CV) of Turtle Rock summer Chinook subyearlings released from the hatchery, brood years 1995-2009. Size targets are provided in the last row of the table.

Brood year	Release year	Fork length (mm)		Mean weight	
		Mean	CV	Grams (g)	Fish/pound
1995	1996	102	6.3	12.6	36
1996	1997	87	8.0	7.4	62
1997	1998	98	6.2	10.2	45
1998	1999	96	6.3	10.7	43

Brood year	Release year	Fork length (mm)		Mean weight	
		Mean	CV	Grams (g)	Fish/pound
1999	2000	90	9.0	9.8	46
2000	2001	100	7.1	11.3	40
2001	2002	104	7.2	13.4	34
2002	2003	97	7.3	11.8	39
2003	2004	101	8.0	12.0	43
2004	2005	100	7.8	11.4	40
2005	2006	100	6.5	12.5	36
2006	2007	95	7.2	9.5	48
2007	2008	79	7.4	5.6	81
2008	2009	86	7.9	7.9	57
2009[a]	2010	89	7.1	7.0	65
Average		***95***	***7.3***	***10.2***	***48***
Targets		***112***	***9.0***	***11.4***	***40***

[a] Pre-release growth sample was conducted using pond mortalities.

Table 11.13. Mean lengths (FL, mm), weight (g and fish/pound), and coefficient of variation (CV) of Turtle Rock summer Chinook accelerated subyearlings released from the hatchery, brood years 1995-2008. Size targets are provided in the last row of the table.

Brood year	Release year	Fork length (mm)		Mean weight	
		Mean	CV	Grams (g)	Fish/pound
1995	1996	129	7.1	27.3	17
1996	1997	107	6.5	15.6	29
1997	1998	117	6.0	18.9	24
1998	1999	119	8.0	18.9	24
1999	2000	114	6.7	19.0	24
2000	2001	111	7.0	16.8	27
2001	2002	117	8.4	19.5	23
2002	2003	116	11.3	21.2	21
2003	2004	113	14.9	17.0	30
2004	2005	117	11.3	20.1	23
2005	2006	119	9.1	22.2	21
2006	2007	118	8.3	19.1	24
2007	2008	95	7.7	10.0	45
2008[a]	2009	97	8.6	10.6	43
Average		***114***	***8.6***	***18.3***	***27***
Targets		***112***	***9.0***	***11.4***	***40***

[a] The 2008 brood year was the last year of the accelerated subyearling program.

Size at release of the brood year 2014 yearling summer Chinook was 87.6% and 69.4% of the fork length and weight targets, respectively, for the Chelan Falls group. This group exceeded the target CV for length (Table 11.14).

Table 11.14. Mean lengths (FL, mm), weight (g and fish/pound), and coefficient of variation (CV) of Turtle Rock/Chelan summer Chinook yearling releases, brood years 1995-2014. Size targets are provided in the last row of the table.

Brood year	Release year	Acclimation facility	Fork length (mm)		Mean weight	
			Mean	CV	Grams (g)	Fish/pound
1995	1997	Turtle Rock	-	-	-	-
1996	1998	Turtle Rock	166	14.2	60.9	7
1997	1999	Turtle Rock	198	4.6	91.3	5
1998	2000	Turtle Rock	161	11.9	53.9	8
1999	2001	Turtle Rock	164	18.6	59.0	8
2000	2002	Turtle Rock	170	15.3	59.0	8
2001	2003	Turtle Rock	154	22.3	48.6	9
2002	2004	Turtle Rock	157	16.7	44.0	12
2003	2005	Turtle Rock	173	13.8	54.7	8
2004	2006	Turtle Rock	176	20.6	45.3	7
2005	2007	Turtle Rock	158	11.0	43.5	10
2006	2008	Chelan Nets	172	14.5	58.4	8
		Turtle Rock	157	25.8	54.1	8
2007	2009	Chelan Nets	153	18.8	45.7	10
		Turtle Rock	167	14.6	49.3	9
2008	2010	Chelan Nets	146	22.9	40.6	11
		Turtle Rock	172	15.9	58.5	8
2009	2011	Chelan Nets	158	15.1	46.6	10
		Turtle Rock	174	17.5	59.3	8
2010	2012	Chelan Falls	132	27.4	33.2	14
2011	2013	Chelan Falls	148	18.6	42.6	11
2012	2014	Chelan Falls	129	17.1	24.5	19
2013	2015	Chelan Falls	137	9.8	26.8	17
2014	2016	Chelan Falls	141	13.5	31.5	14
Average			***159***	***16.5***	***49.2***	***10***
Targets[a]			***161***	***9.0***	***45.4***	***13***

[a] For size-target studies, fish per pound (fpp) targets for brood year 2012 were 10, 13, 18, 22 fpp.

Survival Estimates

Normal subyearling releases

Overall survival of the normal subyearling Turtle Rock summer Chinook program from green egg to release was below the standard set for the program (Table 11.15). Lower than expected survival at ponding and post-ponding reduced the overall program performance. This program was discontinued in 2010.

Table 11.15. Hatchery life-stage survival rates (%) for Turtle Rock subyearling (zero program) summer Chinook, brood years 2004-2009. Survival standards or targets are provided in the last row of the table.

Brood year	Collection to spawning		Unfertilized egg-eyed	Eyed egg-ponding	30 d after ponding	100 d after ponding	Ponding to release	Transport to release	Unfertilized egg-release
	Female	Male							
2004	NA	NA	93.5	74.4	93.9	91.4	90.8	99.7	63.1
2005	NA	NA	94.4	87.9	85	84.8	84.2	99.4	69.8
2006	NA	NA	97.8	87.9	85.0	84.8	84.2	99.4	72.4
2007	NA	NA	92.7	84.9	88.5	86.7	84.8	99.6	66.7
2008	NA	NA	78.8	95.0	80.7	79.3	79.9	99.8	59.8
2009	NA	NA	95.0	89.4	89.5	89.2	79.7	89.5	67.7
Average	***NA***	***NA***	***92.0***	***86.6***	***87.1***	***86.0***	***83.9***	***97.9***	***66.6***
Median	***NA***	***NA***	***94.0***	***87.9***	***86.8***	***85.8***	***84.2***	***99.5***	***67.2***
Standard	***90.0***	***85.0***	***92.0***	***98.0***	***97.0***	***93.0***	***90.0***	***95.0***	***81.0***

Accelerated subyearling releases

Overall survival of the accelerated subyearling Turtle Rock summer Chinook program from green egg to release was below the standard set for the program (Table 11.16). Lower than expected survival in post-ponding reduced the overall program performance. This program was discontinued in 2010.

Table 11.16. Hatchery life-stage survival rates (%) for Turtle Rock subyearling (accelerated program) summer Chinook, brood years 2004-2009. Survival standards or targets are provided in the last row of the table.

Brood year	Collection to spawning		Unfertilized egg-eyed	Eyed egg-ponding	30 d after ponding	100 d after ponding	Ponding to release	Transport to release	Unfertilized egg-release
	Female	Male							
2004	NA	NA	92.5	98.3	93.4	92.4	90.0	97.8	81.8
2005	NA	NA	93.8	94.6	83.7	83.4	81.7	98.8	72.5
2006	NA	NA	86.1	94.6	83.7	83.4	81.7	98.8	66.5
2007	NA	NA	93.4	95.4	78.4	77.5	76.3	98.9	67.9
2008[a]	NA	NA	93.4	95.0	79.8	78.8	78.2	99.3	67.1
Average	***NA***	***NA***	***91.8***	***95.6***	***83.8***	***83.1***	***81.6***	***98.7***	***71.2***
Median	***NA***	***NA***	***93.4***	***95.0***	***83.7***	***83.4***	***81.7***	***98.8***	***67.9***
Standard	***90.0***	***85.0***	***92.0***	***98.0***	***97.0***	***93.0***	***90.0***	***95.0***	***81.0***

[a] The 2008 brood year was the last year of the accelerated subyearling program.

Yearling releases

Overall survival of the 2014 brood yearling Chelan Falls summer Chinook program from green egg to release was below the standard set for the program (Table 11.17). This is largely because of lower unfertilized egg to eyed egg and eyed egg to ponding survival.

Table 11.17. Hatchery life-stage survival rates (%) for Turtle Rock/Chelan Falls yearling summer Chinook, brood years 2004-2014. Survival standards or targets are provided in the last row of the table.

Brood year	Collection to spawning		Un-fertilized egg-eyed	Eyed egg-ponding	30 d after ponding	100 d after ponding	Ponding to release	Transport to release	Un-fertilized egg-release
	Female	Male							
2004	NA	NA	92.9	97.7	96.8	96.4	95.5	99.6	86.7
2005	NA	NA	89.1	97.5	98.1	97.8	96.6	99.1	83.9
2006	NA	NA	86.2	78.8	97.6	97.1	95.2	98.7	64.8
2007 (Turtle Rock)	NA	NA	80.3	97.6	98.8	98.2	95.4	99.1	74.8
2007 (Chelan Falls)	NA	NA	80.3	97.6	98.8	98.2	94.9	97.1	74.4
2008 (Turtle Rock)	NA	NA	93.5	98.0	99.4	97.2	95.9	98.8	87.8
2008 (Chelan Falls)	NA	NA	93.5	98.0	97.6	98.7	96.4	99.3	88.2
2009 (Turtle Rock)	NA	NA	90.8	96.8	99.7	99.0	97.2	98.1	85.5
2009 (Chelan Falls)	NA	NA	90.9	96.9	99.8	99.0	96.7	97.7	85.2
2010 (Chelan Falls)	NA	NA	94.8	97.7	99.4	95.2	92.4	97.6	85.5
2011 (Chelan Falls)	NA	NA	90.0	99.4	91.7	98.2	83.4	85.2	74.6
2012 (Chelan Falls)	NA	NA	93.5	98.5	99.8	99.3	95.9	96.7	88.3
2013 (Chelan Falls)	100.0	98.1	90.6	96.5	99.5	98.9	98.5	99.7	86.1
2014 (Chelan Falls)	89.6	98.8	83.6	96.3	99.6	98.8	97.0	98.3	78.1
Average (Chelan)	***94.8***	***98.5***	***89.3***	***96.2***	***98.3***	***98.0***	***95.1***	***97.5***	***81.7***
Median (Chelan)	***94.8***	***98.5***	***90.7***	***97.6***	***99.1***	***98.2***	***95.9***	***98.5***	***85.4***
Standard	***90.0***	***85.0***	***92.0***	***98.0***	***97.0***	***93.0***	***90.0***	***95.0***	***81.0***

11.3 Spawning Surveys

Surveys for summer Chinook redds in the Chelan River were conducted from late September to late-November 2016. Total redd counts were conducted in the river (see Appendix O for more details).

Redd Counts

A total of 448 summer Chinook redds were counted in the Chelan River in 2016 (Table 11.18). This was higher than the overall average of 305 redds.

Table 11.18. Total number of redds counted in the Chelan River, 2000-2016.

Survey year	Total redd count
2000	196
2001	240
2002	253
2003	173

Survey year	Total redd count
2004	185
2005	179
2006	208
2007	86
2008	153
2009	246
2010	398
2011	413
2012	426
2013	729
2014	400
2015	448
2016	448
Average	***305***
Median	***246***

Redd Distribution

Summer Chinook redds were not evenly distributed among the four sampling areas within the Chelan River. Most redds (46%) were located in the Chelan Tailrace (Table 11.19). Fewer summer Chinook spawned in the Habitat Pool and Columbia Tailrace.

Table 11.19. Total number of summer Chinook redds counted in different survey areas within the Chelan River during September through early November 2016.

Survey area	Total redd count	Percent
Chelan Tailrace	207	46
Columbia Tailrace	74	16
Habitat Channel	106	24
Habitat Pool	61	14
Totals	***448***	***100***

Spawn Timing

Spawning in 2016 began the first week of October, peaked mid-October, and ended mid-November. Peak spawning occurred in the Habitat Pool in early October and during mid-October in the Chelan Tailrace, Habitat Channel, and Columbia Tailrace (Figure 11.1).

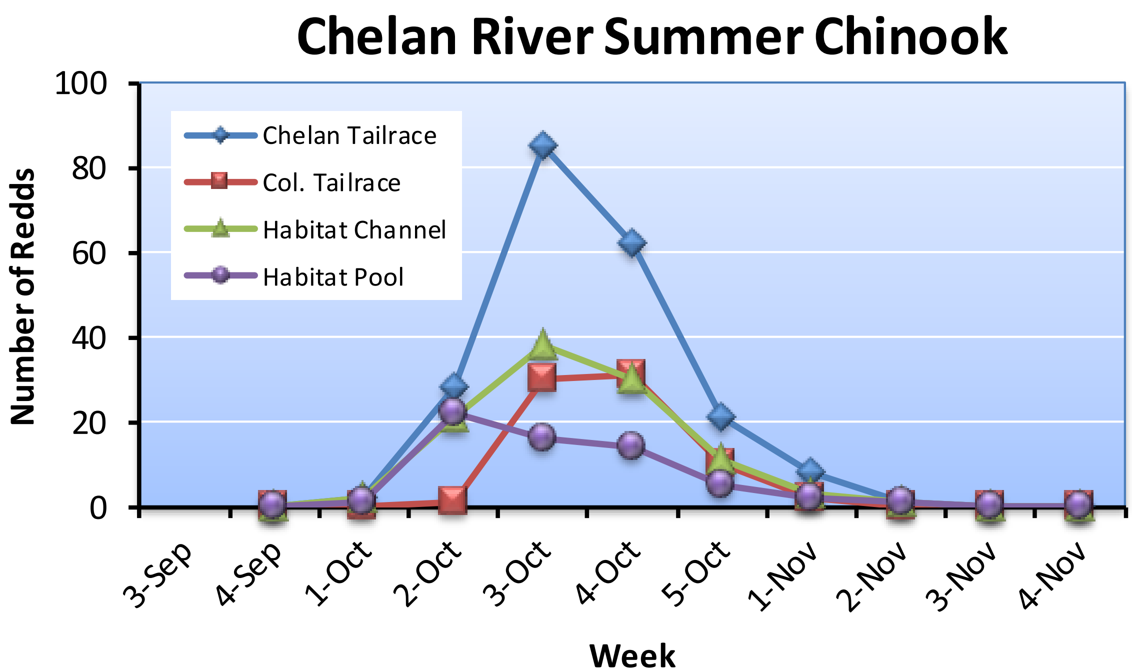

Figure 11.1. Number of new summer Chinook redds counted during different weeks within different sections of the Chelan River, September through November 2016.

Spawning Escapement

Spawning escapement for summer Chinook in the Chelan River was calculated as the total number of redds times the fish per redd ratio estimated from fish sampled at Wells Dam.[33] The estimated fish per redd ratio for Methow summer Chinook in 2016 was 2.01. Multiplying this ratio by the number of redds counted in the Chelan River resulted in a total spawning escapement of 900 summer Chinook (Table 11.20).

Table 11.20. Spawning escapements for summer Chinook in the Chelan River for return years 2000-2016.

Return year	Fish/Redd	Redds	Total spawning escapement
2000	2.40	196	470
2001	4.10	240	984
2002	2.30	253	582
2003	2.42	173	419
2004	2.25	185	416
2005	2.93	179	524
2006	2.02	208	420
2007	2.20	86	189
2008	3.25	153	497

[33] Expansion factor = (1 + (number of males/number of females)).

Return year	Fish/Redd	Redds	Total spawning escapement
2009	2.54	246	625
2010	2.81	398	1,118
2011	3.10	413	1,280
2012	3.07	426	1,308
2013	2.31	729	1,684
2014	2.75	400	1,100
2015	3.21	448	1,438
2016	2.01	448	900
Average	***2.69***	***305***	***821***
Median	***2.54***	***246***	***625***

11.4 Carcass Surveys

Surveys for summer Chinook carcasses within the Chelan River were conducted during late September to mid-November 2016 (see Appendix O for more details).

Number sampled

A total of 253 summer Chinook carcasses were sampled during September through late-November in the Chelan River (Table 11.21). This was higher than the overall average of 178 carcasses sampled since 2000.

Table 11.21. Numbers of summer Chinook carcasses sampled within each survey area within the Chelan River, 2000-2016; ND = no data.

Survey year	Number of summer Chinook carcasses				
	Chelan Tailrace	Columbia Tailrace	Habitat Channel	Habitat Pool	Total
2000	ND	ND	ND	ND	**48**
2001	ND	ND	ND	ND	**101**
2002	ND	ND	ND	ND	**145**
2003	ND	ND	ND	ND	**168**
2004	ND	ND	ND	ND	**159**
2005	ND	ND	ND	ND	**103**
2006	ND	ND	ND	ND	**107**
2007	ND	ND	ND	ND	**106**
2008	ND	ND	ND	ND	**132**
2009	ND	ND	ND	ND	**51**
2010	ND	ND	ND	ND	**106**
2011	ND	ND	ND	ND	**201**
2012	ND	ND	ND	ND	**317**
2013	50	120	157	28	**355**
2014	171	82	50	6	**309**

Survey year	Number of summer Chinook carcasses				
	Chelan Tailrace	Columbia Tailrace	Habitat Channel	Habitat Pool	Total
2015	49	255	41	18	**363**
2016	27	128	64	34	**253**
Average	***74***	***146***	***78***	***22***	***178***
Median	***50***	***124***	***57***	***23***	***145***

Carcass Distribution and Origin

Summer Chinook carcasses were not evenly distributed among survey areas within the Chelan River in 2016 (Table 11.22). Most of the carcasses in the Chelan River were found in the Columbia Tailrace.

In 2016, hatchery and wild summer Chinook carcasses were not distributed equally among the survey areas within the Chelan River (Table 11.22; Figure 11.2). A larger percentage of hatchery carcasses occurred in the Columbia Tailrace, Habitat Channel, and Habitat Pool, while a larger percentage of wild summer Chinook carcasses occurred in the Chelan Tailrace. There was a larger sample size of hatchery than wild summer Chinook carcasses in the Chelan River in 2016.

Table 11.22. Numbers of wild and hatchery summer Chinook carcasses sampled within different survey areas on the Chelan River, 2000-2016; ND = no data.

Survey year	Origin	Survey reach				Total
		Chelan Tailrace	Columbia Tailrace	Habitat Channel	Habitat Pool	
2000	Wild	ND	ND	ND	ND	**17**
	Hatchery	ND	ND	ND	ND	**31**
2001	Wild	ND	ND	ND	ND	**26**
	Hatchery	ND	ND	ND	ND	**75**
2002	Wild	ND	ND	ND	ND	**37**
	Hatchery	ND	ND	ND	ND	**108**
2003	Wild	ND	ND	ND	ND	**33**
	Hatchery	ND	ND	ND	ND	**135**
2004	Wild	ND	ND	ND	ND	**91**
	Hatchery	ND	ND	ND	ND	**68**
2005	Wild	ND	ND	ND	ND	**42**
	Hatchery	ND	ND	ND	ND	**61**
2006	Wild	ND	ND	ND	ND	**69**
	Hatchery	ND	ND	ND	ND	**38**
2007	Wild	ND	ND	ND	ND	**35**
	Hatchery	ND	ND	ND	ND	**71**
2008	Wild	ND	ND	ND	ND	**69**
	Hatchery	ND	ND	ND	ND	**63**
2009	Wild	ND	ND	ND	ND	**2**
	Hatchery	ND	ND	ND	ND	**49**
2010	Wild	ND	ND	ND	ND	**46**

Survey year	Origin	Survey reach				Total
		Chelan Tailrace	Columbia Tailrace	Habitat Channel	Habitat Pool	
	Hatchery	ND	ND	ND	ND	**60**
2011	Wild	ND	ND	ND	ND	**89**
	Hatchery	ND	ND	ND	ND	**112**
2012	Wild	ND	ND	ND	ND	**64**
	Hatchery	ND	ND	ND	ND	**253**
2013	Wild	18	55	51	6	**130**
	Hatchery	23	65	106	22	**225**
2014	Wild	32	142	18	1	**193**
	Hatchery	17	113	23	17	**170**
2015	Wild	35	137	11	0	**183**
	Hatchery	21	117	23	21	**180**
2016	Wild	15	63	26	7	**111**
	Hatchery	12	65	38	27	**142**
Average	***Wild***	***25***	***99***	***27***	***4***	***73***
	Hatchery	***18***	***90***	***48***	***22***	***108***
Median	***Wild***	***25***	***99***	***26***	***4***	***64***
	Hatchery	***18***	***90***	***38***	***22***	***75***

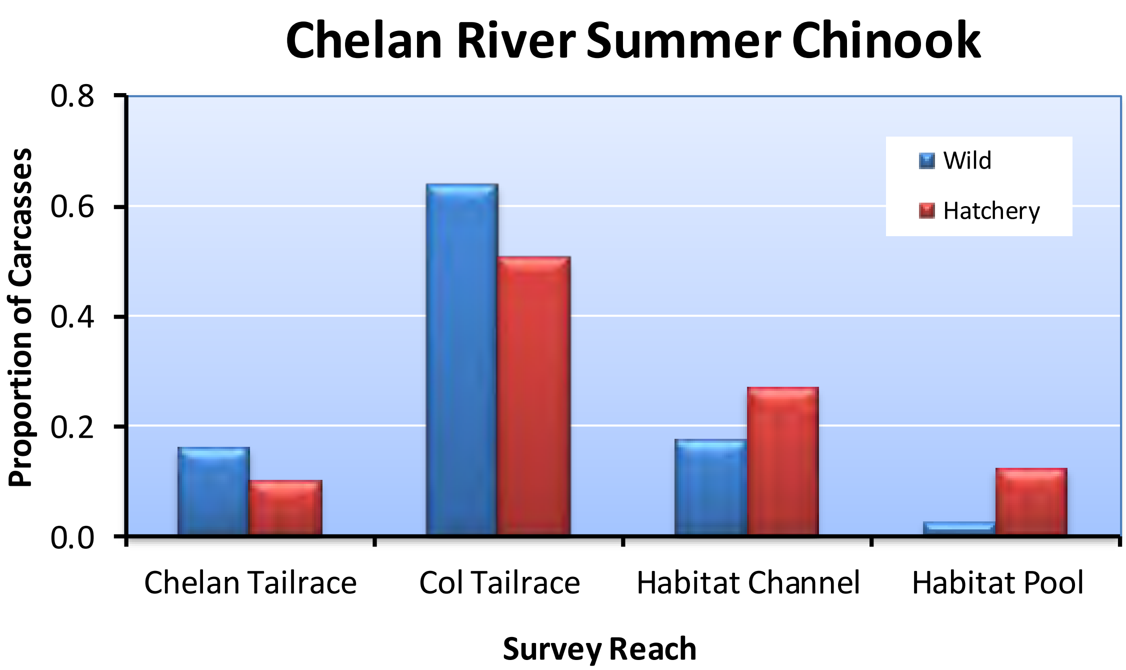

Figure 11.2. Average distribution of wild and hatchery produced carcasses in different survey areas within the Chelan River, 2013-2016.

Sampling Rate

Overall, 28% of the total spawning escapement of summer Chinook in the Chelan River was sampled in 2016 (Table 11.16). Sampling rates among survey reaches varied from 6 to 86%.

Table 11.23. Number of redds and carcasses, total spawning escapement, and sampling rates for summer Chinook in the Chelan River, 2016.

Survey reach	Total number of redds	Total number of carcasses	Total spawning escapement	Sampling rate
Chelan Tailrace	207	27	416	0.06
Columbia Tailrace	74	128	149	0.86
Habitat Channel	106	64	213	0.30
Habitat Pool	61	34	123	0.28
Total	***448***	***253***	***900***	***0.28***

Length Data

Mean lengths (POH, cm) of male and female summer Chinook carcasses sampled during surveys on the Chelan River in 2016 are provided in Table 11.24. The average size of males and females sampled in the Chelan River were 62 cm and 68 cm, respectively.

Table 11.24. Mean lengths (postorbital-to-hypural length; cm) and standard deviations (in parentheses) of male and female summer Chinook carcasses sampled in different areas on the Chelan River, 2016.

Stream/watershed	Mean length (cm)	
	Male	Female
Chelan Tailrace	64.5 (4.2)	66.0 (4.3)
Columbia Tailrace	62.7 (8.8)	67.6 (4.7)
Habitat Channel	60.7 (7.6)	68.6 (5.1)
Habitat Pool	62.5 (6.6)	67.4 (5.7)
Total	***62.2 (7.8)***	***67.7 (4.9)***

11.5 Life History Monitoring

Life history characteristics of Chelan Falls and Turtle Rock summer Chinook were assessed by examining carcasses on spawning grounds and by reviewing tagging data and fisheries statistics.

Contribution to Fisheries

Normal subyearling releases

Most of the harvest on Turtle Rock summer Chinook (normal subyearling releases) occurred in the Ocean (10-100% of the fish harvested; Table 11.25). Brood years 1995 and 2006 provided the largest total harvests, while brood year 1997 and 1998 provided the lowest. The subyearling hatchery program was discontinued after brood year 2009.

Table 11.25. Estimated number and percent (in parentheses) of Turtle Rock summer Chinook (normal subyearling releases) captured in different fisheries, brood years 1995-2009.

Brood year	Ocean fisheries	Columbia River Fisheries			Total
		Tribal	Commercial (Zones 1-5)	Recreational (sport)	
1995	688 (84)	106 (13)	11 (1)	16 (2)	821
1996	72 (80)	0 (0)	5 (6)	13 (14)	90
1997	10 (100)	0 (0)	0 (0)	0 (0)	10
1998	21 (100)	0 (0)	0 (0)	0 (0)	21
1999	184 (64)	26 (9)	4 (1)	75 (26)	289
2000	36 (55)	8 (12)	8 (12)	14 (21)	66
2001	164 (64)	30 (12)	20 (8)	44 (17)	258
2002	23 (20)	33 (29)	3 (3)	56 (49)	115
2003	9 (10)	55 (61)	2 (2)	24 (27)	90
2004	42 (37)	29 (25)	2 (2)	42 (37)	115
2005	100 (38)	95 (36)	24 (9)	44 (17)	263
2006	305 (41)	288 (38)	53 (7)	104 (14)	750
2007	110 (34)	91 (28)	21 (6)	104 (32)	326
2008	42 (31)	32 (24)	4 (3)	56 (42)	134
2009	82 (39)	68 (33)	6 (3)	52 (25)	208
Average	***126 (53)***	***57 (21)***	***11 (4)***	***43 (21)***	***237***
Median	***72 (41)***	***32 (24)***	***5 (3)***	***44 (21)***	***134***

Accelerated subyearling releases

Most of the harvest on Turtle Rock summer Chinook (accelerated subyearling releases) occurred in ocean fisheries (Table 11.26). Ocean harvest has made up 0% to 100% of all Turtle Rock summer Chinook harvested. Brood year 1999 provided the largest total harvest, while brood years 1995, 1997, 2002, and 2003 provided the lowest. This program was discontinued after brood year 2008.

Table 11.26. Estimated number and percent (in parentheses) of Turtle Rock summer Chinook (accelerated subyearling releases) captured in different fisheries, brood years 1995-2008.

Brood year	Ocean fisheries	Columbia River Fisheries			Total
		Tribal	Commercial (Zones 1-5)	Recreational (sport)	
1995	3 (100)	0 (0)	0 (0)	0 (0)	3
1996	77 (89)	5 (6)	5 (6)	0 (0)	87
1997	3 (100)	0 (0)	0 (0)	0 (0)	3
1998	102 (95)	2 (2)	3 (3)	0 (0)	107
1999	1,026 (76)	142 (10)	12 (1)	178 (13)	1,358
2000	117 (100)	0 (0)	0 (0)	0 (0)	117
2001	205 (59)	49 (14)	13 (4)	80 (23)	347

Brood year	Ocean fisheries	Columbia River Fisheries			Total
		Tribal	Commercial (Zones 1-5)	Recreational (sport)	
2002	9 (100)	0 (0)	0 (0)	0 (0)	9
2003	0 (0)	0 (0)	0 (0)	0 (0)	0
2004	50 (30)	79 (47)	6 (4)	34 (20)	169
2005	65 (59)	12 (11)	26 (24)	7 (6)	110
2006	130 (43)	113 (37)	16 (5)	43 (14)	302
2007	169 (41)	168 (41)	15 (4)	59 (14)	411
2008	20 (54)	2 (5)	4 (11)	11 (30)	37
Average	***141 (68)***	***41 (12)***	***7 (4)***	***29 (9)***	***219***
Median	***71 (67)***	***4 (6)***	***5 (3)***	***4 (3)***	***109***

Yearling releases

Most of the harvest on Turtle Rock/Chelan Falls summer Chinook (yearling releases) occurred in ocean fisheries (Table 11.27). Ocean harvest has made up 39% to 95% of all Turtle Rock summer Chinook harvested. Brood years 1998, 2008, and 2010 provided the largest harvest, while brood years 1995 and 1996 provided the lowest.

Table 11.27. Estimated number and percent (in parentheses) of Turtle Rock/Chelan Falls summer Chinook (yearling releases) captured in different fisheries, brood years 1995-2010.

Brood year	Ocean fisheries	Columbia River Fisheries			Total
		Tribal	Commercial (Zones 1-5)	Recreational (sport)	
1995	456 (75)	51 (8)	31 (5)	70 (12)	608
1996	771 (95)	14 (2)	2 (0)	21 (3)	808
1997	2,835 (91)	61 (2)	27 (1)	176 (6)	3,099
1998	4,284 (90)	224 (5)	16 (0)	230 (5)	4,754
1999	1,658 (73)	233 (10)	7 (0)	383 (17)	2,281
2000	1,214 (72)	147 (9)	54 (3)	273 (16)	1,688
2001	1,952 (59)	453 (14)	178 (5)	729 (22)	3,312
2002	1,018 (50)	384 (19)	102 (5)	537 (26)	2,041
2003	758 (46)	449 (27)	70 (4)	378 (23)	1,655
2004	827 (39)	560 (26)	127 (6)	605 (29)	2,119
2005	500 (44)	303 (27)	123 (11)	206 (18)	1,132
2006	1,163 (39)	880 (30)	231 (8)	688 (23)	2,962
2007	753 (49)	367 (24)	67 (4)	349 (23)	1,536
2008	3,697 (51)	1,155 (16)	248 (3)	2,168 (30)	7,268
2009	1,698 (51)	773 (23)	122 (4)	742 (22)	3,335
2010	3,882 (46)	2,798 (33)	394 (5)	1,395 (16)	8,469
Average	***1,717 (61)***	***553 (17)***	***112 (4)***	***559 (18)***	***2,942***
Median	***1,189 (51)***	***367 (17)***	***86 (4)***	***381 (20)***	***2,200***

Straying

Normal subyearling releases

Assessment of straying was based on evaluating the location of CWT recoveries. There were 17 tag codes used to differentiate Turtle Rock/Chelan normal subyearling releases by brood year, release type, and location. There was one subyearling group released into the Chelan River in 2010 (brood year 2009). There were also six non-associated releases.[34] All tag codes, except brood year 2009, recovered in the Chelan River or other tributaries in the Upper Columbia were considered strays.

Rates of Turtle Rock summer Chinook (normal subyearling releases) straying into spawning areas in the upper basin have been low. Although Turtle Rock summer Chinook have strayed into other spawning areas, they made up less than 10% of the spawning escapement within those areas (Table 11.28). The Chelan tailrace has received the largest number of Turtle Rock strays. This hatchery program was discontinued after brood year 2009.

Table 11.28. Number (No.) and percent of spawning escapements within other non-target basins that consisted of Turtle Rock summer Chinook (normal subyearling releases), return years 1998-2015. For example, for return year 2003, 0.6% of the summer Chinook spawning escapement in the Okanogan River basin consisted of Turtle Rock summer Chinook. Percent strays should be less than 10%.

Return year	Wenatchee		Methow		Okanogan		Chelan		Entiat		Hanford Reach	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
1998	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
1999	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
2000	8	0.1	3	0.3	13	0.4	63	13.4	0	0.0	0	0.0
2001	0	0.0	5	0.2	13	0.1	0	0.0	0	0.0	0	0.0
2002	0	0.0	0	0.0	13	0.1	0	0.0	0	0.0	0	0.0
2003	7	0.1	7	0.2	19	0.6	6	1.4	0	0.0	0	0.0
2004	5	0.0	4	0.2	13	0.2	6	1.4	0	0.0	0	0.0
2005	5	0.1	0	0.0	5	0.1	0	0.0	2	0.5	0	0.0
2006	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
2007	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
2008	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
2009	0	0.0	16	0.9	0	0.0	2	0.3	9	3.6	0	0.0
2010	0	0.0	26	1.0	0	0.0	0	0.0	14	3.2	0	0.0
2011	0	0.0	14	0.5	0	0.0	34	2.7	0	0.0	0	0.0
2012	0	0.0	0	0.0	0	0.0	0	0.0	8	0.9	0	0.0
2013	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
2014	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
2015	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Average	***1***	***0.0***	***4***	***0.2***	***4***	***0.1***	***6***	***1.1***	***2***	***0.5***	***0***	***0.0***

34 Non-associated releases are release groups not containing any coded-wire tagged fish.

Return year	Wenatchee		Methow		Okanogan		Chelan		Entiat		Hanford Reach	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Median	***0***	***0.0***	***0***	***0.0***	***0***	***0.0***	***0***	***0.0***	***0***	***0.0***	***0***	***0.0***

On average, about 29% of the brood year returns have strayed into spawning areas in the upper basin (Table 11.29). Depending on brood year, percent strays into spawning areas have ranged from 0-100%. Few (2.3% on average) have strayed into non-target hatchery programs.

Table 11.29. Number and percent of Turtle Rock summer Chinook (normal subyearling releases) that homed to the target hatchery and strayed to non-target spawning areas and non-target hatchery programs, by brood years 1995-2009.

Brood year	Homing				Straying			
	Target stream		Target hatchery*		Non-target streams		Non-target hatcheries	
	Number	%	Number	%	Number	%	Number	%
1995	-	-	197	74.1	64	24.1	5	1.9
1996	-	-	54	54.5	44	44.4	1	1.0
1997	-	-	2	28.6	5	71.4	0	0.0
1998	-	-	0	0.0	24	100.0	0	0.0
1999	-	-	40	43.5	52	56.5	0	0.0
2000	-	-	5	50.0	5	50.0	0	0.0
2001	-	-	56	77.8	16	22.2	0	0.0
2002	-	-	10	100.0	0	0.0	0	0.0
2003	-	-	27	100.0	0	0.0	0	0.0
2004	-	-	71	97.3	2	2.7	0	0.0
2005	-	-	80	92.0	7	8.0	0	0.0
2006	-	-	194	72.1	72	26.8	3	1.1
2007	-	-	113	68.5	34	20.6	18	10.9
2008	-	-	16	80.0	0	0.0	4	20.0
2009	27	42.2	29	45.3	8	12.5	0	0.0
Average	***27***	***42.2***	***60***	***65.6***	***22***	***29.3***	***2***	***2.3***
Median	***27***	***42.2***	***40***	***72.1***	***8***	***22.2***	***0***	***0.0***

* Homing to the target hatchery includes Turtle Rock hatchery fish that were captured and included as broodstock in the Turtle Rock Hatchery program. These hatchery fish were typically collected at Wells Dam and Wells Hatchery.

Accelerated subyearling releases

Assessment of straying was based on evaluating the location of CWT recoveries. There were 16 tag codes used to differentiate Turtle Rock accelerated subyearling releases by brood year and release type. There were also four non-associated releases. All tag codes recovered in the Chelan River or other tributaries in the Upper Columbia were considered strays.

Rates of Turtle Rock summer Chinook (accelerated subyearling releases) straying into spawning areas in the upper basin have been low. Although Turtle Rock summer Chinook have strayed into other spawning areas, they made up less than 10% of the spawning escapement within those areas

(Table 11.30). The Chelan tailrace, Entiat Basin, and Methow River basin have received the largest numbers of Turtle Rock strays. This hatchery program was discontinued after brood year 2008.

Table 11.30. Number (No.) and percent of spawning escapements within other non-target basins that consisted of Turtle Rock summer Chinook (accelerated subyearling releases), return years 1998-2014. For example, for return year 2001, 0.2% of the summer Chinook spawning escapement in the Methow River basin consisted of Turtle Rock summer Chinook. Percent strays should be less than 10%.

Return year	Wenatchee		Methow		Okanogan		Chelan		Entiat		Hanford Reach	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
1998	3	0.1	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
1999	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
2000	7	0.1	0	0.0	0	0.0	24	3.6	0	0.0	0	0.0
2001	0	0.0	12	0.4	31	0.3	0	0.0	0	0.0	0	0.0
2002	0	0.0	5	0.1	0	0.0	0	0.0	0	0.0	0	0.0
2003	0	0.0	45	1.1	0	0.0	22	5.3	13	1.9	16	0.0
2004	0	0.0	7	0.3	0	0.0	14	3.3	0	0.0	18	0.0
2005	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
2006	0	0.0	0	0.0	0	0.0	0	0.0	7	1.3	0	0.0
2007	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
2008	0	0.0	7	0.4	0	0.0	27	5.4	0	0.0	0	0.0
2009	19	0.2	0	0.0	0	0.0	2	0.3	0	0.0	0	0.0
2010	0	0.0	19	0.8	0	0.0	0	0.0	10	2.3	0	0.0
2011	17	0.2	10	0.3	10	0.1	0	0.0	15	3.2	0	0.0
2012	0	0.0	0	0.0	0	0.0	0	0.0	8	0.9	0	0.0
2013	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
2014	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Average	***3***	***0.0***	***6***	***0.2***	***2***	***0.0***	***5***	***1.1***	***3***	***0.6***	***2***	***0.0***
Median	***0***	***0.0***	***0***	***0.0***	***0***	***0.0***	***0***	***0.0***	***0***	***0.0***	***0***	***0.0***

On average, about 29% of the brood year returns have strayed into spawning areas in the upper basin (Table 11.31). Depending on brood year, percent strays into spawning areas have ranged from 0-83%. Few (1.3% on average) have strayed into non-target hatchery programs.

Table 11.31. Number and percent of Turtle Rock summer Chinook (accelerated subyearling releases) that homed to the target hatchery and strayed to non-target spawning areas and non-target hatchery programs, by brood years 1995-2008.

Brood year	Homing				Straying			
	Target stream		Target hatchery*		Non-target streams		Non-target hatcheries	
	Number	%	Number	%	Number	%	Number	%
1995	-	-	7	70.0	3	30.0	0	0.0
1996	-	-	33	32.4	69	67.6	0	0.0
1997	-	-	6	100.0	0	0.0	0	0.0

Brood year	Homing				Straying			
	Target stream		Target hatchery*		Non-target streams		Non-target hatcheries	
	Number	%	Number	%	Number	%	Number	%
1998	-	-	2	16.7	10	83.3	0	0.0
1999	-	-	138	54.1	117	45.9	0	0.0
2000	-	-	12	40.0	18	60.0	0	0.0
2001	-	-	57	89.1	7	10.9	0	0.0
2002	-	-	0	0.0	0	0.0	0	0.0
2003	-	-	3	100.0	0	0.0	0	0.0
2004	-	-	90	75.6	29	24.4	0	0.0
2005	-	-	64	75.3	19	22.4	2	2.4
2006	-	-	88	88.9	7	7.1	4	4.0
2007	-	-	133	61.9	81	35.8	12	5.3
2008	-	-	21	84.0	8	25.8	2	6.5
Average	**-**	**-**	***47***	***63.4***	***26***	***29.5***	***1***	***1.3***
Median	**-**	**-**	***27***	***72.7***	***9***	***25.1***	***0***	***0.0***

* Homing to the target hatchery includes Turtle Rock hatchery fish that were captured and included as broodstock in the Turtle Rock Hatchery program. These hatchery fish were typically collected at Wells Dam and Wells Hatchery.

Yearling releases

Assessment of straying was based on evaluating the location of CWT recoveries. Yearlings have been released in the Columbia River and in the Chelan River. There were 16 tag codes used to differentiate Turtle Rock yearling releases by brood year, release type, and location. All these fish were released into the Columbia River and therefore any tag recoveries in the Chelan River or other tributaries were considered strays. In contrast, there were 21 tag codes[35] used to differentiate Chelan River yearling releases by brood year, release type, and location (there were four non-associated releases). All these fish were released into the Chelan River and therefore any tag recoveries in tributaries other than the Chelan River were considered strays.

Rates of Turtle Rock/Chelan Falls summer Chinook (yearling releases) straying into spawning areas in the upper basin have varied widely depending on spawning area. Most of these fish strayed to spawning areas within the Chelan tailrace (Turtle Rock released fish), Entiat Basin, and Methow River basin. On average, Turtle Rock summer Chinook have made up 4-13% of the spawning escapement within those basins (Table 11.32). Relatively few, on average, have strayed to spawning areas in the Okanogan River basin, Wenatchee River basin, and the Hanford Reach (i.e., they made up less than 2% of the spawning escapement in these areas).

[35] The Regional Mark Information System (RMIS) indicates that one tag code was released into Lake Chelan. Interestingly, some of these fish have been reported in ocean and Columbia River fisheries.

Table 11.32. Number (No.) and percent of spawning escapements within other non-target basins that consisted of Turtle Rock/Chelan Falls summer Chinook (yearling releases), return years 1998-2015. For example, for return year 2003, 4.3% of the summer Chinook spawning escapement in the Methow River basin consisted of Turtle Rock summer Chinook. Percent strays should be less than 10%.

Return year	Wenatchee		Methow		Okanogan		Chelan		Entiat		Hanford Reach	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
1998	0	0.0	2	0.3	0	0.0	0	0.0	0	0.0	0	0.0
1999	3	0.1	2	0.2	0	0.0	0	0.0	0	0.0	0	0.0
2000	18	0.3	57	4.8	167	4.5	73	15.5	0	0.0	10	0.0
2001	109	1.0	523	18.9	334	3.1	316	32.1	0	0.0	7	0.0
2002	92	0.6	437	9.4	194	1.4	191	32.8	136	27.1	0	0.0
2003	64	0.5	170	4.3	14	0.4	165	39.4	180	26.0	9	0.0
2004	10	0.1	55	2.5	116	1.7	75	18.0	0	0.0	0	0.0
2005	5	0.1	73	2.9	78	0.9	88	16.8	46	12.5	0	0.0
2006	0	0.0	100	3.7	25	0.3	64	15.2	30	5.5	0	0.0
2007	0	0.0	65	4.8	31	0.7	40	21.2	58	24.0	19	0.1
2008	18	0.3	72	3.7	60	0.9	110	22.1	46	14.4	0	0.0
2009	8	0.1	95	5.4	32	0.4	5	0.8	18	7.1	0	0.0
2010	12	0.2	105	4.2	111	1.9	0	0.0	30	6.9	0	0.0
2011	8	0.1	88	3.0	35	0.4	15	1.2	12	2.6	0	0.0
2012	21	0.2	33	1.1	43	0.5	110	8.4	29	3.2	0	0.0
2013	0	0.0	128	3.6	20	0.2	14	0.8	0	0.0	0	0.0
2014	7	0.1	22	1.4	24	0.2	16	1.5	18	3.2	0	0.0
2015	0	0.0	176	4.5	10	0.1	0	0.0	6	1.5	0	0.0
Average	***21***	***0.2***	***122***	***4.4***	***72***	***1.0***	***71***	***12.5***	***34***	***7.4***	***3***	***0.0***
Median	***8***	***0.1***	***81***	***3.7***	***34***	***0.5***	***52***	***11.8***	***18***	***3.2***	***0***	***0.0***

Since 2005, on average, about 17% of the brood year returns have strayed into spawning areas in the upper basin (Table 11.33). Depending on brood year, percent strays into spawning areas have ranged from 8-29%. Few (4% on average) have strayed into non-target hatchery programs.

Table 11.33. Number and percent of Turtle Rock/Chelan Falls summer Chinook (yearling releases) that homed to the target hatchery and strayed to non-target spawning areas and non-target hatchery programs, by brood years 1995-2010.

Brood year	Homing				Straying			
	Target stream		Target hatchery[a]		Non-target streams		Non-target hatcheries	
	Number	%	Number	%	Number	%	Number	%
1995	-	-	180	39.3	278	60.7	0	0.0
1996	-	-	218	27.2	583	72.8	0	0.0
1997	-	-	254	14.2	1531	85.6	3	0.2
1998	-	-	166	16.1	864	83.8	1	0.1

Brood year	Homing				Straying			
	Target stream		Target hatchery[a]		Non-target streams		Non-target hatcheries	
	Number	%	Number	%	Number	%	Number	%
1999	-	-	181	42.7	243	57.3	0	0.0
2000	-	-	102	29.1	249	70.9	0	0.0
2001	-	-	389	58.2	279	41.8	0	0.0
2002	-	-	303	54.3	254	45.5	1	0.2
2003	-	-	373	62.3	225	37.6	1	0.2
2004	-	-	287	56.6	219	43.2	1	0.2
Average[b]	-	-	***245***	***40.0***	***473***	***59.9***	***1***	***0.1***
Median[b]	-	-	***236***	***41.0***	***266***	***59.0***	***1***	***0.0***
2005	149	29.4	202	39.9	144	28.5	11	2.2
2006	429	40.3	376	35.3	223	21.0	36	3.4
2007	121	27.5	218	49.5	69	15.7	32	7.3
2008	775	40.5	736	38.5	326	17.1	75	3.9
2009	97	8.8	877	79.4	92	8.3	39	3.5
2010	583	53.4	404	37.0	95	8.7	10	0.9
Average[c]	***359***	***33.3***	***469***	***46.6***	***158***	***16.5***	***34***	***3.5***
Median[c]	***289***	***34.9***	***390***	***39.2***	***119.5***	***16.4***	***34***	***3.5***

[a] Homing to the target hatchery includes Turtle Rock/Chelan Hatchery fish that were captured and included as broodstock in the Turtle Rock/Chelan Hatchery program. These hatchery fish are typically collected at Wells Dam, Wells Hatchery, and the Eastbank Hatchery Outfall.
[b] Summary statistics for yearling Turtle Rock summer Chinook released into the Columbia River (brood years 1995-2004).
[c] Summary statistics for yearling Turtle Rock/Chelan River summer Chinook released into the Chelan River (brood years 2005 to present).

Post-Release Survival and Travel Time

We used PIT-tagged fish to estimate survival rates and travel times (arithmetic mean days) of hatchery summer Chinook from the Turtle Rock/Chelan River release sites to McNary Dam, and smolt to adult ratios (SARs) from release to detection at Bonneville Dam (Table 11.34).[36] Over the seven brood years for which PIT-tagged hatchery fish were released, survival rates from the release sites to McNary Dam ranged from 0.423 to 0.798; SARs from release to detection at Bonneville Dam ranged from 0.010 to 0.028. Average travel times from release sites to McNary Dam ranged from 15 to 33 days.

Much of the variation in survival rates and travel time among brood years resulted from releases of different experimental groups (Table 11.34). For example, brood years 2007 and 2008 were each split into two experimental groups (Circular Reuse group and Standard Raceway group). For both brood years, survival from the release site to McNary Dam and SARs were greater for the Circular Reuse fish than for the Standard Raceway fish. For both brood years, travel time from

[36] It is important to point out that because of fish size differences among rearing tanks or raceways, fish PIT tagged in one tank or raceway may not represent untagged fish rearing in other tanks or raceways.

release to McNary Dam appeared to be longer for the Standard Raceway fish than for the Circular Reuse fish.

Another experiment was conducted with brood years 2012, 2013, and 2014 (Table 11.34). These brood years were split into different treatment groups based on fish size. Based on available information, there were no clear differences in survival rates and travel times to McNary Dam among the different experimental groups. SARs for these fish will be calculated after all fish have returned to the Columbia River.

Table 11.34. Total number of Turtle Rock/Chelan Falls yearling summer Chinook released with PIT tags, their survival and travel times (mean days) to McNary Dam, and smolt-to-adult (SAR) ratios for brood years 2007-2014. Standard errors are shown in parentheses. NA = not available (i.e., not all the fish from the release groups have returned to the Columbia River); fpp = fish per pound.

Brood year	Raceway/Program	Number of tagged fish released	Survival to McNary Dam	Travel time to McNary Dam	SAR to Bonneville Dam
2007	Circular Reuse	9,975	0.722 (0.036)	22.4 (8.6)	0.017 (0.001)
	Standard	9,937	0.550 (0.034)	28.4 (11.6)	0.010 (0.001)
2008	Circular Reuse	11,082	0.631 (0.040)	26.5 (9.8)	0.028 (0.002)
	Standard	11,070	0.581 (0.038)	27.9 (18.7)	0.025 (0.001)
2009	Turtle Rock	4,945	0.603 (0.061)	15.4 (8.6)	0.018 (0.002)
	Chelan Net Pens	5,048	0.616 (0.059)	19.5 (10.2)	0.012 (0.002)
2010	Chelan Falls	4,186	0.655 (0.050)	22.5 (12.1)	0.025 (0.002)
2011*	Chelan Falls	4,075	0.552 (0.054)	27.2 (11.5)	0.016 (0.002)
2012	Chelan Falls (Small Fish)	4,983	0.590 (0.049)	25.0 (11.2)	NA
	Chelan Falls (Big Fish)	4,960	0.579 (0.043)	24.4 (10.1)	NA
2013	Chelan Falls (Small Fish)	4,958	0.423 (0.068)	33.0 (13.6)	NA
	Chelan Falls (Big Fish)	4,963	0.760 (0.175)	28.6 (12.4)	NA
2014	Chelan Falls (10 fpp)	2,478	0.798 (0.077)	16.4 (5.9)	NA
	Chelan Falls (13 fpp)	2,360	0.672 (0.074)	16.1 (5.6)	NA
	Chelan Falls (18 fpp)	2,495	0.637 (0.064)	18.7 (7.8)	NA
	Chelan Falls (22 fpp)	2,481	0.449 (0.049)	20.6 (9.6)	NA

* Brood year 2011 experienced high mortality due to fungus, bacterial cold-water disease, bacterial gill disease, and erythrocytic inclusion body syndrome during April 2013.

Smolt-to-Adult Survivals

Subyearling-to-adult and smolt-to-adult survival ratios (SARs) were calculated as the number of hatchery adult recaptures divided by the number of tagged hatchery subyearling or yearling Chinook released. For these analyses, SARs were based on CWT returns.

Normal subyearling releases

For the available brood years, SARs for normal subyearling-released Chinook have ranged from 0.000036 to 0.001886 (Table 11.35). This hatchery program was discontinued after brood year 2009.

Table 11.35. Subyearling-to-adult ratios (SARs) for Turtle Rock normal subyearling-released summer Chinook, brood years 1995-2009.

Brood year	Number released[a]	Estimated adult captures[b]	SAR
1995	201,230	204	0.001014
1996	371,848	187	0.000503
1997	496,904	18	0.000036
1998	194,723	28	0.000144
1999	197,793	203	0.001026
2000	222,460	28	0.000126
2001	211,306	328	0.001552
2002	200,163	38	0.000190
2003	203,410	49	0.000241
2004	198,019	91	0.000460
2005	197,135	143	0.000725
2006	188,250	355	0.001886
2007	194,437	216	0.001111
2008	152,993	77	0.000503
2009	341,928	133	0.000389
Average	***238,173***	***140***	***0.000660***
Median	***200,163***	***133***	***0.000503***

[a] Includes all tag codes and CWT released fish (CWT + Ad Clip fish and CWT-only fish).

[b] Includes estimated recoveries (spawning ground, hatcheries, harvest, etc.) and observed recoveries if estimated recoveries were unavailable.

Accelerated subyearling releases

For the available brood years, SARs for accelerated subyearling-released Chinook have ranged from 0.000011 to 0.004614 (Table 11.36). This hatchery program was discontinued after brood year 2008.

Table 11.36. Subyearling-to-adult ratios (SARs) for Turtle Rock accelerated subyearling-released summer Chinook, brood years 1995-2008.

Brood year	Number released[a]	Estimated adult captures[b]	SAR
1995	166,203	13	0.000078
1996	198,720	79	0.000398
1997	196,459	3	0.000015
1998	185,551	72	0.000388

Brood year	Number released[a]	Estimated adult captures[b]	SAR
1999	192,665	889	0.004614
2000	194,603	63	0.000324
2001	196,355	169	0.000861
2002	200,165	5	0.000025
2003	185,834	2	0.000011
2004	203,255	159	0.000782
2005	192,045	82	0.000427
2006	186,324	217	0.001165
2007	188,328	309	0.001641
2008	197,136	35	0.000178
Average	***191,689***	***150***	***0.000779***
Median	***193,634***	***76***	***0.000393***

[a] Includes all tag codes and CWT released fish (CWT + Ad Clip fish and CWT-only fish).

[b] Includes estimated recoveries (spawning ground, hatcheries, harvest, etc.) and observed recoveries if estimated recoveries were unavailable.

Yearling releases

For the available brood years since 2004, SARs for yearling-released Chinook have ranged from 0.008056 to 0.028164 (Table 11.37).

Table 11.37. Smolt-to-adult ratios (SARs) for Turtle Rock/Chelan Falls yearling-released summer Chinook, brood years 1995-2010.

Brood year	Number released[a]	Estimated adult captures[b]	SAR
1995	145,318	1,047	0.007205
1996	194,251	1,558	0.008021
1997	198,924	4,813	0.024195
1998	215,646	5,764	0.026729
1999	280,683	2,673	0.009523
2000	278,308	2,038	0.007323
2001	199,694	3,937	0.019715
2002	192,234	2,570	0.013369
2003	199,386	2,100	0.010532
2004	202,682	2,594	0.012798
Average[c]	***210,713***	***2,909***	***0.013941***
Median[c]	***199,540***	***2,582***	***0.011665***
2005	202,329	1,630	0.008056
2006	142,699	4,019	0.028164
2007	161,071	1,870	0.011610

Brood year	Number released[a]	Estimated adult captures[b]	SAR
2008	447,155	9,112	0.020378
2009	423,565	4,354	0.010279
2010	547,205	9,284	0.016966
Average[d]	***320,671***	***5,045***	***0.015909***
Median[d]	***312,947***	***4,187***	***0.014288***

[a] Includes all tag codes and CWT released fish (CWT + Ad Clip fish and CWT-only fish).

[b] Includes estimated recoveries (spawning ground, hatcheries, harvest, etc.) and observed recoveries if estimated recoveries were unavailable.

[c] Summary statistics for yearling Turtle Rock summer Chinook released into the Columbia River (brood years 1995-2004).

[d] Summary statistics for yearling Turtle Rock/Chelan River summer Chinook released into the Chelan River (brood years 2005 to present).

11.6 ESA/HCP Compliance

Broodstock Collection

The 2014 brood Chelan Falls (formerly Turtle Rock) summer Chinook program was supported through adult collections at the Eastbank outfall and surplus adults from Chief Joe Hatchery. During 2014, broodstock collections at the Eastbank outfall were consistent with the 2014 Upper Columbia River Salmon and Steelhead Broodstock Objectives and site-based broodstock collection protocols as required in ESA permit 1347. The 2014 collection target totaled 312 summer Chinook. Actual 2014 broodstock collection was 331 adults.

Hatchery Rearing and Release

The brood year 2014 release totaled 465,450 yearling fish. These releases represented 80.8% of the 576,000 Rocky Reach HCP and ESA Section 10 Permit 1347 production for the Chelan Falls yearling summer Chinook production. Lower than expected fertilization rates (83.6%) followed by eyed-egg to ponding survival were the primary factors in not meeting the release goal.

Hatchery Effluent Monitoring

Per ESA Permits 1196, 1347, 1395, 18118, 18120, and 18121, permit holders shall monitor and report hatchery effluents in compliance with applicable National Pollution Discharge Elimination Systems (NPDES) (EPA 1999) permit limitations. There were no NPDES violations reported at PUD Hatchery facilities during the period 1 January through 31 December 2016. NPDES monitoring and reporting for Chelan PUD Hatchery Programs during 2016 are provided in Appendix F.

SECTION 12: REFERENCES

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SECTION 13: APPENDICES

Appendix A: **Abundance and Total Numbers of Chinook Salmon and Trout in the Chiwawa River Basin, Washington, 2016.**

Appendix B: **Fish Trapping at the Chiwawa and Wenatchee Smolt Traps during 2016.**

Appendix C: **Summary of CSS PIT-Tagging Activities in the Wenatchee River Basin, 2016.**

Appendix D: **Wenatchee Steelhead Spawning Escapement Estimates, 2016.**

Appendix E: **Examining the Genetic Structure of Wenatchee River Basin Steelhead and Evaluating the Effects of the Supplementation Program.**

Appendix F: **NPDES Hatchery Effluent Monitoring, 2016.**

Appendix G: **Steelhead Stock Assessment at Priest Rapids Dam, 2016.**

Appendix H: **Wenatchee Sockeye Salmon Spawning Escapement, 2016.**

Appendix I: **Genetic Diversity of Wenatchee Sockeye Salmon.**

Appendix J: **Wenatchee Spring Chinook Redd Estimates, 2016.**

Appendix K: **Genetic Diversity of Natural Chiwawa River Spring Chinook Salmon.**

Appendix L: **Fish Trapping at the Nason Creek Smolt Trap during 2016.**

Appendix M: **Fish Trapping at the White River Smolt Trap during 2016.**

Appendix N: **Genetic Diversity of Upper Columbia Summer Chinook Salmon.**

Appendix O: **Summer Chinook Spawning Ground Surveys in the Methow and Chelan Rivers, 2016.**

Appendix A

Abundance and Total Numbers of Chinook Salmon and Trout in the Chiwawa River basin, Washington, 2016

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January 25, 2017

TO: HCP Hatchery Committee

FROM: Tracy Hillman

Subject: Abundance and Total Numbers of Chinook Salmon and Trout in the Chiwawa River basin, Washington, 2016

The Chelan County Public Utility District (PUD) hatchery program is operated through a habitat conservation plan (HCP) that was incorporated into the PUD's license in 2004. The HCP directed the signatories to develop a monitoring and evaluation plan within one year of the effective date. This resulted in the development of the Conceptual Approach to Monitoring and Evaluating the Chelan County Public Utility District Hatchery Programs (Murdoch and Peven 2005). In 2013, the Hatchery Committees updated the hatchery monitoring and evaluation plan (Hillman et al. 2013). This study will help the Hatchery Committees determine if it is meeting Objective 2 in the updated monitoring and evaluation plan.

Objective 2: *Determine if the proportion of hatchery fish on the spawning grounds affects the freshwater productivity of supplemented stocks.*

We estimated densities and total numbers of age-0 spring Chinook salmon *Oncorhynchus tshawytscha,* trout *Oncorhynchus* sp., and char *Salvelinus* sp. in the Chiwawa River basin, Washington, in August 2016. This was the 24th year of an ongoing study to assess the freshwater productivity (juveniles/redd) of Chinook salmon in the Chiwawa River basin. We used landscape classification to stratify streams in the basin that supported juvenile Chinook salmon (Hillman and Miller 2004). Classification "explained" most of the variability in fish numbers caused by geology, land type, valley bottom type, stream state condition, and habitat type. We identified ten reaches on the lower 31 miles (50 km) of the Chiwawa River and one reach in each of Phelps, Rock, Chikamin, Big Meadow, Alder, Brush, Clear, Y, and Unnamed[1] creeks (Figure 1). Each reach consisted of several combinations of state-type and habitat-type strata. We used classification to find reference areas for reaches in the Chiwawa River. We matched Reach 3 and Reach 8 of the Chiwawa River with a moderately-confined section of Nason Creek (RM 0.62-1.70) and an unconfined area of the Little Wenatchee River (RM 4.39-8.55), respectively

[1]Unnamed tributary that drains the eastside of Chiwawa Ridge. Its confluence with the Chiwawa River is about 1 mile (1.6 km) downstream from the mouth of Phelps Creek.

(Hillman and Miller 2004). Because of the supplementation program in Nason Creek, the use of Nason Creek as a reference for the Chiwawa River is no longer valid. However, as directed by the Hatchery Committee, we continue to sample sites in Nason Creek. Following methods described in Hillman and Miller (2004), we used underwater observations to estimate numbers of fish in 187 randomly selected sites.

During sampling in August 2016, discharge in the Chiwawa River averaged 202 cubic feet per second (cfs) and ranged from 126-325 cfs (Figure 2). Stream temperatures during the study period ranged from 8.0 to 18.0ºC. Fish species observed in the Chiwawa River basin and reference areas during the 1992-2016 survey period[2] included: spring Chinook salmon, coho salmon *O. kisutch*, sockeye salmon *O. nerka*, steelhead/rainbow trout *O. mykiss* (hatchery rainbow were present only in 1992 and 1993), cutthroat trout *O. clarki lewisi*, bull trout *S. confluentus*, brook trout *S. fontinalis*, mountain whitefish *Prosopium williamsoni*, dace *Rhinichthys* sp., northern pikeminnow *Ptychocheilus oregonensis*, suckers *Catostomus* sp., and sculpin *Cottus* sp. The age-0 spring Chinook that we observed in the Chiwawa River basin during the 2016 survey were produced from 543 redds counted in the fall of 2015 (Hillman et al. 2016). Assuming a mean fecundity of 4,847 eggs per female Chinook (from females collected for broodstock), and that no female produced more than one redd (Murdoch et al. 2009), we estimated that the Chiwawa River basin was seeded with 2,631,921 eggs in 2015 (Appendix A).

In 2016, riffles made up the largest fraction of habitat types in reaches of the Chiwawa River basin (54% of the total stream surface area) (Table 1). Pools (24%), glides (6%), and multiple channels (16%) constituted the remaining 46% of the stream surface area. We found woody debris associated with most multiple-channel habitat.

Chinook Salmon Abundance

Chinook salmon were the most abundant salmonid in the Chiwawa River basin. We estimated, based on surface area, that age-0 Chinook salmon numbered 140,172 (±10% of the estimated total) in the Chiwawa River basin in August 2016 (Table 2). Extrapolating based on volume of habitat types, age-0 Chinook numbered 137,525 (±13%) in the Chiwawa River basin. About 3% of the juvenile Chinook were in tributaries to the Chiwawa River. During the 1992-2016 surveys, numbers of age-0 Chinook ranged from 5,815 to 149,563 in the Chiwawa River basin (Figure 3; Appendix A and B). Most of the difference in juvenile numbers among years resulted from different seeding (stock) levels (Figure 4). Numbers of Chinook redds in the Chiwawa River basin during 1992-2015 ranged from 13 to 1,078, resulting in seeding levels of 66,248 to 4,984,672 eggs (Appendix A).

As in most years, age-0 Chinook in 2016 were distributed contagiously among reaches in the Chiwawa River (Table 2). In the Chiwawa River, densities of age-0 Chinook were highest in the upper reaches (Reaches 7-10). The highest densities in the Chiwawa River basin were in tributaries to the Chiwawa River (Table 2). Age-0 Chinook were most abundant in multiple channels and least abundant in glides and riffles. We found the majority of the Chinook

[2] The study period 1992-2016 includes only 24 years of sampling because there was no sampling in 2000.

associated with woody debris in multiple channels (multiple channel use index = 2.83)[3]. These sites (multiple channels) made up 16% of the total surface area of the Chiwawa River basin, but they provided habitat for 56% of all the age-0 Chinook in the basin in 2016 (Appendix C). In contrast, riffles made up 54% of the total surface area, but provided habitat for only 8% of all age-0 Chinook in the Chiwawa River basin (riffle use index = 0.24). Pools made up 24% of the total surface area and provided habitat for 35% of all age-0 Chinook in the basin (pool use index = 1.59). Few Chinook used glides that lacked woody debris (glide use index = 0.25).

As noted earlier, we assumed that the Chiwawa River was seeded with 2,631,921 Chinook eggs (543 redds times 4,847 eggs/female) in fall, 2015, and that at least 140,172 of those survived to August 2016. This means that the egg-to-parr survival was at least 5.3% (95% confidence bound 4.8-5.9%). During 1992-2016, egg-to-parr survival averaged 8.0% (range 2.7-19.1%) in the Chiwawa River basin (Appendix A). This survival rate comports with those from other streams. For example, Mullan et al. (1992) estimated an egg-to-parr survival rate of 9.8% for spring Chinook salmon in Icicle Creek, a tributary of the Wenatchee River. Using a Beverton and Holt model, Hubble (1993) estimated that egg-to-parr survival of Chinook in the Chewuck River, a tributary to the Methow River, ranged between 13% and 32%, depending on percent seeding level in the basin. Kiefer and Forster (1991) estimated a mean egg-to-parr survival rate of 5.5% (range 5.1-6.7%) for naturally-spawning spring Chinook salmon in the entire upper Salmon River. They also noted that egg-to-parr survival of natural spawners and adult outplants in the headwater streams of the upper Salmon River averaged 24.4% (range 16.1-32.0%). Petrosky (1990) reported an egg-to-parr survival range of 1.2-29.0% for Chinook in the upper Salmon River, Idaho. Konopacky et al. (1986) estimated egg-to-parr survival of Chinook in Bear Valley Creek, Idaho, as 8.1-9.4%. Work by Richards and Cernera (1987) in Bear Valley Creek indicated an egg-to-parr survival of 2.1%.

Mean densities of age-0 Chinook salmon in two reaches of the Chiwawa River were generally less than those in corresponding reference areas (Figure 5). Within both the Chiwawa River and its reference areas, pools and multiple channels consistently had the highest densities of age-0 Chinook.

We estimated a total of 282 (±43% of the estimated total) age-1+ Chinook salmon in the Chiwawa River basin in August 2016 (Table 3). In August 1992-2016, numbers of age-1+ Chinook ranged from 5 to 967 in the Chiwawa River basin (Figure 3; Appendix B). These fish occurred throughout the Chiwawa River. We found relatively few age-1+ Chinook in tributaries; although, numbers in Big Meadow Creek were higher in 2015 than in past years. Age-1+ Chinook were most abundant in multiple channels and pools.

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[3] The habitat use index was calculated as follows: Multiple channel use = $(parr_{mc}/parr_t) / (area_{mc}/area_t)$, where $parr_{mc}$ = the number of parr counted in multiple channel habitat, $parr_t$ = the total number of parr counted within all habitat types, $area_{mc}$ = the area of multiple channel habitat within the sampling frame, and $area_t$ = the total area of the sampling frame. A multiple channel use index value of 1 would indicate that parr were uniformly distributed among habitat types and exhibited no preference for multiple habitat types. Values greater than 1 indicate use of multiple channels to a greater extent than the average, while scores between 0 and 1 indicate below-average use of multiple channel habitat.

Juvenile Chinook Salmon Productivity (Fish/Redd)

Freshwater productivity of juvenile Chinook salmon was estimated as the number of parr (age-0 Chinook) per redd in the Chiwawa River basin. Theoretically, the relationship between number of parr and redds can be explained mathematically provided the relationship between the two parameters goes through the origin, increases monotonically at low spawning levels, and shows some level of density dependence at high spawning levels. We identified four alternative hypotheses that may explain the relationship between spawning level (redds) and numbers of age-0 Chinook:

1. The first hypothesis assumed that the number of juveniles increases constantly toward an asymptote as the number of redds increases. After the asymptote is reached, the number of juveniles neither increases nor decreases. The asymptote represents the maximum number of juveniles the system can support (i.e., carrying capacity for the system). This hypothesis was modeled with a Beverton-Holt curve that took the form:

$$\boldsymbol{J = \frac{(\alpha R)}{(\beta + R)}}$$

   where $\boldsymbol{J}$ is the number of juvenile (age-0) Chinook, $\boldsymbol{R}$ is the number or redds, $\boldsymbol{\alpha}$ is the maximum number of juveniles produced, and $\boldsymbol{\beta}$ is the number of redds needed to produce (on average) juveniles equal to one-half the maximum number of juveniles.

2. The second hypothesis, like the first, assumed that the number of juveniles increases toward an asymptote (carrying capacity) as the number of redds increases. After the carrying capacity is reached, the number of juveniles neither increases nor decreases. The carrying capacity represents the maximum number of juveniles the system can support. This hypothesis was modeled with a smooth hockey stick function that took the form:

$$\boldsymbol{J = J_{\infty}\left(1 - e^{-\left(\frac{\alpha}{J_{\infty}}\right)R}\right)}$$

   where $\boldsymbol{J}$ and $\boldsymbol{R}$ are as above, $\boldsymbol{\alpha}$ is the slope at the origin of the spawner-recruitment curve, and $\boldsymbol{J_{\infty}}$ is the carrying capacity of juveniles.

3. The third hypothesis assumed that the number of juveniles increases to a maximum and then declines as the number or redds increases. In this case, mortality rate of juveniles (or eggs) is proportional to the initial number of redds. Higher mortality rate is associated with density-dependent growth coupled with size-dependent predation. This hypothesis was modeled with a Ricker curve that took the form:

$$\boldsymbol{J = \alpha R e^{-\beta R}}$$

   where $\boldsymbol{J}$ and $\boldsymbol{R}$ are as above, $\boldsymbol{\alpha}$ is the number of juveniles per redd at low spawning levels, and $\boldsymbol{\beta}$ describes how quickly the juveniles per redd drop as the number of redds increases.

4. The fourth hypothesis, like the first, assumed that the number of juveniles increases constantly, but unlike the first, the number of juveniles does not reach an asymptote. Rather, the number of juveniles increases indefinitely, but at a slowing rate of increase. This hypothesis was modeled with both a Cushing curve and a Gamma function. The

Cushing curve took the form:

$$\boldsymbol{J = \alpha R^{\gamma}}$$

where $\boldsymbol{J}$ and $\boldsymbol{R}$ are as above, $\boldsymbol{\alpha}$ is the number of juveniles per redd at low spawning levels, and $\boldsymbol{\gamma}$ describes the level of density dependence at high spawning levels. The Gamma function is a three-parameter model that has the form:

$$\boldsymbol{J = \alpha R^{\gamma} e^{-\beta R}.}$$

This is an un-normalized gamma function that is similar to the Cushing curve when $\beta = 0$.

We used Akaike's Information Criterion for small sample size (AIC_c) to determine which model(s) best explained the productivity of juvenile Chinook in the Chiwawa River basin. AIC_c was estimated as:

$$\boldsymbol{AIC_c = -2log\big(\pounds(\theta|data)\big) + 2K + \left(\frac{2K(K+1)}{n-K-1}\right)}$$

where $\boldsymbol{log(\pounds(\theta|data))}$ is the maximum likelihood estimate, $\boldsymbol{K}$ is the number of estimable parameters (structural parameters plus the residual variance parameter), and $\boldsymbol{n}$ is the sample size (Burnham and Anderson 2002). We used least-squares methods to estimate $\boldsymbol{log(\pounds(\theta|data))}$, which was calculated as $\boldsymbol{log(\sigma^2)}$, where $\boldsymbol{\sigma^2}$ = residual sum of squares divided by the sample size ($\boldsymbol{\sigma^2 = RSS/n}$). AIC_c assesses model fit in relation to model complexity (number of parameters). The model with the smallest AIC_c value represents the "best approximating" model within the model set. Remaining models were ranked relative to the best model using AIC_c difference scores (**ΔAIC_c**), Akaike weights ($\boldsymbol{w_i}$), and evidence ratios. Models with **ΔAIC_c** values less than 2 indicate that there is substantial support for these models as being the best-fitting models within the set (Burnham and Anderson 2002). Models with values greater than 2 have less support. Akaike weights are probabilities estimating the strength of the evidence supporting a particular model as being the best model within the model set. Models with small $\boldsymbol{w_i}$ values are less plausible as competing models (Burnham and Anderson 2002). If no single model could be specified as the best model, a "best subset" of competing models was identified using (1) AIC_c differences to indicate the level of empirical support each model had as being the best model, (2) evidence ratios based on Akaike weights to indicate the relative probability that any model is the best model, and (3) coefficients of determination (R^2) assessing the explanatory power of each model.

The use of AIC_c indicated that the Beverton-Holt model best approximated the information in the juveniles/redd data (Table 4; Figure 6). The estimated structural parameters for this model were:

$$Juveniles = \frac{(152{,}439 \times Redds)}{(191 + Redds)}$$

where the bootstrap estimated standard errors for the two parameters were 17,210 and 56, respectively. The adjusted $R^2 = 0.84$. The second-best model was the smooth hockey stick model, which was 1.70 AIC_c units from the best model (Table 4; Figure 6). The estimated parameters for this model were:

$$LN(Juveniles) = 11.7 + LN\left(1 - e^{-\left(\frac{715.9}{116,314}\right)Redds}\right)$$

where the bootstrap estimated standard errors of the two parameters were 0.1 and 391, respectively, and the $R^2 = 0.83$. The AIC_c difference scores, Akaike weights, and evidence ratios indicated that there was substantial support for both the Beverton-Holt and smooth hockey stick models (Table 4). There was less support for the remaining models (Ricker, Gamma[4], and Cushing), which were > 2 AIC_c units from the best models. This was further supported by the fact that, relative to the best models, the remaining models had evidence ratios greater than 10.

Although the Beverton-Holt, smooth hockey stick, and Ricker models have different biological assumptions, they all indicated a density-dependent relationship between spawning levels (redds) and juvenile Chinook production. This was not only evident in the best approximating models, but there was also a significant negative relationship between juveniles per redd and numbers of redds in the Chiwawa River basin (Figure 7). Although data at high seeding levels are lacking, the Beverton-Holt model estimates the population capacity[5] of juvenile Chinook in the Chiwawa River basin at about 152,000 parr. This equates to about 1,197 Chinook parr per hectare. In contrast, the smooth hockey stick model, which fit the data as well as the Beverton-Holt model, estimates the population carrying capacity for juvenile Chinook at about 116,000 parr. This equates to about 913 Chinook parr per hectare. As a comparison, Thorson et al. (2013) estimated the carrying capacity for 15 populations of juvenile Chinook in the Snake River metapopulation as 5,000 juveniles per hectare. However, those authors noted that the estimate could be biased because of imperfect detectability and estimates of spawning numbers.

Steelhead/Rainbow Abundance

Based on stream surface area, we estimated a total of 16,244 (±14% of the estimated total) age-0 steelhead/rainbow (<4 in) in reaches of the Chiwawa River basin in August 2016 (Table 5). During the 1992-2016 survey period, numbers of age-0 steelhead/rainbow ranged from 1,410 to 45,727 in the Chiwawa River basin (Figure 8; Appendix B). In 1992-2016, numbers of age-0 steelhead/rainbow varied among reaches, but were typically highest in the lower reaches of the Chiwawa River. In all years they most often used riffle and multiple channel habitats in the Chiwawa River, although we also found them associated with woody debris in pool and glide habitat. In tributaries, they were generally most abundant in small pools. Those that we observed in riffles selected stations in quiet water behind small and large boulders or occupied stations in quiet water along the stream margin. In pool and multiple-channel habitats, we found age-0 steelhead/rainbow using the same kinds of habitat as age-0 Chinook salmon.

We estimated that 4,031 (±15% of the estimated total) age-1+ steelhead/rainbow (4-8 in) lived in reaches of the Chiwawa River basin in August 2016 (Table 6). During the survey period 1992-

[4] The γ parameter in the Gamma model was greater than 0, which means that this model is nearly identical to the Ricker model.

[5] In these analyses, we are calculating "population" carrying capacity (*K*), which is defined as the maximum equilibrium population size estimated with population models. This should not be confused with "habitat" carrying capacity (*C*), which is defined as the maximum population of a given species that a particular environment can sustain.

2016, numbers of age-1+ steelhead/rainbow ranged from 754 to 22,130 (Figure 8; Appendix B). In most years, we found these fish in nearly all reaches, but they were typically most numerous in lower reaches of the Chiwawa River. We observed age-1+ steelhead/rainbow mostly in pool, riffle, and multiple-channel habitats. Those that we observed in pools were usually in deeper water than age-0 steelhead/rainbow and Chinook. Like age-0 steelhead/rainbow, age-1+ steelhead/rainbow selected stations in quiet water behind boulders in riffles, but we generally did not find the two age groups together. Age-1+ steelhead/rainbow appeared to use deeper and faster water than did age-0 steelhead/rainbow.

We estimated that steelhead/rainbow larger than 8 inches numbered 14 (±71% of the estimated total) in the Chiwawa River basin in August 2016 (Table 7). During the period 1992-2016, steelhead/rainbow numbers ranged from 8 to 1,869 (Appendix B). Steelhead/rainbow larger than 8 inches were most abundant in the lower Chiwawa River; however, in 1992 and 1993, they were most abundant near campgrounds in Reaches 8, 9, and 10 (these were mostly hatchery rainbow trout planted near the campgrounds). We found very few in tributaries. Most of the steelhead/rainbow larger than 8 inches used deep pools (>5 feet), and occupied stations near the bottom at the upstream end of pools.

Bull Trout Abundance

We estimated, based on surface area that at least 291 (±20% of the estimated total) juvenile (2-8 in) bull trout lived in reaches of the Chiwawa River basin in August 2016 (Table 8). We found most of these fish in the upper-most reaches of the Chiwawa River and in Rock and Phelps creeks. During 1992-2016, numbers of juvenile bull trout ranged from 79 to 505 (Figure 9; Appendix B). These estimates and those for adult bull trout are incomplete because we did not sample the entire range of bull trout in all tributaries. That is, we did not extend our surveys into the headwaters of the Chiwawa River because there were no juvenile Chinook there. Areas beyond the distribution of juvenile Chinook salmon are known to support bull trout, steelhead/rainbow, and cutthroat trout (USFS 1993). In addition, our estimates of bull trout abundance were based on daytime snorkel surveys, which may underestimate the actual abundance of bull trout.[6] Several studies (e.g., Goetz 1994; Thurow and Schill 1996; Hillman and Chapman 1996; Bonar et al. 1997) have found bull trout population estimates based on nighttime snorkeling to be in some cases more accurate than daytime snorkeling, especially for juvenile bull trout. Our estimates of adult bull trout numbers may be more accurate than those for juveniles.

In all years, we found most juvenile bull trout in the upstream reaches of the Chiwawa River. In 2016, they occurred primarily in Reaches 9-10 on the Chiwawa River. We found the majority of these fish in multiple channels, pools, and riffles, and few in glides. They consistently occupied stations close to the stream bottom over rubble and small boulder substrate or near woody debris. This is similar to the observation of Pratt (1984) in the upper Flathead River Basin in Montana. She found that juvenile bull trout lay close to instream cover and that they tended to conceal

[6] Because there are no estimates for probability of detecting bull trout with daytime underwater observation methods in the Chiwawa River basin, we could not adjust bull trout numbers based on detectability. Therefore, the numbers reported in this report likely underestimate the "true" number of bull trout in the survey area.

themselves. Consequently, she found it difficult to estimate accurately their numbers. Although this implies that we underestimated numbers of juvenile bull trout in the Chiwawa River, the relative distribution of juvenile bull trout is valid if we assume that we saw the same fraction of juveniles in all reaches (i.e., detection probability was the same across survey sites).

We estimated a total of 1,254 (±12% of the estimated total) adult (>8 in) bull trout in reaches of the Chiwawa River basin in August 2016 (Table 9). This was the second highest number of adult bull trout that we recorded during the more than 20-year survey period. During 1992-2016, numbers of adult bull trout ranged from 76 to 2,286 (Figure 9; Appendix B). As with juvenile bull trout, we found most of the adult bull trout upstream from Reach 6; although they were found in all reaches on the Chiwawa River. We found few adult bull trout in tributaries of the Chiwawa River. Adult bull trout primarily used pools and multiple channel habitat, although most of the smaller adults (<10 in) used riffles.

Abundance of Other Salmonids

In August 2016, we estimated that at least 66 brook trout, an exotic species closely related to the bull trout, occurred in the Chiwawa River, Chikamin Creek, Big Meadow Creek, Minnow Creek, and in the Little Wenatchee River survey areas. In both the Chiwawa and Little Wenatchee rivers, brook trout usually used multiple channels and pools. Few appeared to be bull trout/brook trout hybrids. In Chikamin, Minnow, and Big Meadow creeks, brook trout were most abundant in pools. Brook trout lengths ranged from 2-12 inches.

At least 550 westslope cutthroat trout occurred in the Chiwawa River, Phelps Creek, Rock Creek, and Little Wenatchee River survey areas in August 2016. These fish most often occurred in pools and multiple channel habitats. They ranged in size from 2-22 inches. Juvenile coho salmon were observed in Nason Creek and the Chiwawa River.

We observed both juvenile and adult mountain whitefish in the Chiwawa River, Phelps Creek, Rock Creek, Nason Creek, and the Little Wenatchee River survey areas. In sum, at least 6,031 adult and 1,454 juvenile whitefish lived in these streams in August 2016. We found few whitefish in most tributaries to the Chiwawa River.

Conclusion

This was the 24th year of a study to monitor trends in juvenile spring Chinook production in the Chiwawa River basin. As shown in Figure 3, numbers of juvenile Chinook salmon in the Chiwawa River basin have fluctuated widely over the 24-year period. Numbers of juveniles in 2001, 2002, and 2009-2016 were some of the highest recorded, while numbers in the mid-1990s were some of the lowest. Interestingly, the highest spawning escapements (highest redd numbers) resulted in the lowest egg-parr survival rates (Appendix A). This is supported by the fact that the best approximating models clearly demonstrated a density-dependent relationship between seeding levels and juvenile production. Indeed, there was a significant negative relationship between parr per redd and numbers of redds in the Chiwawa River basin. This is an important observation because some of the hypotheses in the revised monitoring and evaluation plan (Hillman et al. 2013) are only valid when the supplemented population is below its carrying capacity.

The best fitting stock-recruitment models indicate that the population capacity of the Chiwawa River basin is between 140,000 to 185,000 spring Chinook parr. This equates to an overall density of about 1,100-1,400 parr per hectare. These densities can be achieved with about 490 redds. Assuming a female Chinook produces only one redd (Murdoch et al. 2009), a spawning escapement of about 490 females is needed to fill the capacity of the Chiwawa River basin.

The proportion of hatchery-origin spawners (pHOS) within the Chiwawa River basin during the survey period has ranged from 0 to 100%. Thus, some of the variation in juvenile productivity may be related to pHOS. Although there appeared to be a negative relationship between juvenile productivity (parr/redd) and pHOS, the correlation was not significant (Figure 10). In addition, there was no relationship between juvenile productivity and pHOS after the effects of spawning escapement were removed from the analysis (Figure 10). This suggests that spawning escapement has a larger effect on juvenile productivity than does the presence of hatchery spawners.

The presence of density dependence in the early life stages of spring Chinook is not surprising. Rarely does density dependence appear in numbers of adult spring Chinook or on their spawning grounds. The Chiwawa River basin appears to have plenty of spawning habitat, as indicated by the large numbers of spawners and redds widely distributed throughout the basin during high spawning escapements. However, those large spawning escapements did not translate into large numbers of juveniles or smolts. Thus, density-dependent regulation appears to occur sometime during the early life stages of the fish, likely at the fry stage. It is possible that physical habitat (space) during higher flows when fry are emerging may limit juvenile Chinook production in the basin. Low nutrient levels and its effects on food webs may also be a limiting factor in the basin. If spawning escapements remain relatively high, marine-derived nutrients should increase in the basin, resulting in more food for juvenile Chinook salmon.

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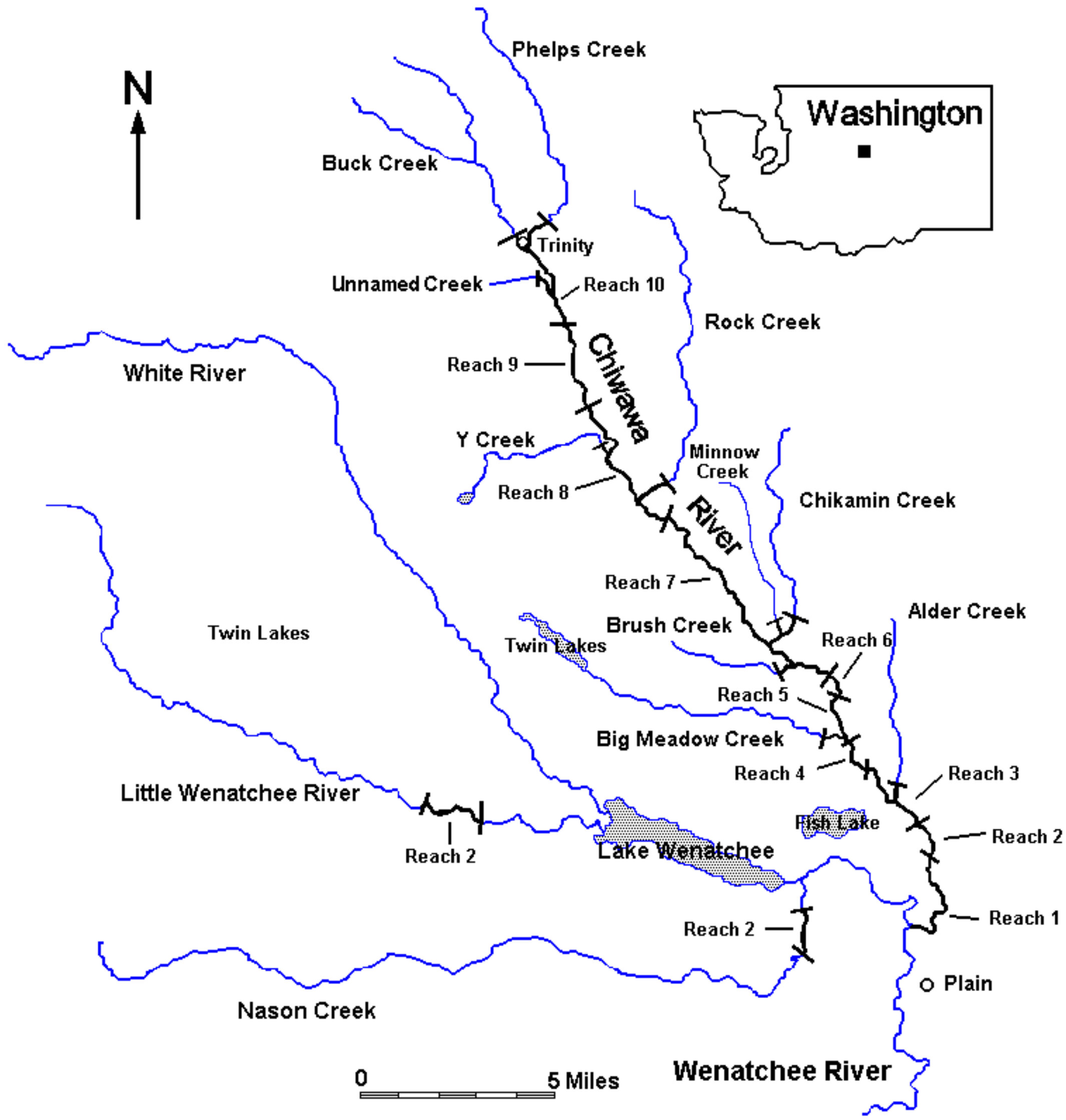

Figure 1. Location of study reaches on the Chiwawa River, and Chikamin, Rock, Big Meadow, Unnamed, Alder, Brush and Phelps creeks, Chelan County, Washington. Reach 2 on Nason Creek and Reach 2 on the Little Wenatchee River were matched with Reaches 3 and 8 on the Chiwawa River, respectively.

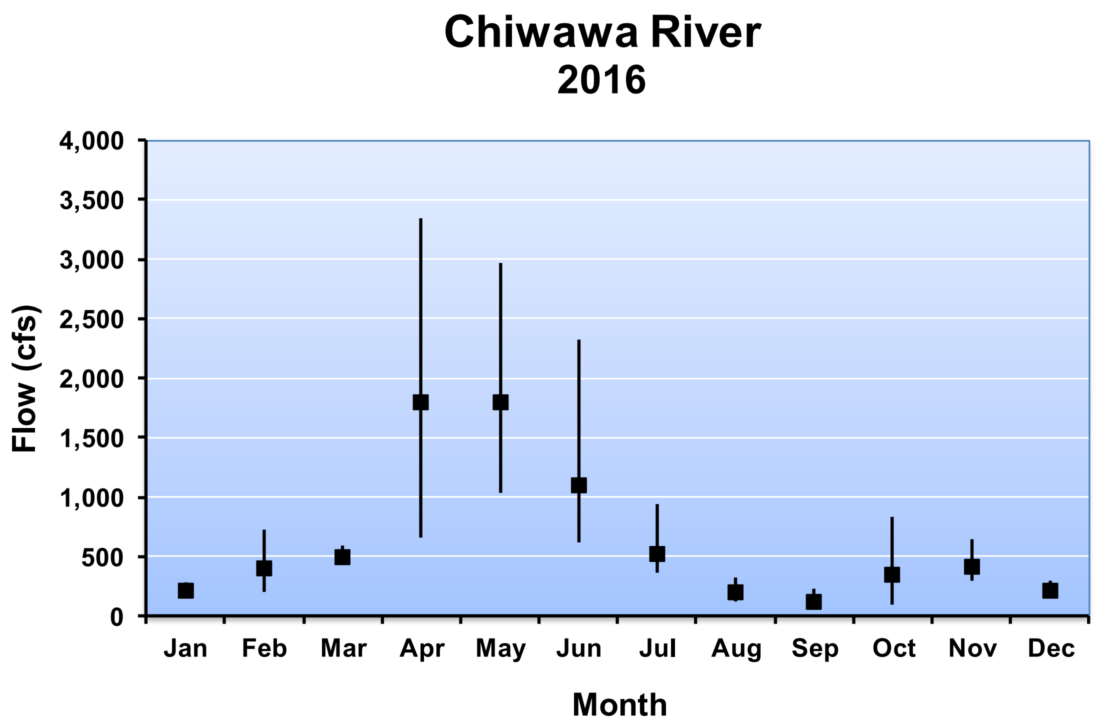

Figure 2. Mean, minimum, and maximum monthly flows in the Chiwawa River for 2016.

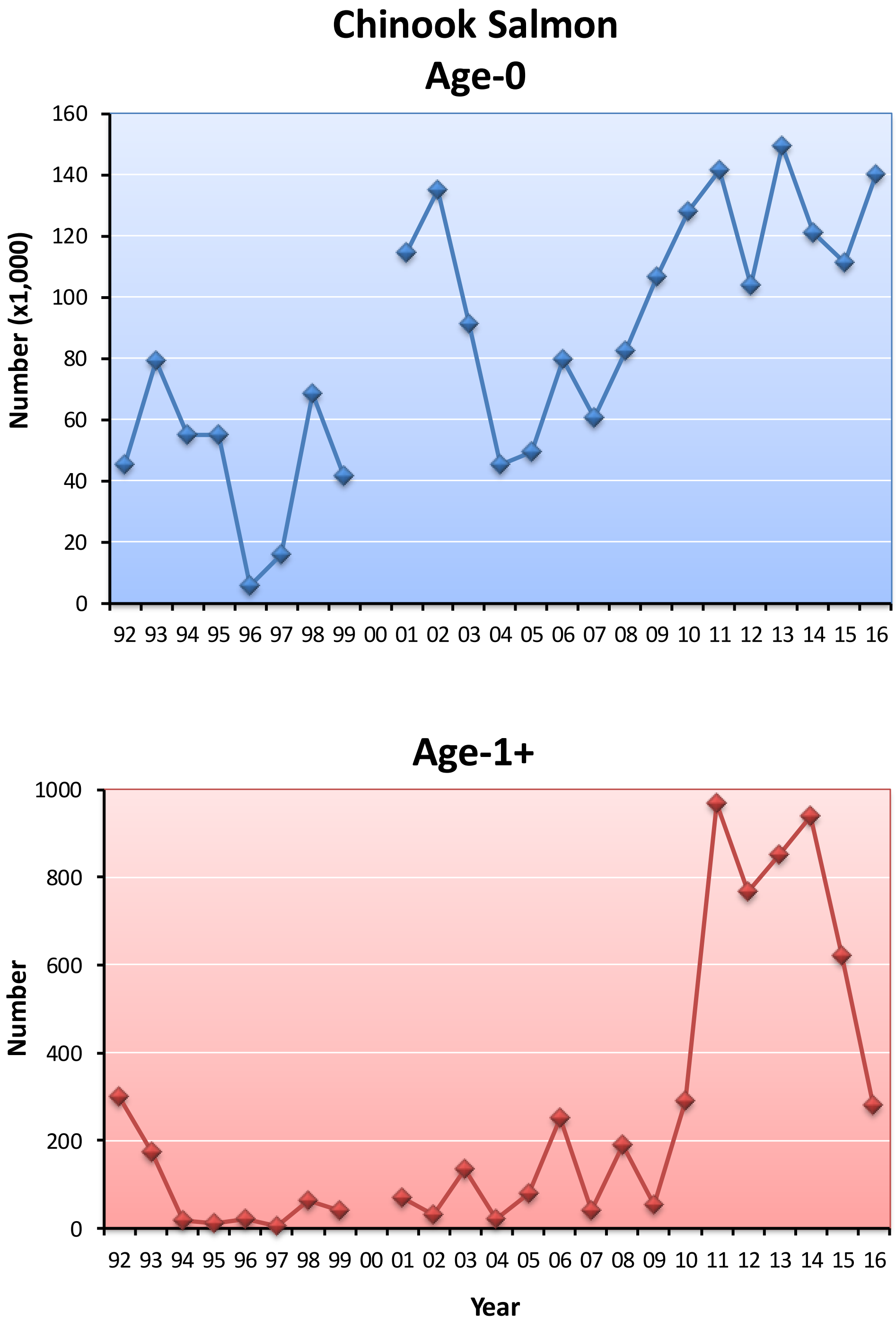

Figure 3. Numbers of age-0 and age-1+ Chinook salmon within the Chiwawa River basin in August 1992-2016; ND = no data.

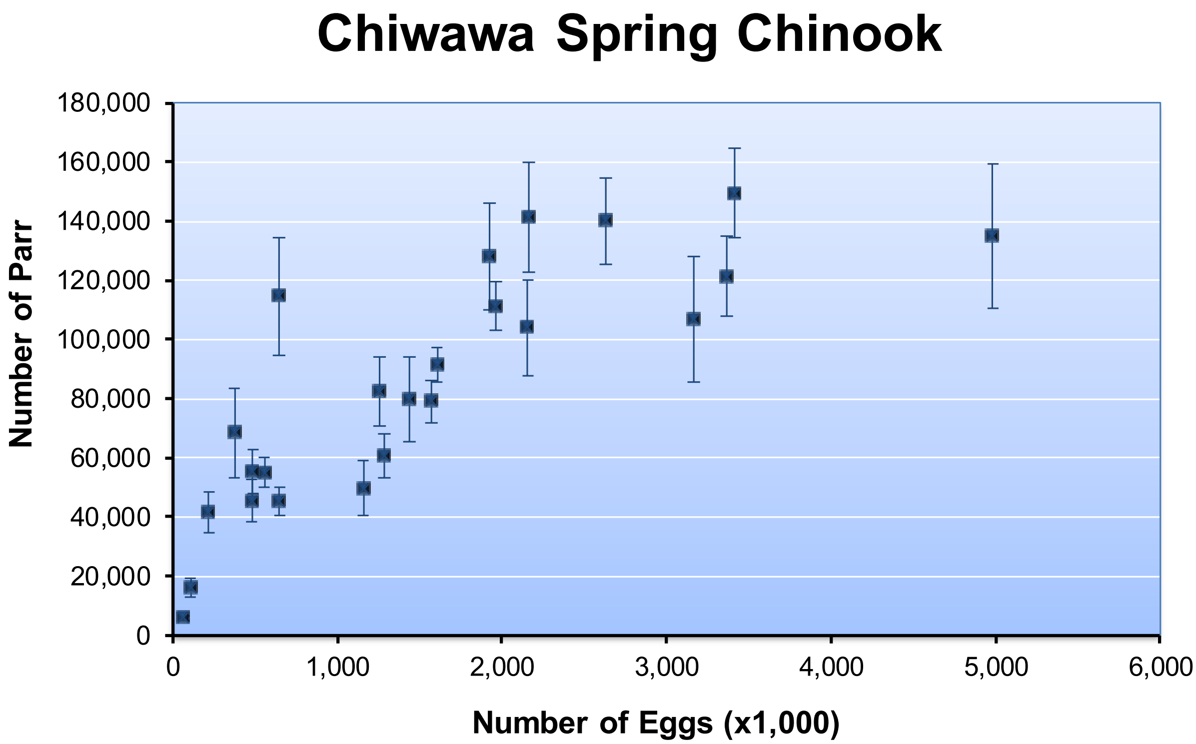

Figure 4. Relationship between total number of Chinook salmon parr counted during the summer (based on fish/ha) and number of eggs deposited in the Chiwawa River basin, 1992-2016. Vertical bars indicate 95% confidence bounds.

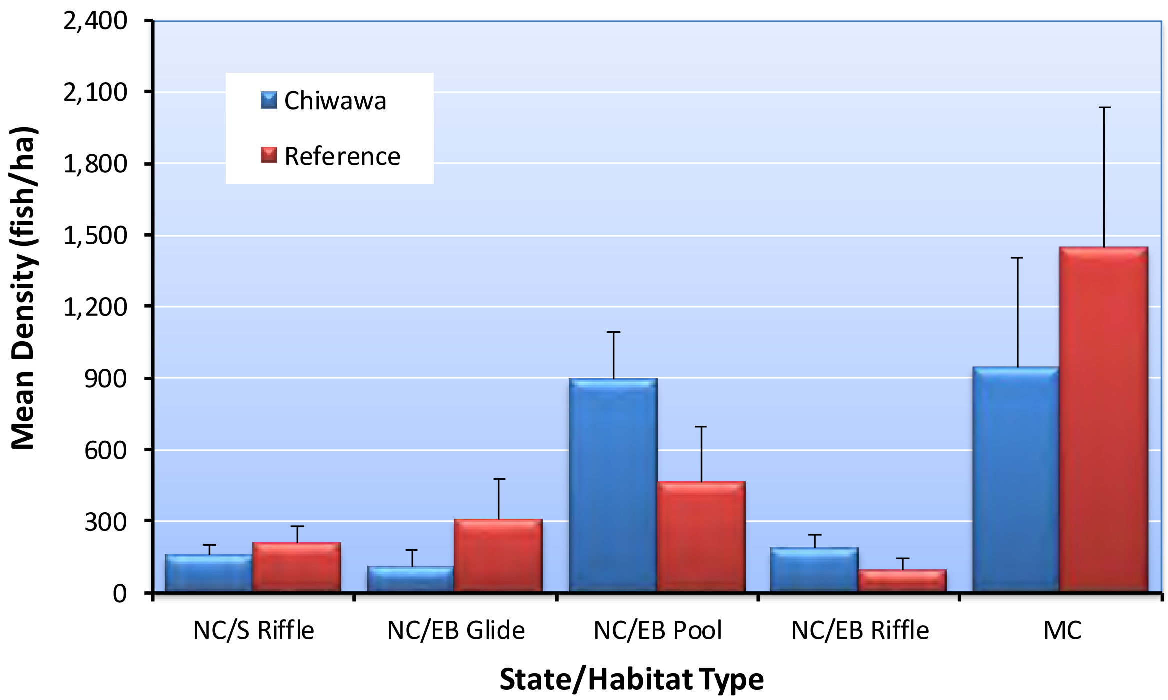

Figure 5. Comparison of the means (95% CI) of age-0 Chinook salmon densities (fish/ha) within state/habitat types in Reaches 3 and 8 of the Chiwawa River and their matched reference areas on Nason Creek and the Little Wenatchee River. There was no sampling in 2000 and no sampling in reference areas in 1992.

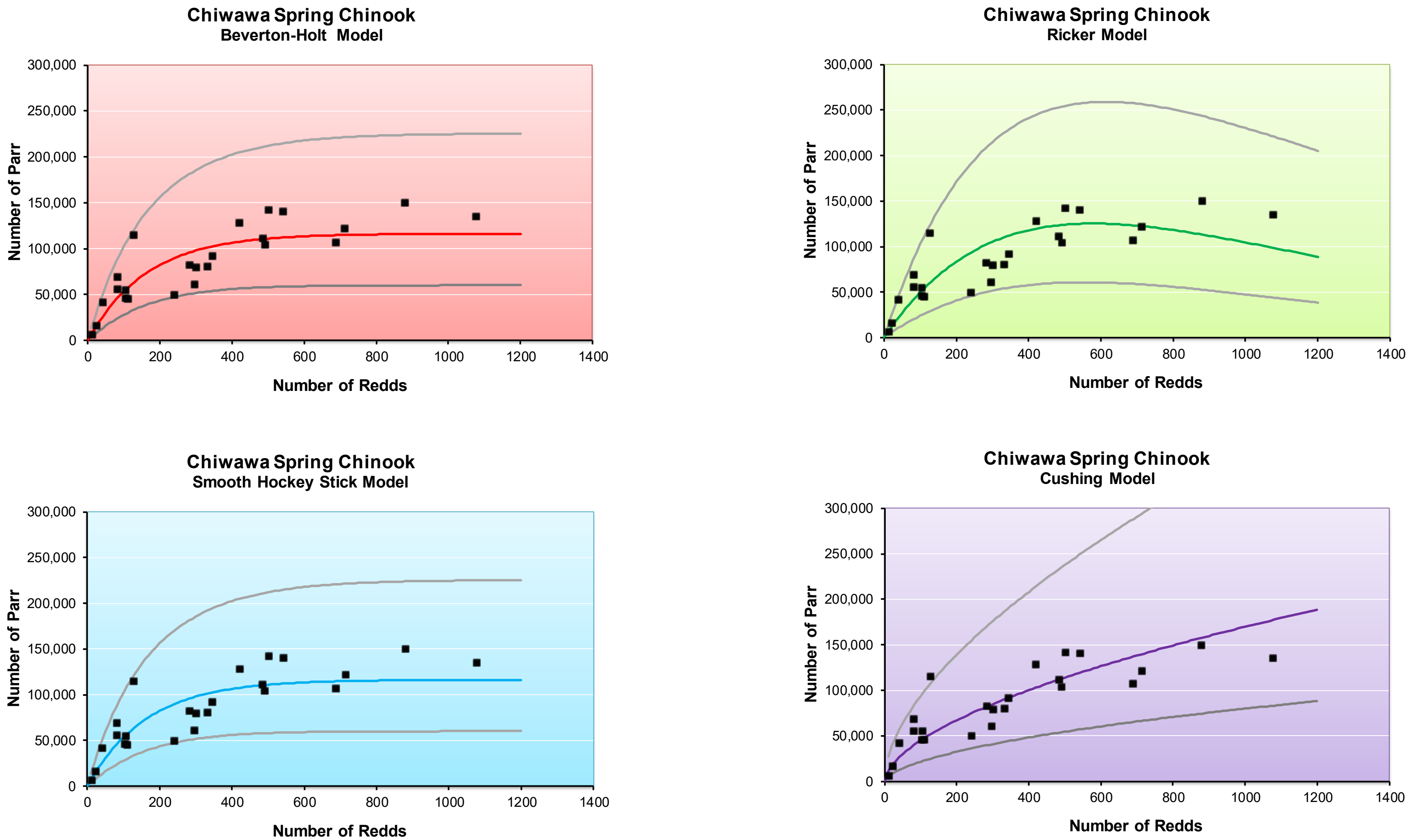

Figure 6. Relationship between numbers of juvenile (age-0) Chinook and redds in the Chiwawa River basin, 1992-2016 (no sampling occurred in 2000). Figures show the fit of the Beverton-Holt model, smooth hockey stick, Ricker model, and the Cushing model to the data. Gray lines indicate the upper and lower 95% C.B.

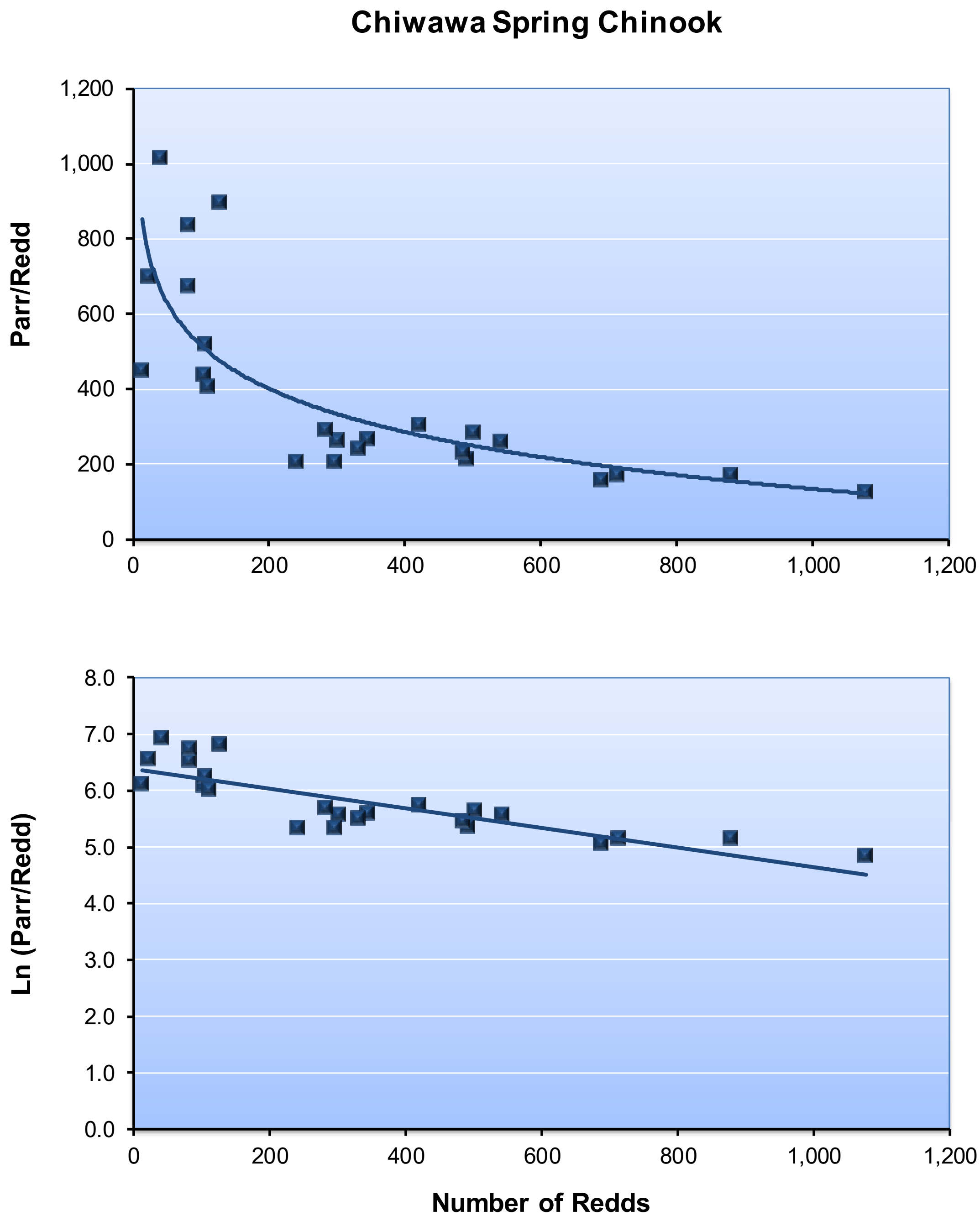

Figure 7. Relationship between parr/redd and numbers of redds (top figure) and natural log parr/redd and numbers of redds (bottom figure) in the Chiwawa River basin, 1992-2016. No sampling was conducted in 2000. Estimates for 1993-2016 included the Chiwawa River and its tributaries; the 1992 estimate included only the Chiwawa River. The linear relationship LN(P/R) = 6.38 – 0.002(Redds) was significant with P = 0.0000; R^2 = 0.690.

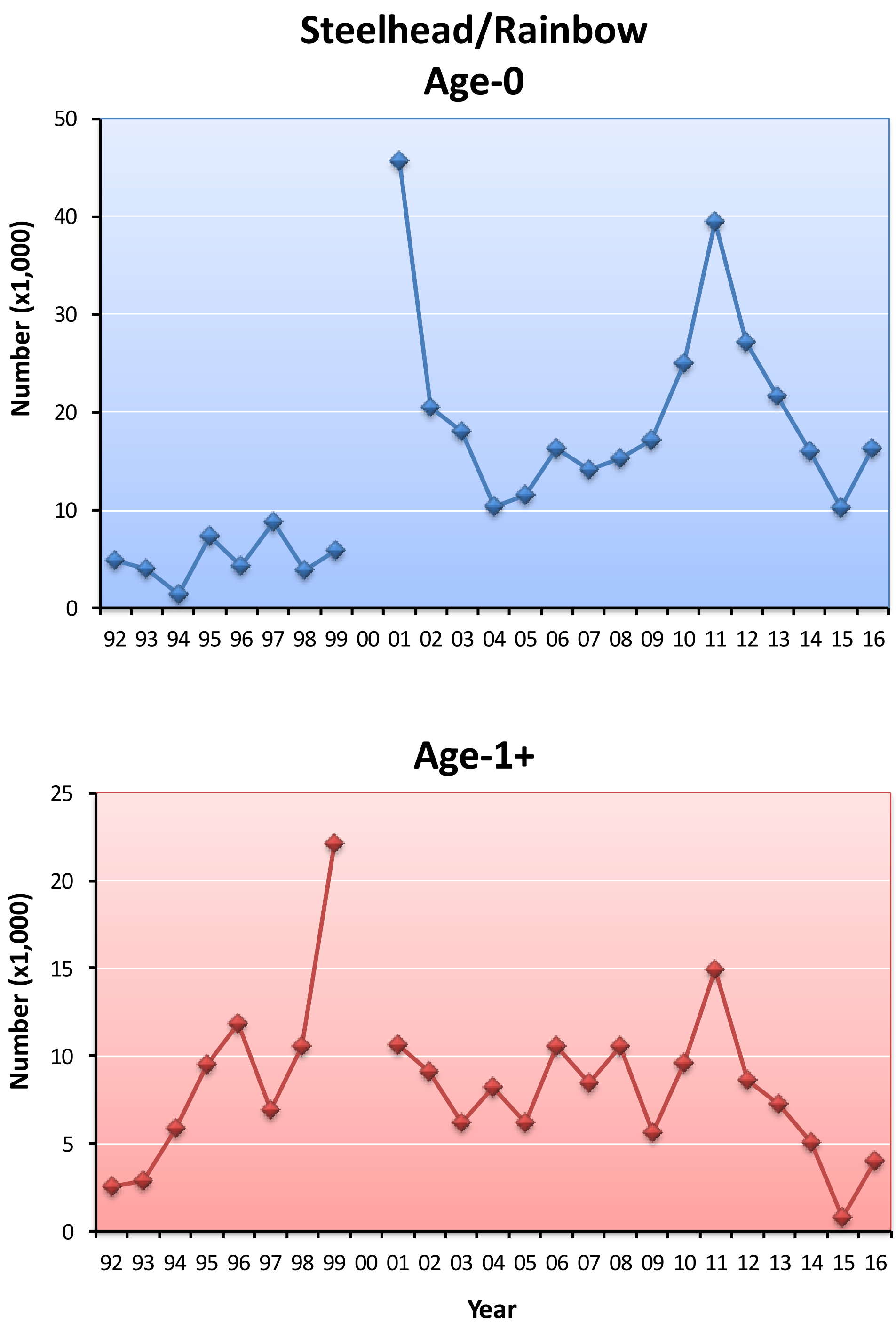

Figure 8. Numbers of age-0 (<4 in) and age-1+ (4-8 in) steelhead/rainbow within the Chiwawa River basin in August 1992-2016; ND = no data.

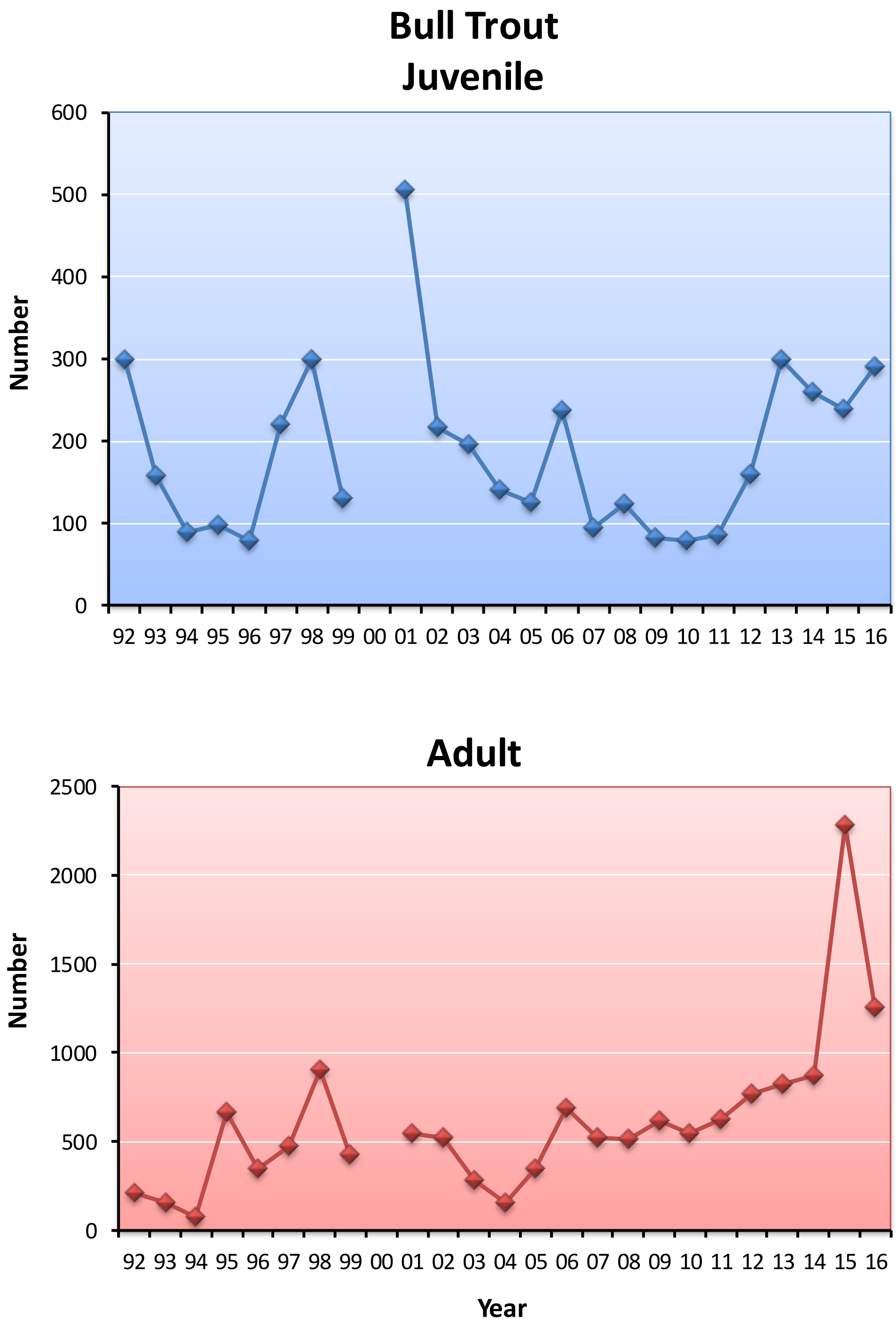

Figure 9. Numbers of juvenile (2-8 inches) and adult (>8 inches) bull trout within the Chiwawa River basin in August 1992-2016; ND = no data.

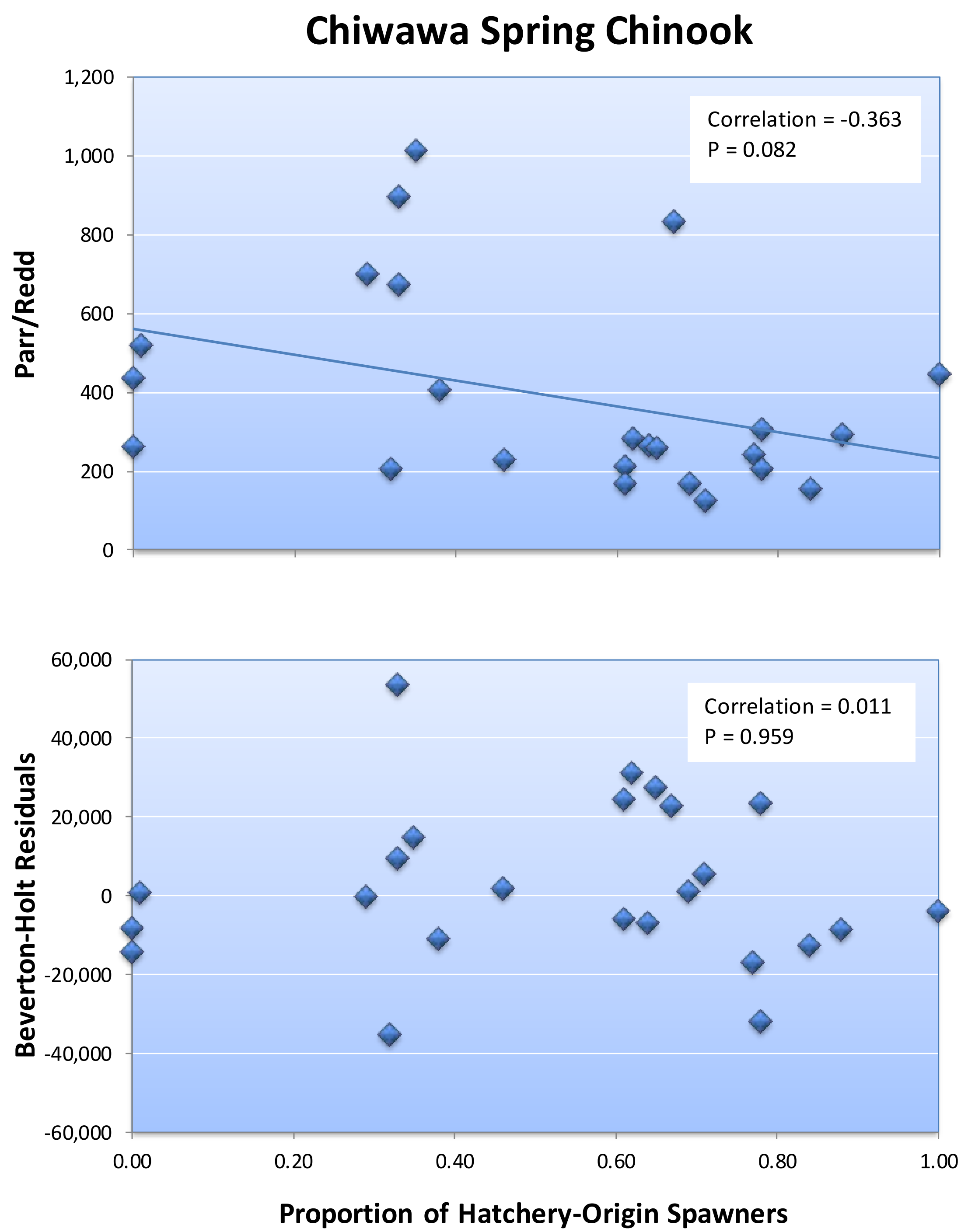

Figure 10. Relationship between juvenile productivity (parr/redd) and the proportion of hatchery-origin spawners (pHOS) (top figure) and the relationship between the residuals from the Beverton-Holt stock/recruitment relationship and pHOS (bottom figure).

Table 1. Description, location (river mile), and area (hectares) of land-class strata (reaches) used by age-0 Chinook salmon in the Chiwawa River basin, 2016. Reaches were classified according to geologic district, landtype association, valley-bottom type, stream state-type, and habitat type within the Cascade Ecoregion; MCV = moderately confined valley, CC = confined canyon, UCV = unconfined valley, NC = natural channel, EB = eroded banks, S = straight, G = glide, P = pool, R = riffle, and MC = multiple channel. See Hillman and Miller (2004) for definitions of stream state codes.

Reach	RM	Gradient	Geologic district	Landtype association	Valley bottom type	Stream state type	Habitat type	Area (ha)	
								Total	Sample
Chiwawa River									
1	0.00-3.77	0.007	Glacial Drift over Chumstick Formation	Glacial Valley	MCV Alluvial	NC/EB	G	0.60	0.60
						NC/EB	P	1.37	1.01
						NC/EB	R	16.35	1.75
2	3.77-5.51	0.010	Glacial Drift over Chumstick Formation	Glacial Canyon	CC Fluvial	NC/EB	G	0.26	0.26
						NC/EB	P	0.78	0.29
						NC/EB	R	7.21	0.67
3	5.51-7.88	0.009	Glacial Drift over Chumstick Formation	Glacial Valley	MCV Alluvial	NC/S	R	5.71	0.80
						NC/EB	G	0.13	0.13
						NC/EB	R	4.21	0.47
						MC	MC	0.32	0.32
4	7.88-8.90	0.007	Glacial Drift over Chumstick Formation	Glacial Canyon	CC Fluvial	NC/EB	P	0.39	0.27
						NC/EB	R	2.86	0.42
						MC	MC	0.44	0.44
5	8.90-10.83	0.011	Glacial Drift over Chumstick Formation	Glacial Valley	MCV Alluvial	NC/EB	P	0.13	0.13
						NC/EB	R	11.44	0.99
6	10.83-11.80	0.008	Glacial Drift over Chumstick Formation	Glacial Canyon	CC Fluvial	NC/EB	P	0.37	0.37
						NC/EB	R	3.53	0.98
						MC	MC	0.36	0.36
7	11.80-20.03	0.001	Glacial Drift over Chumstick Formation	Glacial Valley	UCV Alluvial	NC	G	2.13	0.73
						NC	P	6.52	0.70
						NC	R	0.99	0.20
						NC/EB	G	2.55	1.36
						NC/EB	P	6.89	1.84
						NC/EB	R	4.75	0.52
						MC	MC	4.30	1.65
8	20.03-25.42	0.003	Glacial Drift over Swakane Gneiss	Glacial Valley	UCV Alluvial	NC/EB	G	2.44	1.06
						NC/EB	P	7.41	2.24
						NC/EB	R	5.24	0.98
						EB	P	0.22	0.22
						EB	R	0.34	0.34
						MC	MC	7.79	2.65
9	25.42-28.81	0.007	Glacial Drift over Swakane Gneiss	Glacial Valley	MCV Alluvial	NC	P	4.52	0.51
						NC	R	2.80	0.58
						MC	MC	2.88	0.95
10	28.81-31.11	0.011	Pre-upper Jurassic Gneiss	Glacial Valley	MCV Alluvial	NC	P	0.60	0.31
						NC	R	2.24	0.49
						MC	MC	4.13	0.44

Table 1. Concluded.

Reach	RM	Gradient	Geologic district	Landtype association	Valley bottom type	Stream state type	Habitat type	Area (ha)	
								Total	Sampled
Trinity Side Channel									
10b	0.00-0.75	0.011	Pre-upper Jurassic Gneiss	Glacial Valley	MCV Alluvial	NC	P	0.39	0.09
						NC	R	0.12	0.03
						NC	MC	0.18	0.18
Phelps Creek									
1	0.00-0.35	0.043	Pre-upper Jurassic Gneiss	Glacial Valley	MCV Alluvial	NC	R	0.00	0.00
						NC	MC	0.18	0.18
Chikamin Creek[1]									
1	0.00-0.94	0.013	Glacial Drift over Chumstick Formation	Glacial Valley	UCV Alluvial	NC	G	0.02	0.02
						NC	P	0.21	0.05
						NC	R	0.32	0.03
						MC	MC	0.09	0.09
Rock Creek									
1	0.00-0.73	0.020	Glacial Drift over Swakane Gneiss	Glacial Valley	UCV Alluvial	NC	P	0.18	0.04
						NC	R	0.36	0.05
						MC	MC	0.07	0.07
Unnamed Creek									
1	0.00-0.05		Pre-upper Jurassic Gneiss	Glacial Valley	MCV Alluvial	NC	P	0.00	0.00
						NC	R	0.00	0.00
Big Meadow Creek									
1	0.00-0.35	0.025	Glacial Drift over Chumstick Formation	Glacial Valley	MCV Alluvial	NC	G	0.01	0.01
						NC	P	0.17	0.08
						NC	R	0.13	0.05
						NC	MC	0.00	0.00
Alder Creek									
1	0.00-0.01		Glacial Drift over Chumstick Formation	Glacial Valley	MCV Alluvial	NC	P	0.003	0.003
						NC	R	0.007	0.007
Brush Creek									
1	0.00-0.01		Glacial Drift over Chumstick Formation	Glacial Valley	UCV Alluvial	NC	P	0.002	0.002
						NC	R	0.006	0.006
Clear Creek									
1	0.00-0.05		Glacial Drift over Chumstick Formation	Glacial Valley	UCV Alluvial	NC	P	0.002	0.002
						NC	R	0.004	0.004
Y Creek									
1	0.00-0.05		Glacial Drift over Swakane Gneiss	Glacial Valley	UCV Alluvial	NC	P	0.000	0.000
						NC	R	0.000	0.000

[1] Includes the lower 0.2 miles of Minnow Creek.

Table 2. Estimated mean densities (fish/hectare and fish/m^3), total numbers, 95% confidence bounds on total numbers, and error of the estimated total number of age-0 Chinook salmon in reaches in the Chiwawa River basin, Washington, August 2016.

Reach	Mean density		Surface area (ha)			Volume (m^3)		
	Fish/ha	Fish/m^3	Total No.	95% C.B.	± Error	Total No.	95% C.B.	± Error
Chiwawa River								
1	197.7	0.061	3,621	±480	0.13	3,975	±311	0.08
2	349.8	0.079	2,886	±597	0.21	3,004	±601	0.20
3	167.7	0.041	1,739	±97	0.06	1,726	±97	0.06
4	365.3	0.080	1,348	±153	0.11	1,365	±128	0.09
5	86.6	0.020	1,002	±57	0.06	897	±69	0.08
6	188.3	0.051	802	±107	0.13	753	±116	0.15
7	1,301.4	0.186	36,608	±7,797	0.21	35,873	±8,470	0.24
8	1,078.2	0.177	25,272	±7,382	0.29	22,786	±10,263	0.45
9	2,420.1	0.410	24,685	±7,779	0.32	23,332	±7,993	0.34
10	4,942.0	1.393	37,856	±5,774	0.15	39,575	±9,230	0.23
Phelps Creek								
1	594.4	0.301	107	±0	0.00	107	±0	0.00
Chikamin Creek[1]								
1	2,568.8	1.178	1,644	±519	0.32	1,576	±654	0.41
Rock Creek								
1	1,624.6	0.641	991	±302	0.30	1,018	±388	0.38
Unnamed Creek								
1	0.0	0.000	0	±0	0.00	0	±0	0.00
Big Meadow Creek								
1	4,928.1	2.265	1,508	±408	0.27	1,435	±801	0.56
Alder Creek								
1	2000.0	2.326	20	±0	0.00	20	±0	0.00
Brush Creek								
1	7,250.0	9.508	58	±0	0.00	58	±0	0.00
Clear Creek								
1	5,000.0	4.808	25	±0	0.00	25	±0	0.00
Y Creek								
1	0.0	0.000	0	±0	0.00	0	±0	0.00
Grand Total	**1,098.1**	**0.217**	**140,172**	**±14,502**	**0.10**	**137,525**	**±18,108**	**0.13**

[1] Includes lower 0.2 miles of Minnow Creek.

Table 3. Estimated mean densities (fish/hectare and fish/m^3), total numbers, 95% confidence bounds on total numbers, and error of the estimated total number of age-1+ Chinook salmon in reaches in the Chiwawa River basin, Washington, August 2016.

Reach	Mean density		Surface area (ha)			Volume (m^3)		
	Fish/ha	Fish/m^3	Total No.	95% C.B.	± Error	Total No.	95% C.B.	± Error
Chiwawa River								
1	0.0	0.000	0	±0	0.00	0	±0	0.00
2	1.0	0.000	8	±10	1.25	8	±12	1.50
3	0.0	0.000	0	±0	0.00	0	±0	0.00
4	1.9	0.000	7	±0	0.00	7	±0	0.00
5	0.0	0.000	0	±0	0.00	0	±0	0.00
6	0.5	0.000	2	±0	0.00	1	±0	0.00
7	0.4	0.000	11	±12	1.09	19	±13	0.68
8	2.8	0.000	65	±56	0.86	52	±72	1.38
9	14.6	0.003	149	±96	0.64	142	±119	0.84
10	1.7	0.001	12	±12	1.00	13	±16	1.23
Phelps Creek								
1	0.0	0.000	0	±0	0.00	0	±0	0.00
Chikamin Creek[1]								
1	0.0	0.000	0	±0	0.00	0	±0	0.00
Rock Creek								
1	0.0	0.000	0	±0	0.00	0	±0	0.00
Unnamed Creek								
1	0.0	0.000	0	±0	0.00	0	±0	0.00
Big Meadow Creek								
1	91.5	0.041	28	±47	1.68	26	±30	1.15
Alder Creek								
1	0.0	0.000	0	±0	0.00	0	±0	0.00
Brush Creek								
1	0.0	0.000	0	±0	0.00	0	±0	0.00
Clear Creek								
1	0.0	0.000	0	±0	0.00	0	±0	0.00
Y Creek								
1	0.0	0.000	0	±0	0.00	0	±0	0.00
Grand Total	**2.2**	**0.000**	**282**	**±122**	**0.43**	**268**	**±144**	**0.54**

[1] Includes lower 0.2 miles of Minnow Creek.

Table 4. Summary of the five productivity models of juvenile (age-0) Chinook salmon in the Chiwawa River basin. Models are shown, including the number of parameters (K), AIC_c values, AIC_c difference scores (Δ_i), the likelihood of the model given the data ($\pounds(g_i|x)$), Akaike weights (w_i), and adjusted R^2 values. The sample size (n) for all models was 24. Models describe the relationship between juvenile Chinook numbers (dependent variable) and redd numbers (independent variable).

Model	K^a	AIC_c	Δ_i	$\pounds(g_i\|x)$	w_i	Adj R^2
Beverton-Holt	3	-130.391	0.000	1.000	0.661	0.841
Smooth Hockey Stick	3	-128.692	1.698	0.428	0.283	0.829
Gamma[b]	4	-123.826	6.565	0.038	0.025	0.805
Ricker	3	-123.279	7.112	0.029	0.019	0.786
Cushing	3	-122.355	8.036	0.018	0.012	0.777

[a] ***K*** is the number of structural parameters in the model plus 1 for σ^2.
[b] The γ parameter in the Gamma model was greater than 0, which means that this model is nearly identical to the Ricker model.

Table 5. Estimated mean densities (fish/hectare and fish/m^3), total numbers, 95% confidence bounds on total numbers, and error of the estimated total number of age-0 (<4 in) steelhead/rainbow in reaches in the Chiwawa River basin, Washington, August 2016.

Reach	Mean density		Surface area (ha)			Volume (m^3)		
	Fish/ha	Fish/m^3	Total No.	95% C.B.	± Error	Total No.	95% C.B.	± Error
Chiwawa River								
1	139.0	0.044	2,546	±280	0.11	2,861	±221	0.08
2	234.8	0.053	1,937	±336	0.17	2,035	±342	0.17
3	264.7	0.064	2,745	±179	0.07	2,679	±162	0.06
4	191.9	0.043	708	±174	0.25	743	±163	0.22
5	97.7	0.022	1,130	±20	0.02	997	±33	0.03
6	70.7	0.018	301	±44	0.15	265	±55	0.21
7	57.0	0.008	1,604	±598	0.37	1,546	±703	0.45
8	0.0	0.000	0	±0	0.00	0	±0	0.00
9	0.0	0.000	0	±0	0.00	0	±0	0.00
10	0.0	0.000	0	±0	0.00	0	±0	0.00
Phelps Creek								
1	0.0	0.000	0	±0	0.00	0	±0	0.00
Chikamin Creek[1]								
1	2,217.2	1.053	1,419	±467	0.33	1,409	±501	0.36
Rock Creek								
1	1,632.8	0.607	996	±261	0.26	963	±311	0.32
Unnamed Creek								
1	0.0	0.000	0	±0	0.00	0	±0	0.00
Big Meadow Creek								
1	8,892.2	4.131	2,721	±2,003	0.74	2,618	±2,887	1.10
Alder Creek								
1	5,000.0	5.581	50	±0	0.00	48	±0	0.00
Brush Creek								
1	7,750.0	10.164	62	±0	0.00	62	±0	0.00
Clear Creek								
1	5,000.0	4.808	25	±0	0.00	25	±0	0.00
Y Creek								
1	0.0	0.000	0	±0	0.00	0	±0	0.00
Grand Total	**127.3**	**0.026**	**16,244**	**±2,217**	**0.14**	**16,251**	**±3,066**	**0.19**

[1] Includes lower 0.2 miles of Minnow Creek.

Table 6. Estimated mean densities (fish/hectare and fish/m^3), total numbers, 95% confidence bounds on total numbers, and error of the estimated total number of age-1+ (4-8 in) steelhead/rainbow in reaches in the Chiwawa River basin, Washington, August 2016.

Reach	Mean density		Surface area (ha)			Volume (m^3)		
	Fish/ha	Fish/m^3	Total No.	95% C.B.	± Error	Total No.	95% C.B.	± Error
Chiwawa River								
1	54.9	0.017	1,005	±145	0.14	1,126	±141	0.13
2	41.9	0.010	346	±162	0.47	363	±164	0.45
3	93.9	0.024	974	±49	0.05	986	±45	0.05
4	60.4	0.014	223	±117	0.52	233	±112	0.48
5	44.3	0.010	513	±34	0.07	453	±45	0.10
6	32.2	0.008	137	±31	0.23	121	±36	0.30
7	7.8	0.001	220	±185	0.84	213	±171	0.80
8	0.0	0.000	0	±0	0.00	0	±0	0.00
9	0.0	0.000	0	±0	0.00	0	±0	0.00
10	0.0	0.000	0	±0	0.00	0	±0	0.00
Phelps Creek								
1	0.0	0.000	0	±0	0.00	0	±0	0.00
Chikamin Creek[1]								
1	400.0	0.180	256	±392	1.53	241	±320	1.33
Rock Creek								
1	65.6	0.025	40	±0	0.00	40	±0	0.00
Unnamed Creek								
1	0.0	0.000	0	±0	0.00	0	±0	0.00
Big Meadow Creek								
1	1,009.8	0.466	309	±307	0.99	295	±396	1.34
Alder Creek								
1	0.0	0.000	0	±0	0.00	0	±0	0.00
Brush Creek								
1	1,000.0	1.312	8	±0	0.00	8	±0	0.00
Clear Creek								
1	0.0	0.000	0	±0	0.00	0	±0	0.00
Y Creek								
1	0.0	0.000	0	±0	0.00	0	±0	0.00
Grand Total	**31.6**	**0.006**	**4,031**	**±590**	**0.15**	**4,079**	**±594**	**0.15**

[1] Includes lower 0.2 miles of Minnow Creek.

Table 7. Estimated mean densities (fish/hectare and fish/m^3), total numbers, 95% confidence bounds on total numbers, and error of the estimated total number of steelhead/rainbow larger than 8 inches in reaches in the Chiwawa River basin, Washington, August 2016.

Reach	Mean density		Surface area (ha)			Volume (m^3)		
	Fish/ha	Fish/m^3	Total No.	95% C.B.	± Error	Total No.	95% C.B.	± Error
Chiwawa River								
1	0.3	0.000	5	±6	1.20	7	±10	0.42
2	0.4	0.000	3	±2	0.67	4	±4	1.00
3	0.0	0.000	0	±0	0.00	0	±0	0.00
4	0.0	0.000	0	±0	0.00	0	±0	0.00
5	0.0	0.000	0	±0	0.00	0	±0	0.00
6	0.0	0.000	0	±0	0.00	0	±0	0.00
7	0.0	0.000	0	±0	0.00	0	±0	0.00
8	0.3	0.000	6	±8	1.33	6	±10	1.67
9	0.0	0.000	0	±0	0.00	0	±0	0.00
10	0.0	0.000	0	±0	0.00	0	±0	0.00
Phelps Creek								
1	0.0	0.000	0	±0	0.00	0	±0	0.00
Chikamin Creek[1]								
1	0.0	0.000	0	±0	0.00	0	±0	0.00
Rock Creek								
1	0.0	0.000	0	±0	0.00	0	±0	0.00
Unnamed Creek								
1	0.0	0.000	0	±0	0.00	0	±0	0.00
Big Meadow Creek								
1	0.0	0.000	0	±0	0.00	0	±0	0.00
Alder Creek								
1	0.0	0.000	0	±0	0.00	0	±0	0.00
Brush Creek								
1	0.0	0.000	0	±0	0.00	0	±0	0.00
Clear Creek								
1	0.0	0.000	0	±0	0.00	0	±0	0.00
Y Creek								
1	0.0	0.000	0	±0	0.00	0	±0	0.00
Grand Total	**0.1**	**0.000**	**14**	**±10**	**0.71**	**17**	**±15**	**0.88**

[1] Includes lower 0.2 miles of Minnow Creek.

Table 8. Estimated mean densities (fish/hectare and fish/m^3), total numbers, 95% confidence bounds on total numbers, and error of the estimated total number of juvenile bull trout (2-8 in) in reaches in the Chiwawa River basin, Washington, August 2016.

Reach	Mean density		Surface area (ha)			Volume (m^3)		
	Fish/ha	Fish/m^3	Total No.	95% C.B.	± Error	Total No.	95% C.B.	± Error
Chiwawa River								
1	0.0	0.000	0	±0	0.00	0	±0	0.00
2	1.6	0.000	13	±17	1.31	15	±20	1.33
3	0.0	0.000	0	±0	0.00	0	±0	0.00
4	0.0	0.000	0	±0	0.00	0	±0	0.00
5	0.0	0.000	0	±0	0.00	0	±0	0.00
6	0.0	0.000	0	±0	0.00	0	±0	0.00
7	0.0	0.000	0	±0	0.00	0	±0	0.00
8	0.0	0.000	0	±0	0.00	0	±0	0.00
9	7.6	0.001	78	±38	0.49	74	±44	0.59
10	21.9	0.011	168	±40	0.24	310	±43	0.14
Phelps Creek								
1	144.4	0.073	26	±0	0.00	26	±0	0.00
Chikamin Creek[1]								
1	0.0	0.000	0	±0	0.00	0	±0	0.00
Rock Creek								
1	9.8	0.004	6	±0	0.00	6	±0	0.00
Unnamed Creek								
1	0.0	0.000	0	±0	0.00	0	±0	0.00
Big Meadow Creek								
1	0.0	0.000	0	±0	0.00	0	±0	0.00
Alder Creek								
1	0.0	0.000	0	±0	0.00	0	±0	0.00
Brush Creek								
1	0.0	0.000	0	±0	0.00	0	±0	0.00
Clear Creek								
1	0.0	0.000	0	±0	0.00	0	±0	0.00
Y Creek								
1	0.0	0.000	0	±0	0.00	0	±0	0.00
Grand Total	**2.3**	**0.001**	**291**	**±58**	**0.20**	**431**	**±65**	**0.15**

[1] Includes lower 0.2 miles of Minnow Creek.

Table 9. Estimated mean densities (fish/hectare and fish/m^3), total numbers, 95% confidence bounds on total numbers, and error of the estimated total number of adult bull trout (>8 in) in reaches in the Chiwawa River basin, Washington, August 2016.

Reach	Mean density		Surface area (ha)			Volume (m^3)		
	Fish/ha	Fish/m^3	Total No.	95% C.B.	± Error	Total No.	95% C.B.	± Error
Chiwawa River								
1	1.1	0.000	20	±15	0.75	20	±15	0.75
2	2.3	0.001	19	±15	0.79	19	±28	1.47
3	2.0	0.001	21	±3	0.14	21	±4	0.19
4	3.3	0.001	12	±4	0.33	12	±5	0.42
5	0.3	0.000	4	±0	0.00	5	±0	0.00
6	1.4	0.000	6	±0	0.00	6	±0	0.00
7	8.6	0.001	242	±74	0.31	232	±133	0.57
8	7.3	0.001	171	±46	0.27	155	±117	0.75
9	22.8	0.004	233	±39	0.17	222	±96	0.43
10	74.5	0.020	519	±117	0.23	540	±92	0.17
Phelps Creek								
1	38.9	0.020	7	±0	0.00	7	±0	0.00
Chikamin Creek[1]								
1	0.0	0.000	0	±0	0.00	0	±0	0.00
Rock Creek								
1	0.0	0.000	0	±0	0.00	0	±0	0.00
Unnamed Creek								
1	0.0	0.000	0	±0	0.00	0	±0	0.00
Big Meadow Creek								
1	0.0	0.000	0	±0	0.00	0	±0	0.00
Alder Creek								
1	0.0	0.000	0	±0	0.00	0	±0	0.00
Brush Creek								
1	0.0	0.000	0	±0	0.00	0	±0	0.00
Clear Creek								
1	0.0	0.000	0	±0	0.00	0	±0	0.00
Y Creek								
1	0.0	0.000	0	±0	0.00	0	±0	0.00
Grand Total	**9.8**	**0.002**	**1,254**	**±152**	**0.12**	**1,239**	**±224**	**0.18**

[1] Includes lower 0.2 miles of Minnow Creek.

APPENDIX A. Numbers of redds, eggs, age-0 Chinook salmon, parr per redd, and percent egg-to-parr survival in the Chiwawa River basin, brood years 1991-2016; NS = not sampled. Numbers of eggs were calculated as the number of redds times the mean fecundity of females collected for broodstock.

Brood Year	Chinook Salmon			Parr/Redd	Egg-to-parr survival (%)
	Redds	Eggs	Age-0 (parr)		
1991	104	478,400	45,483	437	9.5
1992	302	1,570,098	79,113	262	5.0
1993	106	556,394	55,056	519	9.9
1994	82	485,686	55,240	674	11.4
1995	13	66,248	5,815	447	8.8
1996	23	106,835	16,066	699	15.0
1997	82	374,740	68,415	834	18.3
1998	41	218,325	41,629	1,015	19.1
1999	34	166,090	NS	NS	NS
2000	128	642,944	114,617	895	17.8
2001	1,078	4,984,672	134,874	125	2.7
2002	345	1,605,630	91,278	265	5.7
2003	111	648,684	45,177	407	7.0
2004	241	1,156,559	49,631	206	4.3
2005	332	1,436,564	79,902	241	5.6
2006	297	1,284,228	60,752	205	4.7
2007	283	1,256,803	82,351	291	6.6
2008	689	3,163,888	106,705	155	3.4
2009	421	1,925,233	128,220	305	6.7
2010	502	2,165,628	141,510	282	6.5
2011	492	2,157,420	103,940	211	4.8
2012	880	3,716,240	149,563	185	4.4
2013	714	3,367,224	121,240	170	3.6
2014	485	1,961,825	111,224	229	5.7
2015	543	2,631,921	140,172	258	5.3
Average	**333**	**1,525,131**	**84,499**	**388**	**8.0**

APPENDIX B. Estimated numbers of salmonids (based on fish/ha) in the Chiwawa River basin, Washington, 1992-2016; NS = not sampled.

Survey year	Chinook salmon		Steelhead/Rainbow			Bull trout		Cutthroat trout
	Age-0	Age-1+	Age-0	Age-1+	>8 in[1]	2-8 in	>8 in	
1992[2]	45,483	563	4,927	2,533	1,869	299	208	NS
1993	79,113	174	4,004	2,860	768	158	156	NS
1994	55,056	18	1,410	5,856	67	90	76	NS
1995	55,241	13	7,357	9,517	140	97	664	NS
1996	5,815	22	4,245	11,849	78	79	343	NS
1997	16,066	5	8,823	6,905	48	220	472	56
1998	68,415	63	3,921	10,585	78	300	900	93
1999	41,629	41	5,838	22,130	33	130	423	80
2000	NS	NS	NS	NS	NS	NS	NS	NS
2001	114,617	69	45,727	10,623	420	505	542	108
2002	134,874	32	20,521	9,090	181	217	521	111
2003	91,278	134	18,020	6,179	49	196	282	52
2004	45,177	21	10,380	8,190	8	140	157	22
2005	49,631	79	11,463	6,188	48	125	346	23
2006	79,902	388	16,245	10,533	50	238	686	68
2007	60,752	41	14,073	8,448	77	95	520	47
2008	82,351	189	15,230	10,576	144	124	510	109
2009	106,705	54	17,179	5,629	85	82	618	128
2010	128,220	291	25,018	9,616	63	79	547	252
2011	141,510	967	39,446	14,903	65	86	621	240
2012	103,940	767	27,134	8,576	65	159	768	188
2013	149,563	852	21,682	7,253	76	299	820	358
2014	121,240	939	16,083	5,084	87	259	875	761
2015	111,224	620	10,208	754	18	239	2,286	292
2016	140,172	282	16,244	4,031	14	291	1,254	544

[1]During 1992-1993, numbers of steelhead/rainbow greater than 8 inches included both hatchery and wild rainbow trout. Thereafter, only wild trout were observed.
[2]Only the Chiwawa River was sampled in 1992. No tributaries were sampled in that year.

APPENDIX C. Proportion of total habitat available, fraction of all age-0 Chinook within each habitat type, and densities (fish/ha) and numbers of age-0 Chinook within each habitat type in the Chiwawa River basin, survey years 1992-2016; NS = not sampled.

Habitat	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Proportion of total habitat available											
Glide	0.10	0.09	0.10	0.10	0.10	0.09	0.09	0.09	NS	0.07	0.08
Pool	0.19	0.19	0.21	0.18	0.18	0.17	0.16	0.17	NS	0.15	0.16
Riffle	0.61	0.61	0.57	0.59	0.57	0.57	0.58	0.55	NS	0.49	0.48
M. Chan	0.10	0.11	0.12	0.14	0.14	0.17	0.17	0.19	NS	0.29	0.28
Fraction of all age-0 Chinook within habitat types											
Glide	0.07	0.03	0.02	0.01	0.02	0.01	0.01	0.01	NS	0.03	0.01
Pool	0.30	0.28	0.22	0.21	0.30	0.16	0.17	0.14	NS	0.23	0.24
Riffle	0.19	0.16	0.12	0.11	0.43	0.23	0.08	0.11	NS	0.18	0.15
M. Chan	0.45	0.53	0.64	0.67	0.24	0.60	0.74	0.74	NS	0.57	0.60
Densities of age-0 Chinook within habitat types (fish/ha)											
Glide	254	251	93	55	11	12	78	13	NS	351	187
Pool	584	1,049	619	541	82	122	607	257	NS	1,392	1,468
Riffle	116	188	124	91	38	52	79	62	NS	336	300
M. Chan	1,710	3,408	2,985	2,328	84	449	2,620	1,201	NS	1,820	2,069
Number of age-0 Chinook within habitat types											
Glide	2,967	2,458	857	623	137	130	837	157	NS	3,231	1,931
Pool	13,468	21,814	12,131	11,294	1,755	2,553	11,454	5,933	NS	25,890	32,612
Riffle	8,531	12,616	6,698	6,197	2,525	3,699	5,392	4,626	NS	20,629	19,754
M. Chan	20,517	42,225	35,370	36,965	1,396	9,682	50,728	30,912	NS	64,866	80,576

APPENDIX C. Continued.

Habitat	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Proportion of total habitat available											
Glide	0.07	0.07	0.08	0.08	0.07	0.09	0.08	0.08	0.08	0.07	0.07
Pool	0.17	0.16	0.16	0.16	0.17	0.23	0.22	0.23	0.18	0.23	0.23
Riffle	0.49	0.50	0.47	0.47	0.47	0.51	0.54	0.53	0.57	0.53	0.53
M. Chan	0.26	0.27	0.29	0.30	0.29	0.17	0.15	0.16	0.17	0.17	0.17
Fraction of all age-0 Chinook within habitat types											
Glide	0.02	0.01	0.01	0.03	0.02	0.03	0.02	0.02	0.04	0.01	0.02
Pool	0.23	0.07	0.19	0.31	0.46	0.40	0.36	0.34	0.34	0.41	0.37
Riffle	0.15	0.14	0.07	0.12	0.12	0.11	0.11	0.11	0.19	0.15	0.13
M. Chan	0.60	0.77	0.73	0.54	0.40	0.45	0.51	0.53	0.43	0.43	0.48
Densities of age-0 Chinook within habitat types (fish/ha)											
Glide	200	58	49	237	113	238	230	286	526	173	321
Pool	951	155	492	1,240	1,211	1,210	1,453	1,436	1,805	1,360	1,890
Riffle	216	101	60	166	118	156	175	200	330	221	281
M. Chan	1,626	1,008	1,057	1,147	603	1,872	2,993	3,293	2,515	2,061	3,190
Number of age-0 Chinook within habitat types											
Glide	1,884	540	442	2,498	1,120	2,668	2,371	3,164	6,122	1,535	2,822
Pool	21,091	3,183	9,626	26,754	28,851	34,314	39,382	44,765	48,846	42,209	55,651
Riffle	13,783	6,501	3,367	10,753	7,809	9,773	11,558	14,446	27,883	15,418	19,619
M. Chan	54,519	34,952	36,196	46,580	25,409	38,275	55,607	69,609	61,944	44,779	73,057

APPENDIX C. Concluded.

Habitat	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	Mean
Proportion of total habitat available											
Glide	0.07	0.07	0.06								**0.08**
Pool	0.22	0.24	0.24								**0.19**
Riffle	0.54	0.53	0.54								**0.53**
M. Chan	0.17	0.16	0.16								**0.20**
Fraction of all age-0 Chinook within habitat types											
Glide	0.01	0.01	0.01								**0.02**
Pool	0.37	0.31	0.35								**0.30**
Riffle	0.11	0.05	0.08								**0.13**
M. Chan	0.51	0.63	0.56								**0.55**
Densities of age-0 Chinook within habitat types (fish/ha)											
Glide	133	66	114								**169**
Pool	1,569	1,300	1,628								**1,079**
Riffle	190	98	168								**163**
M. Chan	2,957	3,768	3,789								**1,923**
Number of age-0 Chinook within habitat types											
Glide	1,120	518	931								**1,711**
Pool	44,321	34,993	49,103								**25,916**
Riffle	13,085	6,017	11,550								**10,926**
M. Chan	62,713	69,969	78,589								**46,893**

Appendix B

Fish Trapping at the Chiwawa and Wenatchee Rotary Smolt Traps during 2016

Monitoring Juvenile Salmonids in the Wenatchee River basin:
Activities in the Chiwawa River and Lower Wenatchee River during 2016

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February 13, 2017

Table of Contents

Page

Introduction 7

Study Area...7

Methods..11

Rotary Smolt Traps 11

Backpack Electrofishing...12

Results 13

Rotary Smolt Traps – Chiwawa...13

Rotary Smolt Traps – Lower Wenatchee...17

Backpack Electrofishing...23

Discussion...23

Chiwawa River Rotary Smolt Trap Trap..23

Lower Wenatchee River Rotary Smolt Trap Trap...24

Backpack Electrofishing...25

References..26

Appendix A...27

Appendix B...29

Appendix C...30

Appendix D...31

Appendix E...33

Appendix F..34

Appendix G...35

Appendix H...36

List of Figures

Page

Figure 1. Discharge of the Chiwawa River at Plain, USGS gauge # 12456500. Black line represents 2016 discharge and grey line represents mean discharge from 1990-2015................ 8

Figure 2. Wenatchee River basin (with rotary smolt trap locations) 9

Figure 3. Discharge of the Wenatchee River at Monitor, USGS gauge # 12462500. Black line represents 2016 discharge and grey line represents mean discharge from 1990-2015.............. 10

Figure 4. Daily catch of yearling spring Chinook Salmon at the Chiwawa rotary smolt trap. Blue line indicates river discharge and red horizontal line indicates non-trapping period 14

Figure 5. Daily catch of wild spring Chinook subyearling parr at the Chiwawa rotary smolt trap. Blue line indicates river discharge and red horizontal line indicates non-trapping period 15

Figure 6. Daily catch of wild spring Chinook fry at the Chiwawa rotary smolt trap. Blue line indicates river discharge and red horizontal line indicates non-trapping period. 15

Figure 7. Daily catch of all wild steelhead at the Chiwawa rotary smolt trap. Blue line indicates river discharge and red horizontal line indicates non-trapping period...................................... 16

Figure 8. Daily capture of wild yearling Chinook Salmon at the Lower Wenatchee rotary smolt trap. Blue line indicates river discharge and red horizontal line indicates non-trapping period. 18

Figure 9. Daily capture of wild summer Chinook Salmon at the Lower Wenatchee rotary smolt trap. Blue line indicates river discharge and red horizontal line indicates non-trapping period. 19

Figure 10. Daily capture of wild sockeye Salmon at the Lower Wenatchee rotary smolt trap. Blue line indicates river discharge and red horizontal line indicates non-trapping period 20

Figure 11. Daily capture of wild steelhead at the Lower Wenatchee rotary smolt trap. Blue line indicates river discharge and red horizontal line indicates non-trapping period. 21

List of Tables

Page

Table 1. Mean fork length (mm) and weight (g) of spring Chinook Salmon captured in the Chiwawa rotary smolt trap during 2016 .... **Error! Bookmark not defined.**

Table 2. Mean fork length (mm) and weight (g) and of steelhead/rainbow captured in the Chiwawa rotary smolt trap during 2016 .... **Error! Bookmark not defined.**

Table 3. Estimated egg deposition and egg-to-emigrant survival rates for Chiwawa River spring Chinook Salmon .... **Error! Bookmark not defined.**

Table 4. Mean fork length (mm) and weight (g) for wild yearling spring Chinook Salmon sampled at the Lower Wenatchee rotary smolt during 2016 .... **Error! Bookmark not defined.**

Table 5. Mean fork length (mm) and weight (g) of subyearling summer Chinook Salmon sampled at the Lower Wenatchee rotary smolt trap. .... **Error! Bookmark not defined.**

Table 6. Age structure and estimated number of wild sockeye smolts that emigrated from Lake Wenatchee in 2013-2015.. **Error! Bookmark not defined.**

Table 7. Mean fork length (mm) and weight (g) of wild sockeye Salmon smolts sampled at the Lower Wenatchee rotary smolt trap. .... **Error! Bookmark not defined.**

Table 8. Mean fork length (mm) and weight (g) of wild steelhead sampled at the Lower Wenatchee rotary smolt trap .... **Error! Bookmark not defined.**

Table 9. Estimated egg deposition and egg-to-smolt survival rates for Wenatchee Basin spring Chinook Salmon .... **Error! Bookmark not defined.**2

Table 10. Estimated egg deposition and egg-to-emigrant survival rates for Wenatchee Basin summer Chinook Salmon……………………………………………………………………………………………… **Error! Bookmark not defined.**

INTRODUCTION

Background

Monitoring and Evaluation

Productivity indicators in the freshwater environment provide data essential to inform evolving salmon and steelhead hatchery programs. In the Wenatchee River subbasin, the Juvenile Monitoring Component of the Monitoring and Evaluation Plan for PUD Hatchery Programs gather data directed at informing these productivity indicators (see Hillman et al. 2013). More specifically, this data directly addresses Objective 2 of the monitoring and evaluation framework:

"Determine if the proportion of hatchery fish on the spawning grounds affects the freshwater productivity of supplemented stocks."

Objectives

The Washington Department of Fish and Wildlife monitors juvenile salmonids in the Wenatchee River basin with the primary objective of estimating: natural productivity, migration timing, and age with size at migration. This has occurred at the tributary level (Chiwawa River since 1991) and population level (Wenatchee River since 1997). Target species include spring Chinook Salmon *Oncorhynchus tshawytscha* and summer steelhead *O. mykiss* in the Chiwawa River, and is expanded to include sockeye Salmon *O. nerka* and summer Chinook Salmon *O. tshawytscha* in the mainstem Wenatchee River.

Monitoring has primarily been conducted with rotary smolt traps that capture emigrating salmonids from spring through fall. In an effort to reduce biases in emigrant estimates, and to improve understanding of survival and movement during non-trapping periods (December through February), WDFW began remote sampling spring Chinook Salmon in the Chiwawa Basin in 2012.

Study Area

Chiwawa River

The Chiwawa River is a fourth-order river draining a 474-km^2 basin and has a mean annual discharge of 14.4 cubic meters per second (m^3/s); contributing about 15% of the mean annual discharge of the Wenatchee River. The Chiwawa basin is dominated by the snow melt cycle with peak discharge occurring May through July with occasional fall freshets (Figure 1). The Chiwawa River originates in the North Cascades and flows southeast for 60 km before joining the Wenatchee River. This confluence with the Wenatchee River is approximately 9km downstream of Lake Wenatchee and 76 km upstream of the Columbia River (Figure 2). The Chiwawa River basin is relatively natural, with 96% managed as part of the Wenatchee National Forest and the upper 32% designated wilderness.

Precipitation in the basin varies between 76 cm near the confluence and 356 cm at the peaks, while elevations range from 573 to 2,768 m. The river is dynamic with generally shallow pool riffle segments as it meanders through a U-shaped valley formed by ancient glaciers in the region. Gradients remain well under 1% for the majority of the river.

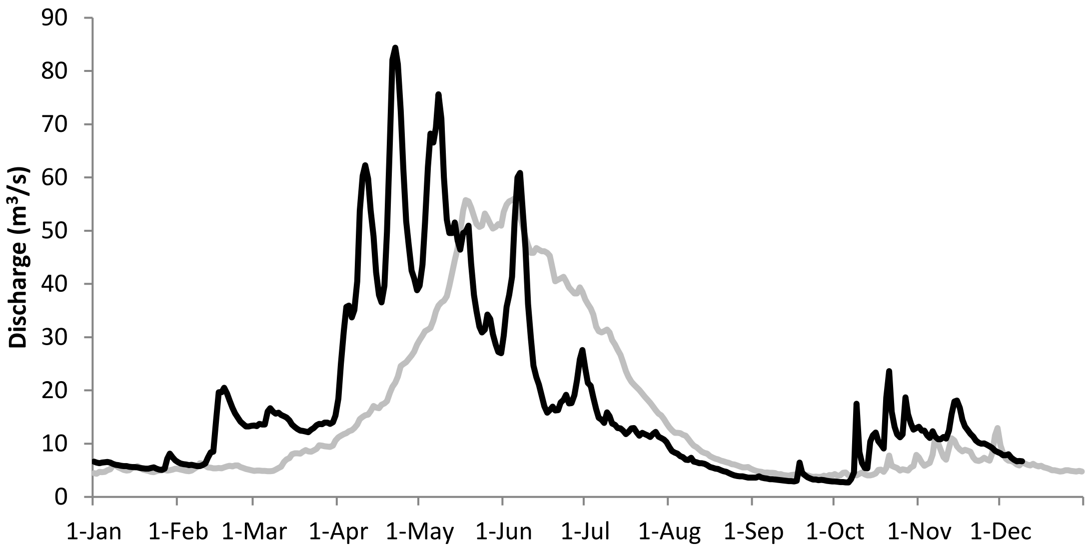

Figure 1. Discharge of the Chiwawa River at Plain, USGS gauge # 12456500. Black line represents 2016 discharge and grey line represents mean discharge from 1990-2015.

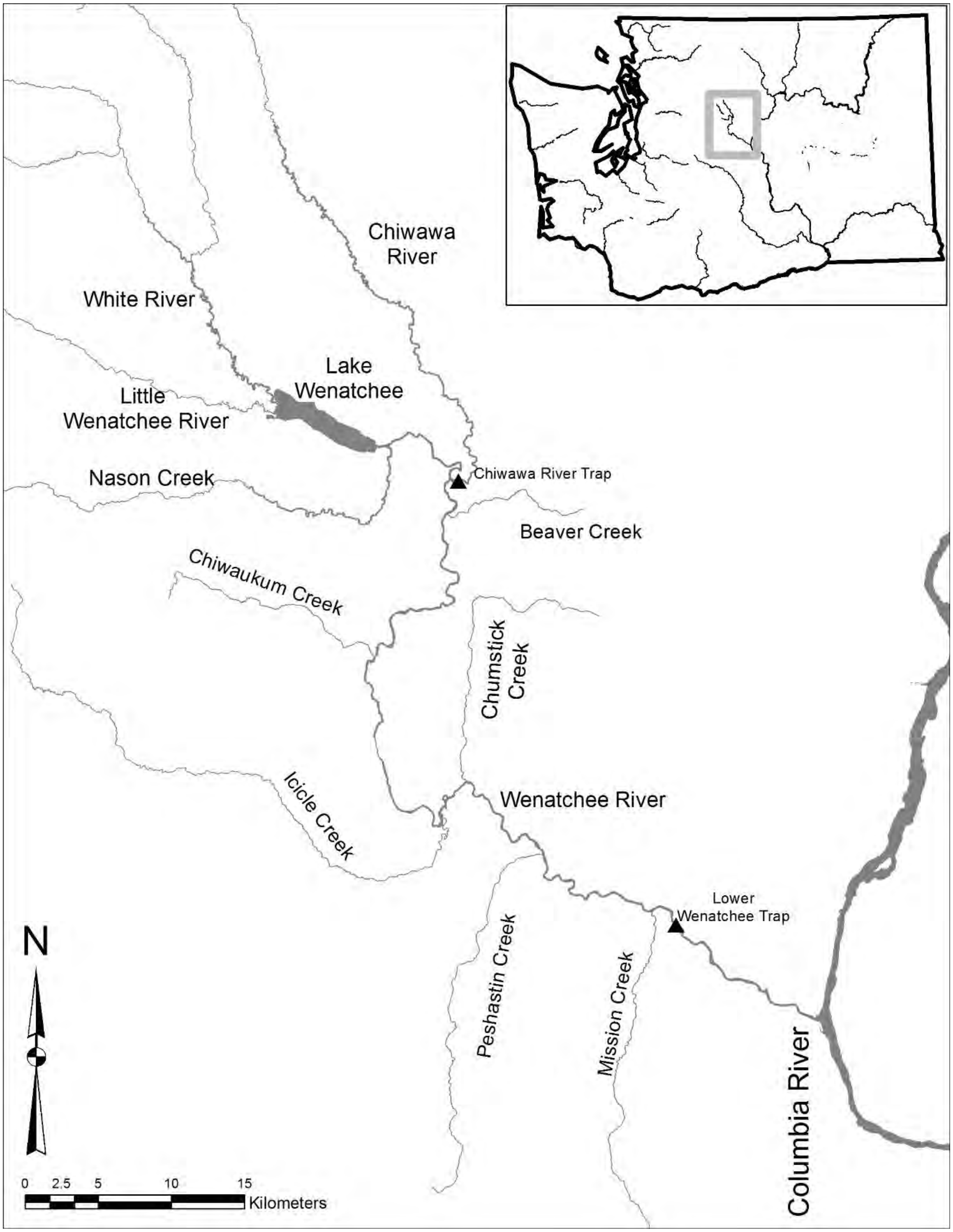

Figure 2. Wenatchee River basin (with rotary smolt trap locations).

Wenatchee River

The Wenatchee River is a fourth-order river draining a 3,437-km^2 basin and has a mean annual discharge of 91.4 m^3/s. The hydrograph is dominated by the snow melt cycle with peak discharge occurring May through July with occasional fall freshets (Figure 3). The mainstem originates at the outlet of Lake Wenatchee and flows southeast 84.5 km before joining the Columbia River, 753 km upstream of the Pacific Ocean (Figure 2). While most of the lowlands (17%) are private, the majority (83%) of basin is public land.

Precipitation in the basin varies from 22 cm near the Columbia River confluence to 381 cm at the crest of the Cascade Mountains with elevations ranging from 237 to 2,768 m. The Wenatchee River has a relatively low gradient except from rkm 40 – 64 where the river flows through a bedrock canyon (Tumwater Canyon) and has a gradient of approximately 9.8 meters per kilometer.

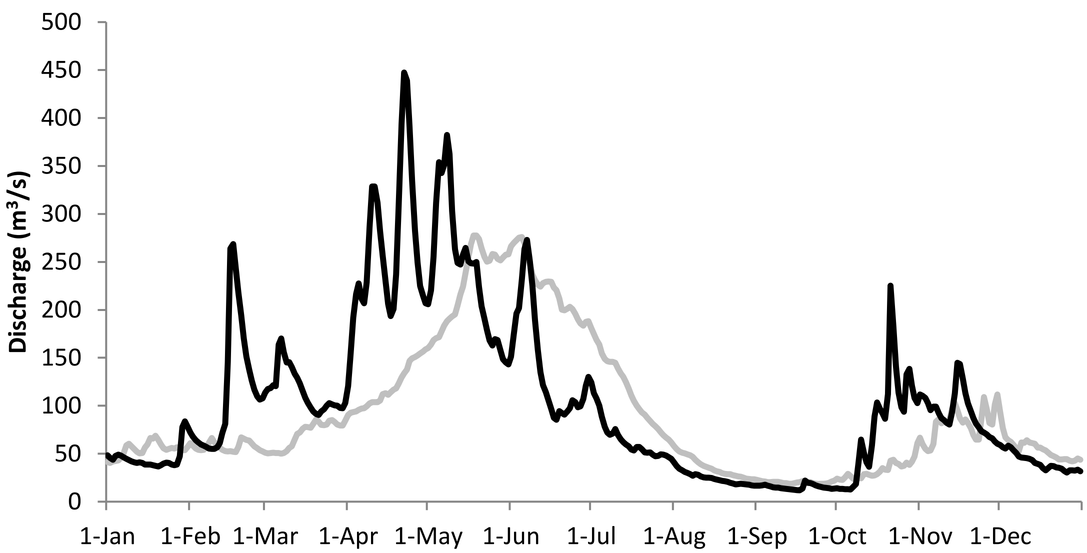

Figure 3. Discharge of the Wenatchee River at Monitor, USGS gauge # 12462500. Black line represents 2016 discharge and grey line represents mean discharge from 1990-2015.

METHODS

Rotary Smolt Traps

Trap Operations

The Chiwawa River trap consists of a single 2.4m cone and has been operating since 1991 at its current location, 0.6 km upstream from the confluence with the Wenatchee River. Trap operations usually begin in late February and continue until ice suspends operations in late fall. The Lower Wenatchee trap consists of two 2.4m cones and has been operating in its current location (rkm 12.5) since 2013. Trap operations usually begin in late January and continue until fall, when river conditions force its removal.

Operational procedures and techniques follow the standardized basin-wide monitoring plan developed by the Upper Columbia Regional Technical Team for the Upper Columbia Salmon Recovery Board (UCSRB; Hillman 2004), which was adapted from Murdoch and Petersen (2000). The traps remain in operation 24 hours a day unless environmental condition (high/low flow, extreme temperature, and high debris), hatchery releases, mechanical failure or human recreational activities halt operations. During periods of high recreational activities in the spring and summer the Lower Wenatchee trap is pulled during daylight hours to minimize human danger.

Fish Sampling

At a minimum of once a day, all fish collected at the traps were identified to genus or species, enumerated, weighed, and fork length (FL) measured. All salmonids were classified as hatchery, wild, or unknown and visually classified as fry, parr, transitional, or smolt. All hatchery salmonids in the basin are marked (adipose fin-clip, coded-wire tags, or Passive Integrated Transponder (PIT) with the exception of coho. Based on length subsamples of known hatchery coho at Leavenworth Fish Hatchery, all coho collected at the Lower Wenatchee rotary smolt trap were considered wild if < 80mm FL or unknown origin if ≥ 80mm FL. All coho collected in the Chiwawa River were considered wild. Target species (≥ 65 mm FL) were tagged using 12.5 mm FDX PIT tags and all PIT tagging information was uploaded to a reginal PIT tag database (PTAGIS) maintained by the Pacific States Marine Fisheries Commission.

A combination of length, time of year, and trap location was used to determine race (spring or summer) of captured juvenile Chinook Salmon. All Chinook Salmon captured in the Chiwawa River trap were considered spring Chinook, regardless of size since summer Chinook Salmon spawning has not been documented upstream of the trap. All yearling (age-1) Chinook captured at the Lower Wenatchee River trap during the spring migration period were considered spring Chinook Salmon because spring Chinook Salmon are yearling migrants and summer Chinook Salmon are typically subyearling migrants. All subyearling fry and parr (age-0) Chinook captured at the Lower Wenatchee River trap during spring were considered summer Chinook Salmon.

Mark–Recapture Trials

Groups of marked juveniles were released during a range of stream discharges in order to determine trapping efficiencies under the varied flow regime. Natural origin fish were marked with a PIT tag if ≥65mm FL or stained with Bismarck Brown dye if <65 mm FL and hatchery origin fish were marked using a caudal fin clip. All marked fish were released evenly upstream on both sides of the river between 1800 hours and 2000 hours. Marked fish from the Lower Wenatchee River trap were transported and released 14.5 km upstream of the trap site while fish from the Chiwawa River trap were released 2.6 km upstream. Each trial was conducted over a four-day (96 hour) period to allow time for passage or capture. Target mark group sizes were based on historical data, location and species, ranging from 100 to over 500 individual fish. See appendix D for mark-recapture trails.

Emigrant Estimates

All emigration estimates were calculated using estimated daily trap efficiency derived from the regression formula using trap efficiency (dependent variable) and discharge (independent variable). Trap efficiency models used a modified Bailey estimator (recaptures + 1) in the calculation of efficiency as a method of bias correction. If a significant relationship ($R^2 > 0.5$ and $P < 0.05$) could not be found a pooled trap efficiency estimate was used. Estimates of emigrating spring Chinook were calculated with and without fry (<50mm FL) due to the uncertainty that these fish were actively migrating to the ocean (UCRTT, 2001). See appendices A and B for detailed equations and information on how the point estimate, variance, and standard error were calculated.

During minor breaks in operation (less than seven days), the number of individual fish collected was estimated. This estimate was calculated using the mean number of fish captured two days prior and two days after the break in operation. For major breaks in operations (greater than seven days), an estimate based on historical run timing was developed. This estimate of daily capture was incorporated into the overall emigration estimate.

Egg-to-emigrant Survival

The estimated total egg deposition (d) was calculated by multiplying the mean fecundity (f) of the brood spawners by the total number of redds (r) found during surveys (Hillman et al. 2015). Egg-to-emigrant survival (s) was calculated by dividing total emigrants (e) by estimated egg deposition (d).

Backpack Electrofishing

Sampling Procedure

From 2012 to present, WDFW has had a goal of PIT tagging 3,000 juvenile spring Chinook Salmon each year. In order to representatively tag the population throughout all reaches, the number of fish tagged in each reach was based on the reach specific abundance encountered during snorkeling surveys in late summer. See Appendix C for further explanation.

Detections and Calculations

Detections occur at PIT tag interrogation sites in and out of the basin as well as rotary smolt traps downstream of the sampling reaches. Calculations of non-trapping emigrant estimates are based on a flow-detection efficiency regression developed using mark-groups previously released to test smolt trap efficiencies. The total number of tagged fish (t) divided by the estimated total parr abundance (p), as based off of standard snorkeling techniques (Hillman et al. 2013), resulted in an overall tag rate (t_i). See Appendix C for further explanation.

RESULTS

Rotary Smolt Traps – Chiwawa

Trap Operation

The Chiwawa trap operated between 2 March and 21 November 2016. During that time the trap was inoperable for 72 days as a result of low or high discharge, debris, hatchery fish releases, and mechanical issues. Forty seven of those days came during the fall when there was not enough discharge to operate the trap. Throughout the year the trap was operated in a single upper position.

Fish Sampling

A total of 27,172 individual fish were collected, with wild spring Chinook Salmon and steelhead comprising 71% and 6% of the total catch, respectively. Additionally, 2,525 hatchery spring Chinook, 1,518 hatchery steelhead, and 3 wild coho were collected. Throughout the sampling period 11,396 PIT tag were deployed into wild spring Chinook and steelhead (10,083 and 1,313 respectively). Spring Chinook mortality for the season totaled 4 yearling, 74 subyearling parr, and 15 fry (0.1%, 0.6%, and 0.4%, respectively). Mortality of steelhead throughout the season totaled 10 (0.6%). The mean fork length (SD) of captured yearling and subyearling spring Chinook Salmon (fry excluded) was 91 (8.5) mm and 71 (12.78) mm, respectively (Table 1).

Table 1. Mean fork length (mm) and weight (g) of spring Chinook Salmon captured in the Chiwawa rotary smolt trap during 2016.

	Yearling transitional/smolts			Subyearling parr		
	Mean	SD	*N*	Mean	SD	*N*
Fork length	91.3	8.5	2,789	71.1	12.8	12,198
Weight	8.3	3.1	2,784	4.7	2.2	10,947

Yearling Spring Chinook (Brood Year 2014)

Wild yearling spring Chinook Salmon were primarily captured between 2 March and 31 May (Figure. 4). A total of 2,807 yearling Chinook Salmon were captured and an estimated 3,414 would have been captured if the trap had operated without interruption. Six mark/recapture efficiency trials using PIT tags were conducted producing a mean trap efficiency of 9.4%. In 2016, mark/recapture trials were conducted at all desired discharge levels and a statistically significant flow-efficiency regression model was obtained ($R^2 = 0.84$, $P < 0.028$). The estimated number (95% C.I.) of yearling spring Chinook Salmon that emigrated from the Chiwawa River in 2015 was 37,170 (±6,524). Smolt survival (SE) to McNary of those tagged fish was 43% (5%) using the Cormack-Jolly-Seber estimator.

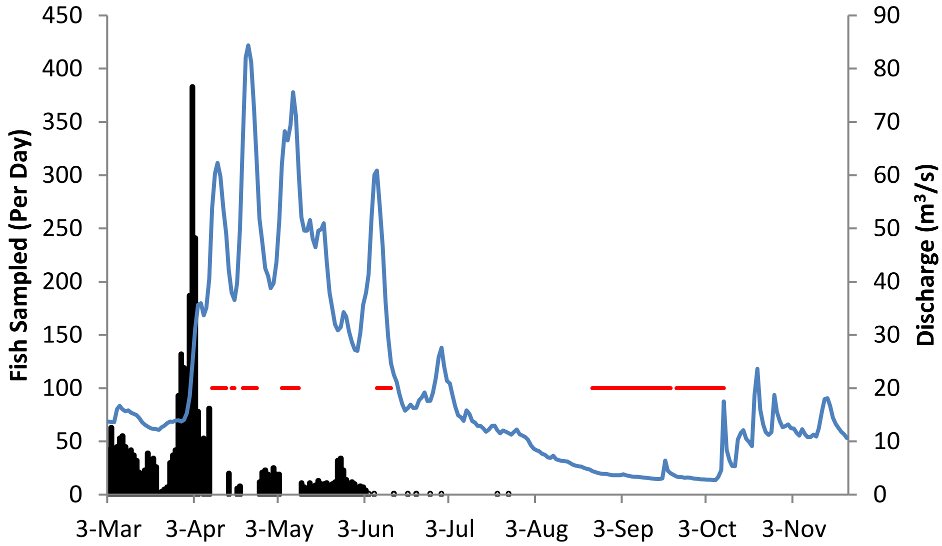

Figure 4. Daily catch of yearling spring Chinook Salmon at the Chiwawa rotary smolt trap. Blue line indicates river discharge and red horizontal line indicates non-trapping period.

Subyearling Spring Chinook (Brood Year 2015)

Wild subyearling spring Chinook Salmon were captured throughout the sampling period, with peak catches of parr in August, October, and November and fry occurring in March and April (Figures 5 and 6, respectively). A total of 12,429 subyearling parr and 3,835 fry were captured with an estimated 13,319 subyearling parr and 4,063 fry had the trap operated without interruption. Twelve mark/recapture efficiency trials were conducted (eight PIT tagged and four Bismarck Brown groups) with a mean trap efficiency of 19.1%. These 12 trials were used to develop a significant regression model for the trap ($R^2 = 0.64$, $P < 0.002$). In 2016, the estimated number of subyearling spring Chinook Salmon emigrating from the Chiwawa River during the sampling period was 80,543 (± 27,967) if you do not include fry or 145,971 (±48,393) if fry are included.

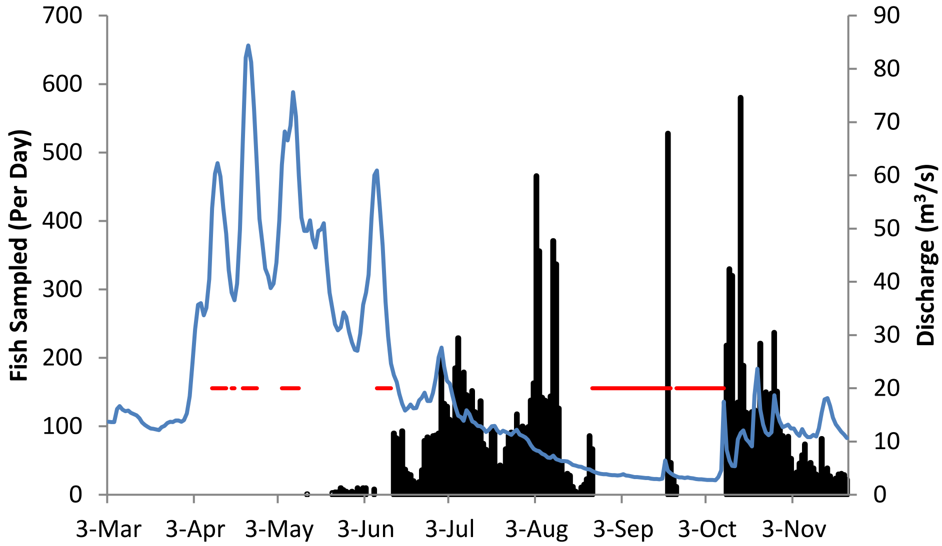

Figure 5. Daily catch of wild spring Chinook subyearling parr at the Chiwawa rotary smolt trap. Blue line indicates river discharge and red horizontal line indicates non-trapping period.

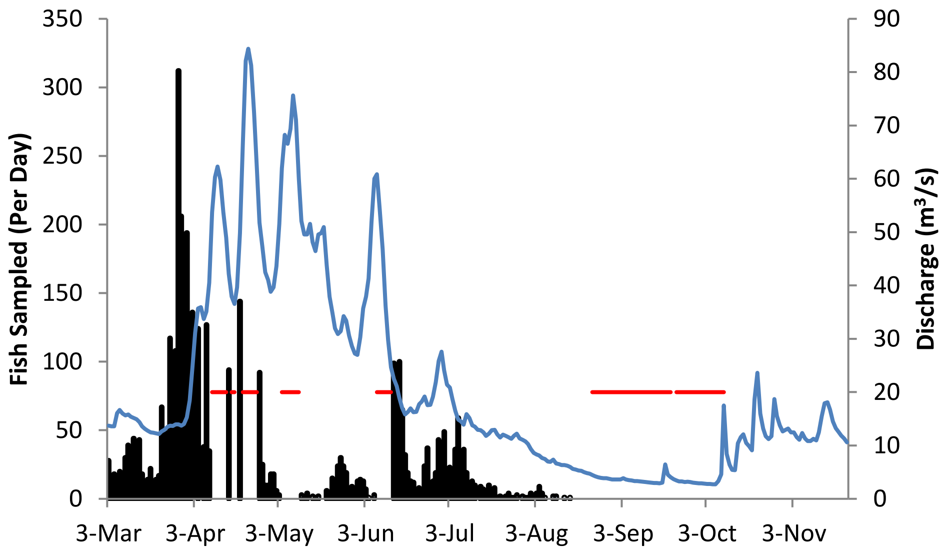

Figure 6. Daily catch of wild spring Chinook fry at the Chiwawa rotary smolt trap. Blue line indicates river discharge and red horizontal line indicates non-trapping period.

Summer Steelhead

During the trapping period, 195 steelhead transitional/smolts and 1,522 steelhead/rainbow parr and fry were captured. While collections occurred in moderate numbers throughout the year, peak collections occurred during September and October (Figure 7). The mean fork length (SD) of steelhead parr and transitional/smolts captured was 83.6 (23.1) and 146.7 (33.4) mm, respectively (Table 2).

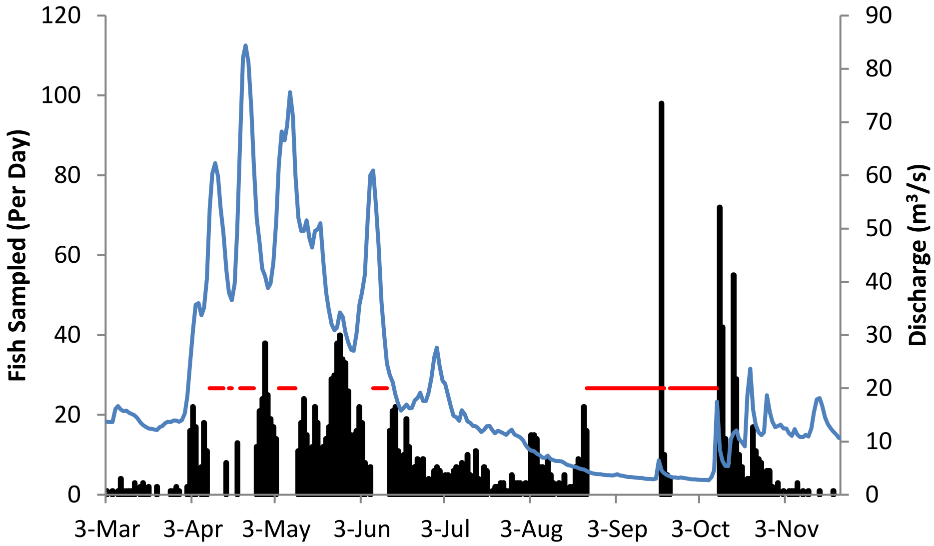

Figure 7. Daily catch of all wild steelhead at the Chiwawa rotary smolt trap. Blue line indicates river discharge and red horizontal line indicates non-trapping period.

Table 2. Mean fork length (mm) and weight (g) and of steelhead/rainbow captured in the Chiwawa rotary smolt trap during 2016.

	Transitional/smolts			Parr		
	Mean	SD	*N*	Mean	SD	*N*
Fork length	146.7	33.4	195	83.6	23.1	1,406
Weight	37.3	23.7	194	7.8	9.4	1,393

Egg-to-emigrant Survival

For BY 2014, 485 redds were counted in the Chiwawa River Basin with an estimated 1,961,825 eggs being deposited. A total of 114,680 emigrants were estimated resulting in an egg-to-emigrant survival of 5.8% (Table 3). This is up from a five year moving average of 3.8%.

Table 3. Estimated egg deposition and egg-to-emigrant survival rates for Chiwawa River spring Chinook Salmon.

Brood Year	Number of redds	Estimated egg deposition	Estimated number				Egg-to-emigrant survival (%)
			Sub-yearling	Non trapping	Yearling	Total emigrants	
1992	302	1,570,098	25,818		39,723	65,541	4.2
1993	106	556,394	14,036		8,662	22,698	4.1
1994	82	485,686	8,595		16,472	25,067	5.2
1995	13	66,248	2,121		3,830	5,951	9.0
1996	23	106,835	3,708		15,475	19,183	18.0
1997	82	374,740	16,228		28,334	44,562	11.9

Brood Year	Number of redds	Estimated egg deposition	Estimated number				Egg-to-emigrant survival (%)
			Sub-yearling	Non trapping	Yearling	Total emigrants	
1998	41	207,675	2,855		23,068	25,923	11.9
1999	34	166,090	4,988		10,661	15,649	9.4
2000	128	642,944	14,854		40,831	55,685	8.7
2001	1,078	4,836,704	459,784		86,482	546,266	11.0
2002	345	1,605,630	93,331		90,948	184,279	11.5
2003	111	648,684	16,881		16,755	33,637	5.2
2004	241	1,156,559	44,079		72,080	116,158	10.0
2005	333	1,436,564	108,595		69,064	177,659	12.3
2006	297	1,284,228	62,922		45,050	107,972	8.4
2007	283	1,241,521	60,196		25,809	86,006	6.9
2008	689	3,163,199	85,161		35,023	120,184	3.8
2009	421	1,925,233	30,996		30,959	61,955	3.2
2010[a]	502	2,165,628	53,619		47,511	101,130	4.7
2011[a]	492	2,157,420	67,982	3,665	37,185	108,832	5.0
2012[a]	880	3,716,240	49,774	25,305	34,334	109,413	2.9
2013[a]	714	3,367,224	73,695	NA	39,396	113,091	3.4
2014[a]	485	1,961,825	77,510	NA	37,170	114,680	5.8
2015[a]	312	1,372,800	80,543	--	--	--	--

[a]calculated with Bailey model

Non-target Taxa

Bull trout (*Salvelinus confluentus*) also comprised a large proportion of incidental species captured. During the trapping period 118 bull trout (15 ≥ 300 mm FL and 103 <300 mm FL) were captured. Additionally, 43 westslope cutthroat trout (*O. clarki lewisi*), and three Eastern brook trout (*S. fontinalis*) were collected. In all, 109 bull trout and 41 westslope cutthroat trout were released with PIT tags. Monthly and annual totals of all fish captured are presented in Appendix E and Appendix F, respectively.

Rotary Smolt Traps – Lower Wenatchee

Trap Operation

The Lower Wenatchee trap operated from 29 January through 26 July 2016. During this time the trap was inoperable for a total of 23 days due to high/low flows, high temperatures, heavy debris, major hatchery releases, and mechanical issues. Extreme river temperatures and low flows resulted in trapping operations being suspended for the season on 26 July. Throughout the season, the trap cones were operated in a single lower position.

Fish Sampling

A total of 43,685 individual fish were collected, with wild summer Chinook Salmon comprising 89% of the total catch. Additionally, 610 wild yearling spring Chinook Salmon, 7,701 hatchery yearling Chinook Salmon, 1,346 wild sockeye, 417 wild steelhead, and 259 hatchery steelhead were captured. Throughout the sampling period 567, 1,065, and 131 PIT tag were deployed into wild yearling spring Chinook, sockeye, and steelhead, respectively. Mortality for the season totaled 2 yearling spring Chinook, 184 subyearling summer Chinook, 63 sockeye, and 6 steelhead (0.3%, 0.7%, 4.7%, and 1.4%, respectively).

Wild Yearling Spring Chinook (Brood Year 2014)

Wild yearling spring Chinook Salmon were primarily captured in February and March (Figure 8). Throughout the trapping period 610 spring Chinook were collected and an estimated 708 would have been collected had the trap operated without interruption. A combination of 2013, 2014, and 2015 trials were used to develop a significant relationship between discharge and trap efficiency (R^2 = 0.62, P = 0.02). This model was used to calculate an emigrant estimate of 36,752 (±5,330). The mean fork length (SD) of captured yearling Chinook was 94 (9.4) mm (Table 4).

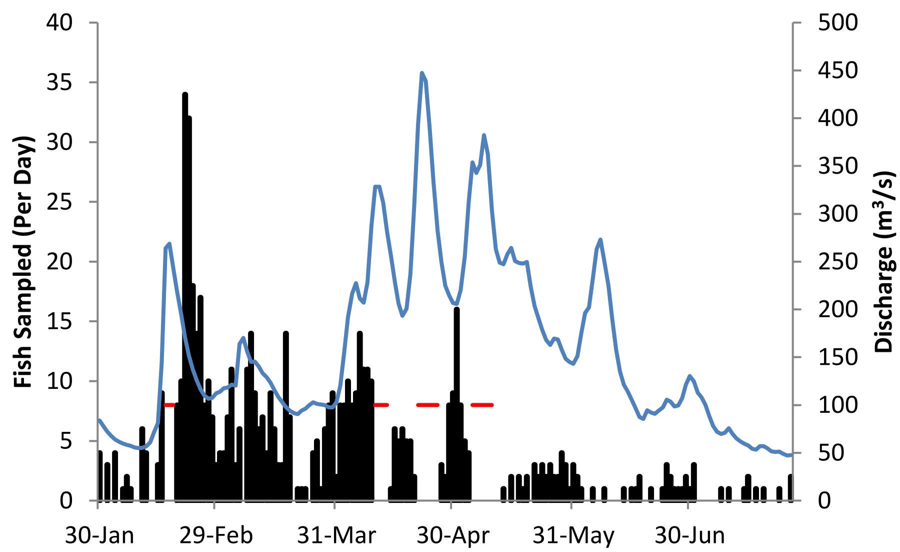

Figure 8. Daily capture of wild yearling Chinook Salmon at the Lower Wenatchee rotary smolt trap. Blue line indicates river discharge and red horizontal line indicates non-trapping period.

Table 4. Mean fork length (mm) and weight (g) for wild yearling spring Chinook Salmon sampled at the Lower Wenatchee rotary trap during 2016.

	Mean	SD	N
Fork length	94	9.4	600
Weight	9.0	2.9	598

Wild Subyearling Summer Chinook (Brood Year 2015)

Wild subyearling summer Chinook dominated the catch (63%) with 27,407 fish being processed, most being collected in April and May (Figure 9). An estimated 35,815 would have been captured had the trap operated without interruption. Over the season, four mark/recapture efficiency trials were carried out using Bismarck Brown dye. When combined with trials from 2014 and 2015 a significant discharge efficiency relationship was developed ($R^2 = 0.56$, $P < 0.001$) and an emigrant estimate (95% C.I.) of 4,023,310 (±676,633) was calculated. The mean fork length (SD) for captured subyearling parr and fry summer Chinook was 64 (10.1) and 40 (3.7), respectively (Table 5). Over the sampling period 18 PIT tags were deployed in summer Chinook.

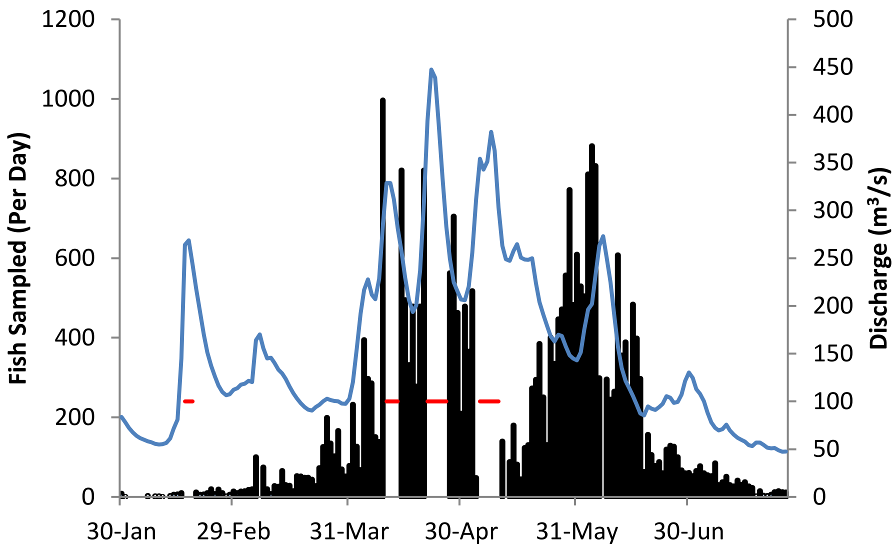

Figure 9. Daily capture of wild summer Chinook Salmon at the Lower Wenatchee rotary smolt trap. Blue line indicates river discharge and red horizontal line indicates non-trapping period.

Table 5. Mean fork length (mm) and weight (g) of subyearling summer Chinook Salmon sampled at the Lower Wenatchee rotary smolt trap.

	Transition / Smolt			Parr			Fry		
	Mean	SD	N	Mean	SD	N	Mean	SD	N
Fork length	82.8	7.3	216	64.1	10.1	2,799	40.9	3.7	3,143
Weight	6.4	1.8	216	3.1	1.6	2,778	0.6	0.3	3,005

Wild Sockeye

A total of 1,346 juvenile sockeye were collected in the 2016 season and an estimated 1,916 had the trap operated without interruption. Almost all of these fish (84%) were collected in April (Figure 10). No mark/recapture efficiency trials were carried out due to mechanical issues during the peak of the run. Mark/recapture efficiency trials from the 2013, 2014, and 2015 seasons created a significant discharge efficiency model ($R^2 = 0.52$, $P < 0.043$). This model produced a 2016 emigrant population estimate (95% C.I.) for juvenile sockeye at 208,250 (±29,447). Smolt survival (SE) to McNary of those tagged fish was 26% (5%) using the Cormack-Jolly-Seber estimator. In 2016, while most were Age 1+ (78%), we saw a large jump in Age 2+ (22%) when compared to 2014 and 2013 (Table 6). Mean fork length (SD) for captured sockeye was 81 (12.1) mm (Table 7).

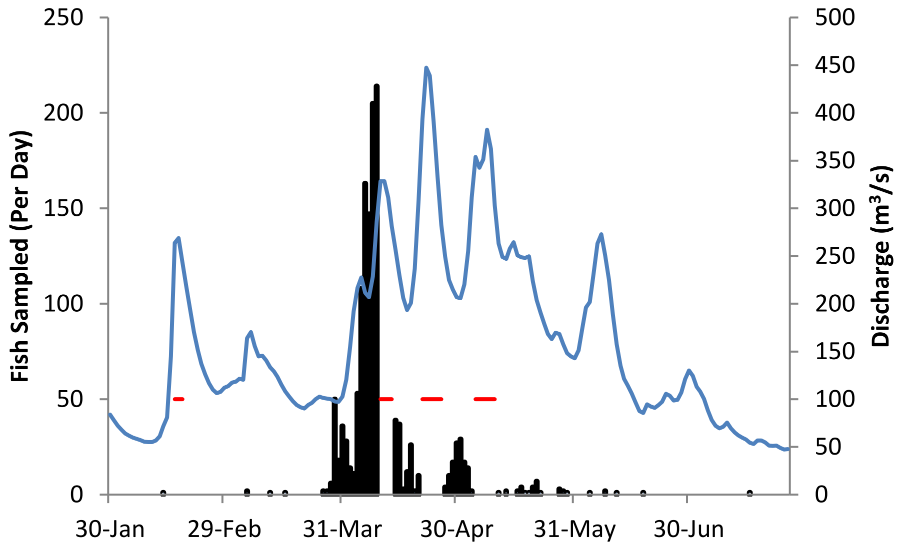

Figure 10. Daily capture of wild sockeye Salmon at the Lower Wenatchee rotary smolt trap. Blue line indicates river discharge and red horizontal line indicates non-trapping period.

Table 6. Age structure and estimated number of wild sockeye smolts that emigrated from Lake Wenatchee in 2013-2015.

Run year	Proportion of Wild Smolts			Total Wild Smolts
	Age 1+	Age 2+	Age 3+	
2013	0.932	0.068	0.00	873,096
2014	0.924	0.076	0.00	1,275,027
2015	0.780	0.220	0.00	1,065,614
2016	NA	NA	NA	208,250

Table 7. Mean fork length (mm) and weight (g) of wild sockeye Salmon smolts sampled at the Lower Wenatchee rotary smolt trap.

	Mean	SD	N
Fork length	81.0	12.1	1,164
Weight	4.7	2.9	1,147

Wild Summer Steelhead

Capture of wild steelhead at the Lower Wenatchee site for all life stages was low, totaling 417 fry, parr, and smolts combined and an estimated 505 collected had the trap operated without interruption. Peak catches of steelhead occurred in July (Figure 11). One mark/recapture trial was conducted using hatchery steelhead transitional/smolts in 2016. When combined with two trials using hatchery steelhead transitional/smolts 2014 a pooled efficiency of 0.028 was used to estimate (95% C.I.) the emigrant population (no fry) at 10,135 (±102,145) parr and smolt emigrant steelhead. If you include fry, the emigrant population was estimated at 18,400 (± 185,447). However, due to the low number of trials, small sample sizes, use of hatchery transitional/smolts surrogates and the relationship not being significant, caution should be used in the interpretation and use of the estimate. Mean length (SE) of transitional/smolts and parr was 159 (29.6) and 83 (24.0) mm, respectively (Table 8).

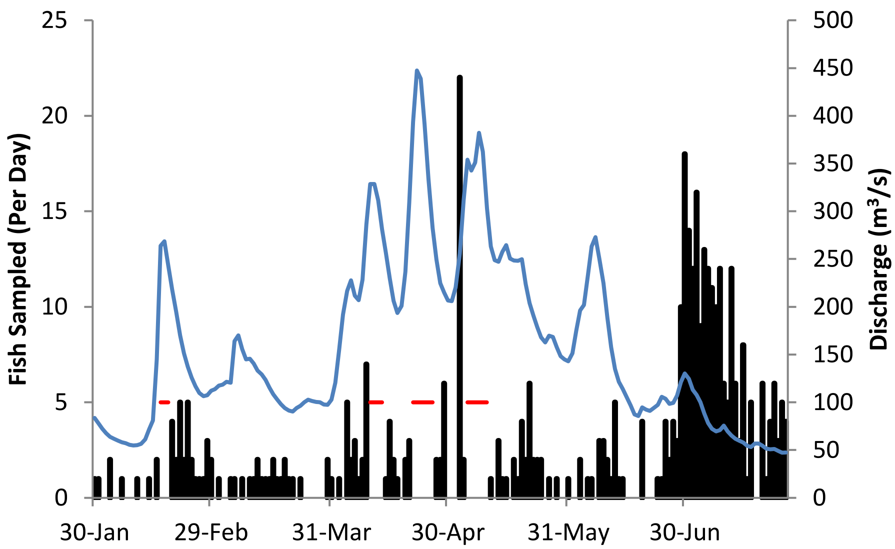

Figure 11. Daily capture of wild steelhead at the Lower Wenatchee rotary smolt trap. Blue line indicates river discharge and red horizontal line indicates non-trapping period.

Table 8. Mean fork length (mm) and weight (g) of wild steelhead sampled at the Lower Wenatchee rotary smolt trap.

	Transitional/Smolt			Parr		
	Mean	SD	N	Mean	SD	N
Fork length	159.4	29.6	66	83.1	24.0	102
Weight	45.7	27.4	66	7.7	6.6	99

Survival

For BY 2014, 885 spring Chinook Salmon redds were surveyed in the Wenatchee Basin producing an estimated 3,894,000 eggs. An estimate of 36,752 emigrants results in an estimated egg-to-emigrant survival of 0.94%. This is down from the last three year average of 1.45% (Table 9).

Table 9. Estimated egg deposition and egg-to-smolt survival rates for Wenatchee Basin spring

Chinook Salmon.

Brood Year	Number of redds	Estimated egg deposition	Estimated number	
			Total emigrants	Egg-to-emigrant survival (%)
2000	350	1,758,050	76,643	4.36
2001	1,876	8,674,624	243,516	2.81
2002	1,139	5,300,906	165,116	3.11
2003	323	1,887,612	70,738	3.75
2004	555	2,663,445	55,619	2.09
2005	829	3,587,083	302,116	8.42
2006	588	2,542,512	85,558	3.37
2007	466	2,069,506	60,219	2.91
2008	1,411	6,479,312	82,137	1.27
2009	--	--	--	--
2010	--	--	--	--
2011	872	3,823,720	89,917	2.35
2012	1,704	7,195,992	67,973	0.94
2013	1,159	5,512,204	58,595	1.06
2014	885	3,894,000	36,752	0.94

For BY 2015, 2,725 summer Chinook Salmon redds were surveyed in the Wenatchee Basin, 95.8% being upstream of the Lower Wenatchee smolt trap. After extrapolating by the proportion of redds above the trap a total emigrant population of 4,023,310 was estimated resulting in an egg-to-emigrant survival of 36.55%. This is down from the last three year average of 83.54% (Table 10).

Table 10. Estimated egg deposition and egg-to-emigrant survival rates for Wenatchee Basin summer Chinook Salmon.

Brood year	Peak total redd expansion	Estimated egg deposition	Redds above trap / total redds	Estimated number		
				Trap estimate	Total emigrants	Egg-to-emigrant survival (%)
1999	2,738	13,654,406	0.988	9,572,392	9,685,591	70.93
2000	2,540	13,820,140	0.983	1,299,476	1,322,383	9.57
2001	3,550	18,094,350	0.987	8,229,920	8,340,342	46.09
2002	6,836	37,488,624	0.977	13,167,855	13,475,368	35.95
2003	5,268	28,241,748	0.996	20,336,968	20,426,149	72.33
2004	4,874	26,207,498	0.989	14,764,141	14,935,745	56.99
2005	3,538	17,877,514	0.993	11,612,939	11,695,581	65.42
2006	8,896	45,663,168	0.979	9,397,044	9,595,512	21.01

Brood year	Peak total redd expansion	Estimated egg deposition	Redds above trap / total redds	Estimated number		
				Trap estimate	Total emigrants	Egg-to-emigrant survival (%)
2007	1,970	10,076,550	0.983	4,470,672	4,546,838	45.12
2008	2,800	14,302,400	0.978	4,309,496	4,405,473	30.8
2009	3,441	18,206,331	0.983	6,695,977	6,814,805	37.43
2010	3,261	16,184,343	0.957	--	--	--
2011	3,078	15,122,214	0.958	--	--	--
2012	2,504	12,021,704	0.93	9,333,214	10,034,508	83.47
2013	3,241	16,162,867	0.947	11,936,928	12,605,925	77.99
2014	3,458	16,556,904	0.959	14,157,778	14,763,064	89.17
2015	2,725	11,491,325	0.958	4,023,310	4,199,697	36.55

Non-target Taxa

No westslope cutthroat trout or bull trout where sampled at the Lower Wenatchee Trap. No PIT tags were applied to non-target taxa. Monthly and annual totals of all fish captured are presented in Appendix G and Appendix H, respectively.

Backpack Electrofishing

Fish Sampling

Between 19 October and 12 November 2015, WDFW personnel sampled the Chiwawa River for a total of 36,782 seconds. During this sampling, a total of 1,103 subyearling Chinook were collected of which 1,054 received a PIT tag. The greatest concentration of juvenile Chinook occurred between rkm 31 and 45 which had a mean sample rate of one Chinook collected for every 24 seconds of sampling. Over the sample period 20 Chinook died resulting in a mortality rate of 1.8%. Additionally, 63 juvenile bull trout were collected and 43 received a PIT tag. Highest catch rates for bull trout were around rkm 47. No mortality was observed for bull trout.

Detections and Calculations

Between the non-trapping season of 25 November 2015 through 1 March 2016, a total of three detections of remotely tagged Chinook were recorded at the lower Chiwawa antenna array. During the 2015 fall (19 October through 24 November) and 2016 spring trapping season (2 March and 30 June), the Chiwawa rotary smolt trap collected 29 and 26 remotely tagged Chinook, respectively. Due to relatively low sample size and poor detection rates at the Chiwawa antenna no emigrant estimate for the non-trapping period was calculated for the BY 2014.

DISCUSSION

Chiwawa River Rotary Smolt Trap

Over the last five years the Chiwawa River smolt trap has had an average installation date of 1 March. With a relatively normal winter the smolt trap was installed on 2 March. However the spring proved to be one of the warmest leading to a record high discharge for much of the spring and very low flows in the fall. In the spring the trap was pulled due to high flow/debris for 22 days and in the fall it was pulled for 47 days due to low flow.

Floods in the fall of 2015 – spring 2016 also caused the substrate to sift and altered the range of flows the Chiwawa River rotary smolt trap is considered operable. New discharge limits are estimated to be between 4.5 and 55.2 m^3/s. For the 2017 field season we will adjust our methodology to allow for sampling during low discharge levels by replacing our 2.4 m smolt trap with a 1.5 m smolt trap as needed.

Due to the assumed change in trap efficiencies associated with a single cone positions and altered substrate new trap efficiency models were developed for subyearling and yearling Chinook. However, a continued reliance upon historic mark/recapture trials for steelhead had to be used. This model will continue to be improved and updated as conditions allow. Historically, emigrant estimates were calculated using the Peterson estimator of abundance (Seber 1982), however more accurate estimates currently utilize a modified Bailey estimator (Murdoch et al. 2012).

The total production estimate for brood year 2014 was 114,680 and comprises estimates of subyearling emigrants in 2015 and yearling emigrants in 2016. Unfortunately, high flows, low antenna detections, and concerns related to spawning bull trout resulted in an abbreviated sampling window and prevented the completion of 2015 remote tagging efforts. This resulted in no estimate being calculated for the 2015 non-trapping season and a known underestimate of the total brood year production. Protocols and field sampling will be continually adapted to fit within environmental and permit constraints and estimates will be improved upon when possible.

Due to the large fall break in trapping historic run timing was used to extrapolate what the catch would have been had the trap been able to operate without interruption. It was estimated 6.5% of subyearling Chinook emigrated during this fall break in trapping so our subyearling Chinook emigrant estimate was adjusted accordingly.

The 2016 field season represented the first year the smolt trap operated with a single cone position. This allowed for a single model to be developed for each life stage and species regardless of when it emigrated, thus removing bias and improving our estimates for subyearling and yearling Chinook. In 2017 we will continue to develop and modify our mark/recapture models paying particular attention to improving our steelhead model.

Lower Wenatchee River Rotary Smolt Trap

Historically, the smolt trap on the mainstem Wenatchee River has moved location numerous times due to poor trap efficiencies of target species and environmental factors causing abbreviated trapping seasons. At the lower Wenatchee site, the smolt trap has been able to operate into September in 2013 and October in 2014. This marks a relatively large increase in operational length over the old site (located 2.5 km downstream) which had an average trap removal date of 14 August. However, since 2014 river discharge and water temperatures have hampered the trapping season for the Lower Wenatchee trap. At this site, the trap is considered operable between discharges of 36.8 and 283.2 m^3/s. In 2016, record high spring discharge resulted in the trap being pulled for 19 days, mostly in April and May. Complicating things further, river temperatures exceeded starting 20°C starting 27 July and trapping operations were again suspended. River temperatures remained elevated and low flow persisted through summer and on 19 August the decision was made to remove the smolt trap. Additionally, mechanical issues hindered catch totals and subsequent emigrant estimates. This was particularly evident when mechanical issues led to only one cone being operable for five days during the peak sockeye emigration. This caused a known underestimate of total catch and emigrant estimate. Overall however, river discharge and temperature continue to be the main issues that impact our trapping season. Adaptive management will be use to ensure maximum efficiency and number of days trapping.

Significant discharge efficiency models were obtained for three of the four target species at the Lower Wenatchee trap during the 2016 trapping season (wild spring and summer Chinook Salmon and sockeye Salmon). Collections of wild steelhead continue to be inadequate for conducting mark–recapture trials. In 2017, hatchery steelhead from the Chiwawa acclimation site will be used in mark/recapture trials in an effort to improve emigrant estimates of this target species. This approach requires the assumption that hatchery fish behave in a similar manner to wild fish, an assumption we will test over time as possible. While the new trap location has allowed for greater operational flexibility, it does require the development of new flow-efficiency models. While this can be accomplished relatively quickly with species that are relatively abundant (e.g., summer Chinook and sockeye), it may take several years for those in low abundance (e.g., steelhead). Fortunately, given similar operation parameters across time, we will be able to reexamine past abundance estimates when those models are fully developed.

Backpack Electrofishing

Remote sampling in the Chiwawa Basin started in 2012. Some success occurred early with PIT tag targets being met, however, there have been substantial obstacles since 2013. Permit restrictions limit field operations until bull trout spawning has concluded; which typically occurs early October. At this time, weather becomes increasingly unfavorable and elevated discharge along with cold air and water temperatures hinder sampling efforts. Since 2014, early high water events hindered sampling efforts and limited not only the area that was sampled, but also the number of fish that were processed. Future investigations will look into alternative sampling techniques and the allocation of personnel to maximize sampling efforts in the basin.

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APPENDICES

Appendix A. Peterson Population and Variance Equations.

Trap efficiency was calculated using the following formula:

Trap efficiency = $E_i = R / Mi,$

Where E_i is the trap efficiency during time period *i*; M_i is the number of marked fish released during time period *i*; and R_i is the number of marked fish recaptured during time period *i*. The number of fish captured was expanded by the estimated daily trap efficiency (*e*) to estimate the daily number of fish migrating past the trap using the following formula:

Estimated daily migration = $\hat{N}_i = C_i / \hat{e}_i$

where N_i is the estimated number of fish passing the trap during time period *i*; C_i is the number of unmarked fish captured during time period *i;* and e_i is the estimated trap efficiency for time period *i* based on the regression equation.

The variance for the total daily number of fish migrating past the trap was calculated using the following formulas:

Variance of daily migration estimate = $$\mathrm{var}\left[\hat{N}_i\right] = \hat{N}_i^2 \frac{\mathrm{MSE}\left(1 + \frac{1}{n} + \frac{\left(X_i - \overline{X}\right)^2}{(n-1)s_X^2}\right)}{\hat{e}_i^2}$$

where X_i is the discharge for time period *i*, and *n* is the sample size. If a relationship between discharge and trap efficiency was not present (i.e., $P < 0.05$; r^2 ⍰0.5), a pooled trap efficiency was used to estimate daily emigration:

Pooled trap efficiency = $e_p = \sum R / \sum M$

The daily emigration estimate was calculated using the formula:

Daily emigration estimate = $\hat{N}_i = C_i / e_p$

The variance for daily emigration estimates using the pooled trap efficiency was calculated using the formula:

Variance for daily emigration estimate = $\mathrm{var}\left[\hat{N}_i\right] = \hat{N}_i^2 \, \frac{e_p(1-e_p)/\sum M}{e_p^2}$

The total emigration estimate and confidence interval was calculated using the following formulas:

Total emigration estimate = $\sum \hat{N}_i$

95% confidence interval = $1.96 \times \sqrt{\sum \mathrm{var}\left[\hat{N}_i\right]}$

Appendix B. Bailey Population and Variance Equations.

Trap efficiency was calculated using the following formula:

Trap efficiency = $E_i = R+1 \ / \ Mi,$

Estimated daily emigration = $\hat{N}_i = \dfrac{C_i + 1}{\hat{e}_i}$

The variance of the total population abundance was calculated as follows:

$$Var\left(\sum_{i=1}^{n} \hat{N}_i\right) = \underbrace{\sum_i Var\left(\frac{(C_i + 1)}{\hat{e}_i}\right)}_{Part\ A} + \underbrace{\sum_i \sum_j Cov\left(\frac{(C_i + 1)}{\hat{e}_i}, \frac{(C_j + 1)}{\hat{e}_j}\right)}_{Part\ B}$$

Part A is the variance of the daily estimates where C_i is the number of fish caught in period *i*, e_i is the estimated trap efficiency for period *i*, and *Cov* is the between day covariance for days that the same linear model is used (part B). For a more details and derivation of Peterson and Bailey estimation methods see Murdoch et al. (2012).

Appendix C. Emigration during non-trapping periods.

A flow-efficiency regression model was developed for the lower Chiwawa River PIT tag interrogation site (CHL) using the same mark/recapture trials used for estimating efficiency at the smolt trap. This CHL model was used to calculate emigration outside of the trapping period by incorporating the tag rate into the Bailey estimator.

$$\text{Estimated daily emigration} = \left(\hat{N}_i = \frac{C_i + 1}{\hat{e}_i}\right) \Big/ t_i$$

Where t_i is equal to the tag rate = $t_i = \frac{t}{p}$

Appendix D: Mark–recapture groups used to developing emigrant estimates. YCW = Yearling spring Chinook wild, YCH = Yearling spring Chinook hatchery, SKW = Sockeye wild, SUCH = summer Chinook wild, SBC = subyearling Chinook wild.

Species	Date	Position	Released	Recaptured	Efficiency (%)	Discharge (m^3/s)
			Lower Wenatchee River rotary smolt trap			
YCW	20-Mar-13	Low	223	5	2.24	88.2
YCW	05-Apr-13	Low	216	4	1.85	211.6
YCW	09-Apr-13	Low	186	3	1.61	187.2
YCW	13-Mar-14	Low	156	2	1.28	121.8
YCW	21-Mar-14	Low	243	4	1.65	102.8
YCW	31-Mar-14	Low	306	9	2.94	82.9
YCW	14-Apr-14	Low	165	4	2.42	127.6
YCH	17-Apr-15	Low	2,045	82	4.01	63.1
SKW	27-Apr-13	Low	565	6	1.06	141.6
SKW	31-Mar-14	Low	322	1	0.31	83.1
SKW	04-Apr-14	Low	599	2	0.33	81.7
SKW	07-Apr-14	Low	633	2	0.32	99.6
SKW	16-Apr-14	Low	591	3	0.51	126.2
SKW	19-Apr-14	Low	385	4	1.04	130.4
SKW	23-Apr-14	Low	504	2	0.40	125.5
SKW	12-Apr-15	Low	540	2	0.37	73.9
SUCH	14-May-14	Low	521	3	0.58	236.4
SUCH	20-May-14	Low	999	5	0.50	289.5
SUCH	27-May-14	Low	1,039	4	0.38	263.3
SUCH	31-May-14	Low	1,129	17	1.51	223.4
SUCH	05-Jun-14	Low	993	3	0.30	287.9
SUCH	08-Jun-14	Low	1,023	5	0.49	259.8
SUCH	16-Jun-14	Low	911	6	0.66	182.2
SUCH	19-Jun-14	Low	960	13	1.35	175.4
SUCH	07-Jul-14	Low	931	13	1.40	153.8
SUCH	11-Jul-14	Low	511	6	1.17	125.0
SUCH	17-Jul-14	Low	407	7	1.72	105.8
SUCH	20-Jul-14	Low	448	4	0.89	91.1
SUCH	24-Jul-14	Low	364	4	1.10	74.4
SUCH	03-Apr-15	Low	540	5	0.93	114.7
SUCH	07-Apr-15	Low	1,170	44	3.76	88.1
SUCH	10-Apr-15	Low	755	13	1.72	76.5

Species	Date	Position	Released	Recaptured	Efficiency (%)	Discharge (m^3/s)
SUCH	23-Apr-15	Low	1,035	17	1.64	99.4
SUCH	22-May-15	Low	974	12	1.23	159.5
SUCH	28-May-15	Low	1,109	3	0.27	164.6
SUCH	25-May-16	Low	1,051	10	0.95	171.5
SUCH	02-Jun-16	Low	1,071	22	2.05	167.6
SUCH	11-Jun-16	Low	685	11	1.61	85.1
		Chiwawa River rotary smolt trap				
YCW	06-Mar-16	Upper	132	15	11.36	14.7
YCW	09-Mar-16	Upper	106	12	11.32	15.8
YCW	12-Mar-16	Upper	126	14	11.11	15.1
YCW	02-Apr-16	Upper	178	11	6.18	22.7
YCW	04-Apr-16	Upper	240	13	5.42	34.4
SBC	16-Jun-16	Upper	265	21	7.92	17.6
SBC	26-Jun-16	Upper	241	32	13.28	17.7
SBC	01-Jul-16	Upper	326	34	10.43	24.9
SBC	07-Jul-16	Upper	246	34	13.82	14.5
SBC	11-Jul-16	Upper	80	13	16.25	14.0
SBC	27-Jul-16	Upper	101	22	21.78	12.1
SBC	04-Aug-16	Upper	209	96	45.93	8.2
SBC	10-Aug-16	Upper	162	51	31.48	6.5
SBC	12-Oct-16	Upper	199	73	36.68	5.7
SBC	17-Oct-16	Upper	185	37	20.00	10.9
SBC	28-Oct-16	Upper	200	22	11.00	16.8
SBC	04-Nov-16	Upper	156	17	10.90	11.8

Appendix E. Monthly collection information for the Chiwawa River rotary smolt trap.

	2016											
Species/Origin	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Total**
Chinook												
Wild												
Yearling	--	--	1,252	1,202	324	27	2	0	0	0	0	2,807
Subyearling	--	--	1,662	985	256	1,863	3,557	2,856	611	3,725	878	16,393
Hatchery	--	--	0	2,523	2	0	0	0	0	0	0	2,525
Steelhead												
Wild												
Smolt	--	--	8	56	46	44	8	16	16	1	0	195
Parr and fry	--	--	21	178	439	201	115	140	101	316	11	1,522
Hatchery	--	--	0	2	1,505	10	0	1	0	0	0	1,518
Coho												
Wild												
Smolt	--	--	0	0	0	0	0	0	0	0	0	0
Parr and fry	--	--	0	0	3	0	0	0	0	0	0	3
Hatchery	--	--	0	0	0	0	0	0	0	0	0	0
Bull trout												
Juvenile	--	--	0	3	2	1	0	4	9	71	13	103
Adult	--	--	1	0	0	2	1	0	7	4	0	15
Westslope cutthroat trout	--	--	0	0	5	13	6	14	4	1	0	43
Eastern brook trout	--	--	0	0	1	1	0	0	0	0	1	3
Rainbow trout	--	--	0	0	0	0	0	0	0	0	0	0
Mountain whitefish	--	--	14	1	6	6	211	570	6	25	44	883
Longnose dace	--	--	5	19	51	213	57	122	388	111	13	979
Northern pikeminnow	--	--	0	0	0	1	26	42	0	0	0	69
Sculpin spp.	--	--	7	5	12	16	21	15	4	9	5	94
Sucker spp.	--	--	0	0	0	0	1	1	0	1	0	3
Dace spp.	--	--	0	5	3	0	1	6	0	0	1	16
Yellow Perch	--	--	0	0	0	0	0	1	0	0	0	1
Redside shiner	--	--	0	0	0	0	0	0	0	0	0	0

Appendix F. Annual collection information from the Chiwawa River rotary smolt trap.

Species origin	2016	2015	2014	2013	2012	2011
Chinook						
Wild						
Yearling	2,807	6,350	5,419	3,199	7,626	4,848
Subyearling	16,393	31,152	23,755	27,621	14,831	20,561
Hatchery	2,525	7,162	5,293	15,909	30,751	25,620
Steelhead						
Wild						
Smolt	195	259	49	85	183	195
Parr and Fry	1,522	3,004	1,889	1,949	1,738	981
Hatchery	1,518	3,151	290	1,539	1,664	8,250
Coho						
Wild						
Smolt	0	0	0	1	1	3
Parr and fry	3	38	12	0	0	4
Hatchery	0	0	1	10	3	0
Bull trout						
Juvenile	103	266	260	310	488	351
Adult	15	32	75	51	31	7
Westslope cutthroat trout	43	72	59	86	60	38
Eastern brook trout	3	8	12	13	66	3
Mountain whitefish	883	5,544	2,970	2,108	3,291	990
Longnose dace	979	2,663	2,633	2,257	1,762	1,526
Northern pikeminnow	69	331	5	71	34	20
Sculpin spp.	94	225	131	91	157	129
Sucker spp.	3	30	4	6	0	0
Dace spp.	16	NA	NA	NA	NA	NA
Redside shiner	0	13	0	0	0	0
Yellow perch	1	0	0	0	0	0

Appendix G. Monthly collection information for the Lower Wenatchee River rotary smolt trap.

	2016											
Species/Origin	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Total**
Chinook												
Wild												
Yearling	4	194	166	141	69	23	13	--	--	--	--	610
Subyearling	10	148	1,752	8,338	7,612	8,677	870	--	--	--	--	27,407
Hatchery	1,858	3,197	37	2,538	69	2	0	--	--	--	--	7,701
Steelhead												
Wild												
Smolt	0	7	3	29	43	5	1	--	--	--	--	88
Parr and fry	2	28	20	15	11	62	191	--	--	--	--	329
Hatchery	0	0	0	101	146	12	0	--	--	--	--	259
Sockeye												
Wild	0	1	118	1,130	91	5	1	--	--	--	--	1,346
Coho												
Wild												
Smolt	0	7	2	0	0	1	0	--	--	--	--	10
Fry and parr	0	45	13	11	18	36	12	--	--	--	--	135
Hatchery	0	0	0	0	212	7	0	--	--	--	--	219
Unknown	0	0	5	1,776	829	17	3	--	--	--	--	2,630
Bull trout												
Juvenile	0	0	0	0	0	0	0	--	--	--	--	0
Adult	0	0	0	0	0	0	0	--	--	--	--	0
Westslope cutthroat trout	0	0	0	0	0	0	0	--	--	--	--	0
Mountain whitefish	0	0	2	7	3	3	0	--	--	--	--	15
Lamprey spp.	35	162	343	89	286	397	185	--	--	--	--	1,497
Longnose dace	1	23	11	28	17	39	44	--	--	--	--	163
Sculpin spp.	1	5	6	7	8	10	19	--	--	--	--	56
Sucker spp.	2	23	14	49	79	86	16	--	--	--	--	269
Dace spp.	1	3	20	25	32	37	15	--	--	--	--	133
Fathead minnow	0	0	0	3	5	0	1	--	--	--	--	9
Redside shiner	0	1	2	1	69	90	26	--	--	--	--	189
Stickleback (3-spined)	0	0	0	0	2	0	0	--	--	--	--	2
Northern pikeminnow	0	11	7	54	181	274	25	--	--	--	--	552
Chiselmouth	0	0	0	1	2	57	6	--	--	--	--	66
Peamouth	0	0	0	0	0	0	0	--	--	--	--	0

Appendix H. Annual collection information from the Lower Wenatchee River rotary smolt trap.

Species/Origin	2016	2015	2014	2013
Chinook				
Wild				
Yearling	610	1,559	1,700	1,854
Subyearling	27,407	252,293	81,445	52,652
Hatchery	7,701	9,920	31,290	13,979
Steelhead				
Wild				
Smolt	88	231	80	173
Parr	329	100	102	537
Hatchery	259	2,288	494	819
Sockeye				
Wild	1,346	4,178	7,678	4,520
Hatchery	0	0	0	72
Coho				
Wild				
Smolt	10	22	220	597
Fry and parr	135	4,972	393	923
Hatchery	219	6,566	16,908	12,960
Unknown	2,630	143	NA	NA
Bull trout				
Juvenile	0	0	3	6
Adult	0	0	0	0
Westslope cutthroat trout	0	1	3	0
Mountain whitefish	15	9	27	110
Lamprey spp.	1,497	283	292	762
Longnose dace	163	242	541	1,382
Sculpin spp.	56	52	128	242
Sucker spp.	269	51	134	240
Redside shiner	189	19	94	423
Stickleback (3-spined)	2	13	66	196
Dace spp.	133	NA	NA	NA
Fathead minnow	9	NA	NA	NA
Northern pikeminnow	552	12	37	39
Chiselmouth	66	6	69	10
Peamouth	0	3	9	10

Appendix C

Summary of PIT-Tagging Activities in the Wenatchee Basin, 2016

Appendix C. Numbers of fish captured, recaptured, PIT tagged, trap and hand mortality, shed tags, and total tags released in the Wenatchee River basin during January through November, 2016.

Sampling Location	Species and Life Stage	Number collected	Number of recaptures	Number tagged	Number died	Shed tags	Total tags released	Percent mortality
Chiwawa Trap	Wild Subyearling Chinook	16,393	89	7,355	82	1	7354	0.50
	Wild Yearling Chinook	2,807	79	2,729	4	3	2,729	0.14
	Wild Steelhead/Rainbow	1,717	18	1,323	10	10	1,313	0.58
	Hatchery Steelhead/Rainbow	1,518	0	1	0	0	1	0.00
	Wild Coho	3	0	0	0	0	0	0.00
	Total	22,438	186	11,408	96	14	11,397	0.43
Chiwawa Remote (Electrofishing)	Wild Subyearling Chinook	1,829	24	1,776	5	0	1,776	0.27
	Wild Yearling Chinook	0	0	0	0	0	0	0.00
	Wild Steelhead/Rainbow	0	0	0	0	0	0	0.00
	Hatchery Steelhead/Rainbow	0	0	0	0	0	0	0.00
	Wild Coho	0	0	0	0	0	0	0.00
	Total	1,829	24	1,776	5	0	1,776	0.27
Nason Creek Trap	Wild Subyearling Chinook	791	48	434	6	0	434	0.76
	Wild Yearling Chinook	61	4	61	0	0	61	0.00
	Wild Steelhead/Rainbow	1,007	6	531	1	1	530	0.10
	Hatchery Steelhead/Rainbow	98	7	0	0	0	0	0.00
	Wild Coho	6	0	6	0	0	6	0.00
	Total	1,963	65	1,032	7	1	1,031	0.36
Nason Creek Remote (Electrofishing)	Wild Subyearling Chinook	828	10	802	14	0	802	1.69
	Wild Yearling Chinook	0	0	0	0	0	0	0.00
	Wild Steelhead/Rainbow	0	0	0	0	0	0	0.00
	Hatchery Steelhead/Rainbow	0	0	0	0	0	0	0.00
	Wild Coho	0	0	0	0	0	0	0.00
	Total	828	10	802	14	0	802	1.69
White River Trap	Wild Subyearling Chinook	197	3	137	2	1	136	1.02
	Wild Yearling Chinook	3	0	3	0	0	3	0.00
	Wild Steelhead/Rainbow	5	0	5	0	0	5	0.00
	Hatchery Steelhead/Rainbow	0	0	0	0	0	0	0.00
	Wild Coho	0	0	0	0	0	0	0.00
	Total	205	0	145	2	1	144	0.98
Lower Wenatchee Trap	Wild Subyearling Chinook	27,407	38	18	184	0	18	0.67
	Wild Yearling Chinook	610	4	538	2	0	538	0.33
	Wild Steelhead/Rainbow	417	0	131	6	0	131	1.44
	Hatchery Steelhead/Rainbow	259	0	0	1	0	0	0.39
	Wild Coho	145	0	0	0	0	0	0.00
	Unknown Coho	2,630	0	2	3	0	2	0.11
	Wild Sockeye	1,346	1	1,065	64	0	1,065	4.75

Sampling Location	Species and Life Stage	Number collected	Number of recaptures	Number tagged	Number died	Shed tags	Total tags released	Percent mortality
	Total	32,814	43	1,754	260	0	1,754	0.79
Total:	**Wild Subyearling Chinook**	47,445	212	10,522	293	2	10,520	0.62
	Wild Yearling Chinook	3,481	87	3,331	6	3	3,331	0.17
	Wild Steelhead/Rainbow	3,146	24	1,990	17	11	1,979	0.51
	Hatchery Steelhead/Rainbow	1,875	7	1	1	0	1	0.05
	Wild Coho	154	0	6	0	0	6	0.00
	Unknown Coho	2,630	0	2	3	0	2	0.11
	Wild Sockeye	1,346	1	1,065	64	0	1,065	4.75
Grand Total:		60,077	331	16,917	384	16	16,904	0.64

Appendix D

Wenatchee Steelhead Spawning Escapement Estimates, 2016

Estimates of Wenatchee Steelhead Spawners in 2016

Kevin See

January 06, 2017

Introduction

Redd counts are an established method to provide an index of adult spawners (Gallagher et al. 2007). In the Wenatchee and Methow subbasins, index reaches are surveyed weekly during the steelhead spawning season (Mar 07, 2016 - May 26, 2016) and non-index reaches are surveyed once during the peak spawning period. The goal of this work is to:

- Predict observer net error, based on a model developed with data from steelhead redd surveys in the Methow, similar to that described in Murdoch et al. (2014).
- Use estimates of observer net error rates and the mean survey interval to estimate the number of redds in each index reach, using a Gaussian area under the curve (GAUC) technique described in Millar et al. (2012).
- Estimate the total number of redds in the non-index reaches by adjusting the observed counts with the estimated net error.
- Convert these estimates of redds in the mainstem areas (surveyed for redds) into estimates of spawners.
- Use PIT-tag based estimates of escapement for all tributaries in the Wenatchee, and combine those estimates with the redd-based estimates of spawners in the mainstem areas to estimate the total number of spawners in the Wenatchee.

Methods

Mainstem areas

The model for observer net error (observed redd counts / true number of redds) is a model averaging of the 2 best models that were fit to 43 data points in the Methow. Both models contained covariates of observed redd density (redds / m) and mean thalweg CV as a proxy for channel complexity. One model also contained discharge while the other also contained total redd survey experience as an additional covariate. Predictions were made using model averaged coefficients (based on AICc model weights) and the 2016 steelhead data. From these survey specific estimates of net error, a mean and standard error of net error was calculated for each reach. The standard deviation was calculated by taking the square root of the sum of the squared standard errors for all predictions within a reach.

Estimates of total redds were made for each index reach using the GAUC model described in Millar et al. (2012). The GAUC model was developed with spawner counts in mind. As it is usually infeasible to mark every individual spawner, only total spawner counts can be used, and an estimate of average stream life must be utilized to translate total spawner days to total unique spawners. However, in adapting this for redd surveys, two modification could be used. The first would fit GAUC models to data showing all visible redds at each survey, and use an estimate of redd life as the equivalent of spawner stream life. However, because conditions can lead to many redds not disappearing before the end of the survey season, the estimates of redd life can be biased low. The second method relies on the fact that individual redds can be marked, and therefore the GAUC model can be fit to new redds only. The equivalent of stream life thus became the mean and standard deviation of the survey interval. We utilized the second method for this analysis.

For non-index reaches, which were surveyed only once during peak spawning, the estimate of total redds was calculated by dividing the observed redds by the estimate of net error associated with that survey. This assumes that no redds were washed out before the non-index survey, and that no new redds appeared after that survey. As the number of redds observed in the non-index reaches ranged from 0 to 3, any violoation of this assumption should not affect the overall estimates very much. Based on the peak spawning time for the associated index reaches, the surveys in the non-index reaches were conducted either at peak spawning, or within 10 days after peak spawning (Figure 2}).

To convert estimates of total redds into estimates of natural and hatchery spawners, total redds were multiplied by a fish per redd (FpR) estimate and then by the proportion of hatchery or wild fish. The fish per redd estimate was based on PIT tags from the branching patch-occupany model (see below) observed to move into the lower or upper Wenatchee (below or above Tumwater dam). FpR was calculated as the ratio of male to female fish, plus 1. This was 1.65 above Tumwater dam, and 1.61 below Tumwater. Reaches W1 - W7 are below Tumwater, while reaches W8 - W10 are above Tumwater. Similarly, the proportion of hatchery and natural origin fish was calculated from the same group of PIT tags for areas above and below Tumwater. The proportion of hatchery origin fish was 0.45 above Tumwater dam, and 0.35 below Tumwater (Table 2).

Tributary areas

Esimates of escapement to various tributaries in the Wenatchee were made using a branching patch-occupancy model (Waterhouse, L. et al., *in prep*) based on PIT tag observations of fish tagged at Priest Rapids dam. All fish that escaped to the various tributaries were assumed to be spawners (i.e. pre-spawn mortality only occurs in the mainstem).

Total spawners

When summing spawner estimates from index reaches to obtain estimates of total spawners in the Wenatchee, an attempt was made to incorporate the fact that the reaches within a stream are not independent. Estimates of correlation between the reaches within a stream were made based on weekly observed redds. Because correlations are often quite high between reaches, this is a better alternative than to naively assume the standard errors between reaches are independent of one another. These estimates of correlation were combined with estimates of standard error for each index reach to calculate a covariance matrix for the Wenatchee index reaches (W6, W8, W9, W10), which was used when summing estimates of spawners to estimate the total standard error. Failure to incorporate the correlations between reaches would result in an underestimate of standard error at the population scale. Non-index reaches were only surveyed once, so it is impossible to estimate a correlation coefficient between non-index reaches and index reaches. Therefore, they were assumed to be independent from the index reachs when summing the estimates of spawners. Because the estimates of tributary spawners were made separately (see above), they were also treated as independent when summing spawner estimates. The uncertainty in each step was carried through the entire analysis via the delta method (Casella and Berger 2002).

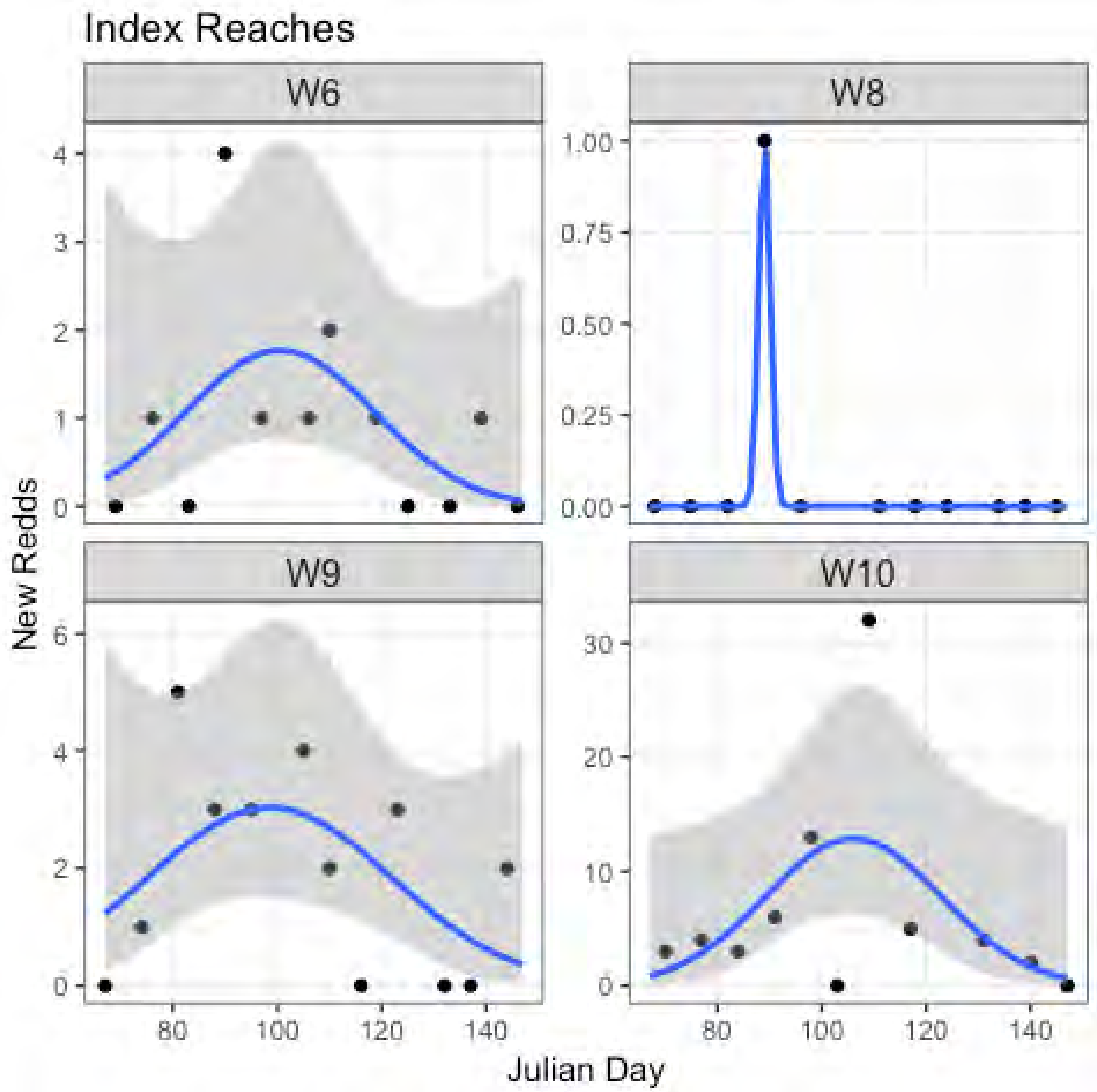
Results

Redd estimates

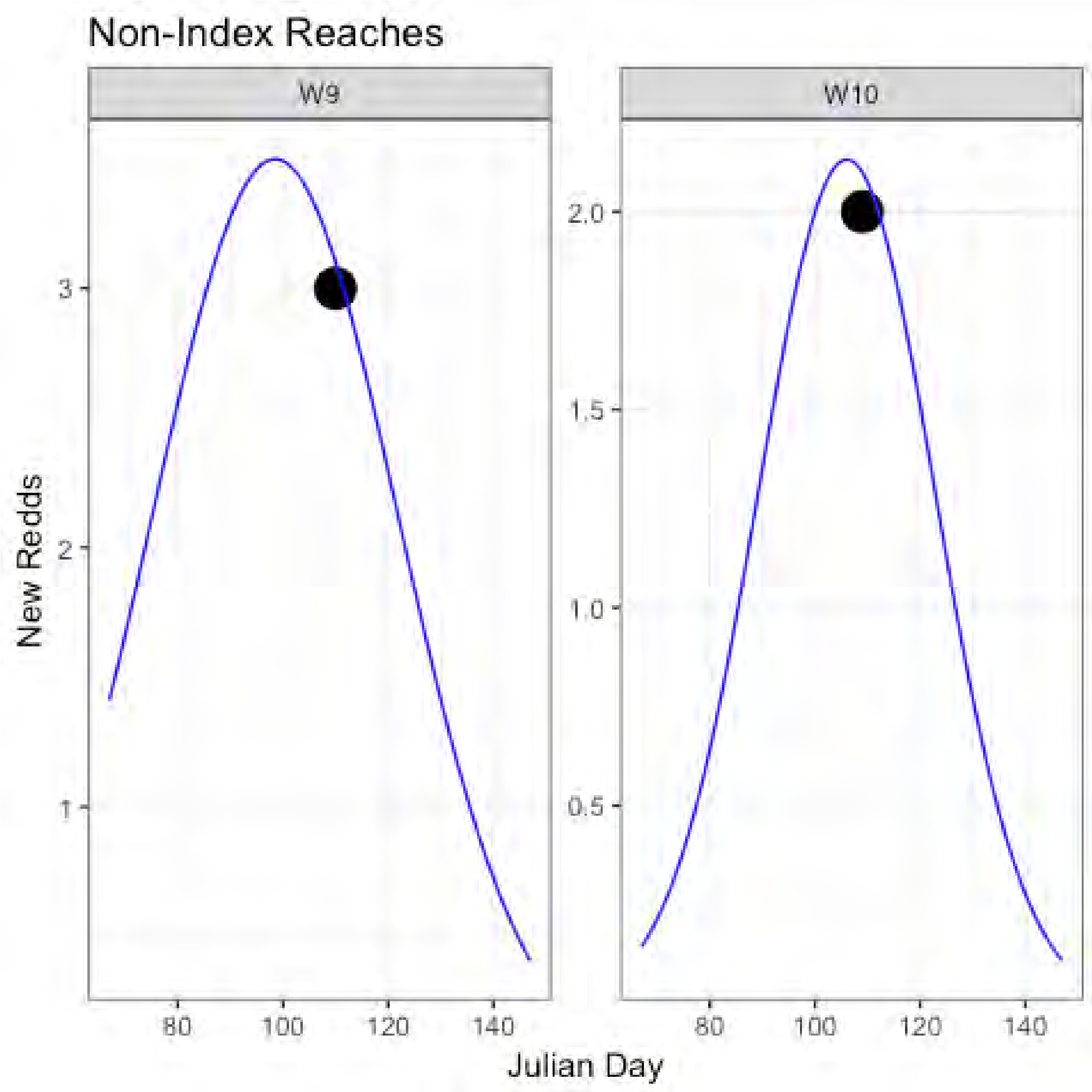
It should be noted that the GAUC parameters from index reaches were not used to estimate total redds in the associated non-index reaches. Figure 4 does illustrate that the non-index reach surveys were conducted close to the period of peak spawning (as determined by the associated index reaches), thus helping to validate the assumptions that go into estimating total redds in non-index reaches.

Table 1: Estimates of mean net error and total redds for each reach.

Reach	Type	Index.Reach	Net.Error	Net.Error.CV	Redds.Counted	Redds.Est	Redds.CV
C1	Index	-	NA	NA	0	0	NA
N1	Index	-	NA	NA	0	0	NA
P1	Index	-	NA	NA	0	0	NA
P1	Non-Index	NA	NA	NA	0	0	NA
W1	Non-Index	W2	NA	NA	0	0	NA
W2	Index	-	0.91	1.98	0	0	NA
W3	Non-Index	W2	NA	NA	0	0	NA
W4	Non-Index	W6	NA	NA	0	0	NA
W5	Non-Index	W6	NA	NA	0	0	NA
W6	Index	-	1.01	1.36	11	11	1.42
W6	Non-Index	W6	1.28	0.52	0	0	NA
W8	Index	-	0.85	1.47	1	1	0.59
W9	Index	-	0.93	1.46	23	26	1.48
W9	Non-Index	W9	0.99	0.42	3	3	0.42
W10	Index	-	0.84	1.31	72	82	1.39
W10	Non-Index	W10	0.66	0.34	2	3	0.34
Total	NA	NA	NA	NA	112	126	1.04



Plots of observed redd counts (black dots) through time for each index reach, and the fitted curve from the GAUC model (blue line) with associated uncertainty (gray).



Observed redd counts for non-index reaches with non-zero peak redd counts. The blue curve shows the GAUC estimated spawning curve, demonstrating how close to peak spawning the non-index surveys were conducted.

Spawner estimates

Table 2: Fish per redd and hatchery / natural origin proportion estimates.

Area	Fish/redd	FpR Std. Error	Prop. Hatchery	Prop Std. Error
Above TUF	1.652	0.070	0.447	0.036
Below TUF	1.613	0.084	0.347	0.043

Table 3: Estimates (CV) of spawners by area and origin.

Area	Type	Hatchery	Natural
Little Wenatchee	Trib	0 (--)	0 (--)
White River	Trib	0 (--)	8 (0.8)
C1	Index	0 (--)	0 (--)
Chiwaukum	Trib	11 (1)	64 (0.36)
Chiwawa	Trib	134 (0.35)	45 (0.44)
Chumstick	Trib	39 (0.37)	74 (0.27)
Icicle	Trib	18 (0.53)	72 (0.25)
Mission	Trib	13 (0.69)	33 (0.38)
N1	Index	0 (--)	0 (--)
Nason	Trib	94 (0.32)	57 (0.39)
P1	Index	0 (--)	0 (--)
P1	Non-Index	0 (--)	0 (--)
Peshastin	Trib	0 (--)	151 (0.19)
W1	Non-Index	0 (--)	0 (--)
W10	Index	61 (1.39)	75 (1.39)
W10	Non-Index	2 (0.35)	3 (0.35)
W2	Index	0 (--)	0 (--)
W3	Non-Index	0 (--)	0 (--)
W4	Non-Index	0 (--)	0 (--)
W5	Non-Index	0 (--)	0 (--)
W6	Index	6 (1.43)	12 (1.42)
W6	Non-Index	0 (--)	0 (--)
W8	Index	1 (0.6)	1 (0.6)
W9	Index	19 (1.48)	24 (1.48)
W9	Non-Index	2 (0.43)	3 (0.42)
Total		400 (0.31)	621 (0.25)

Discussion

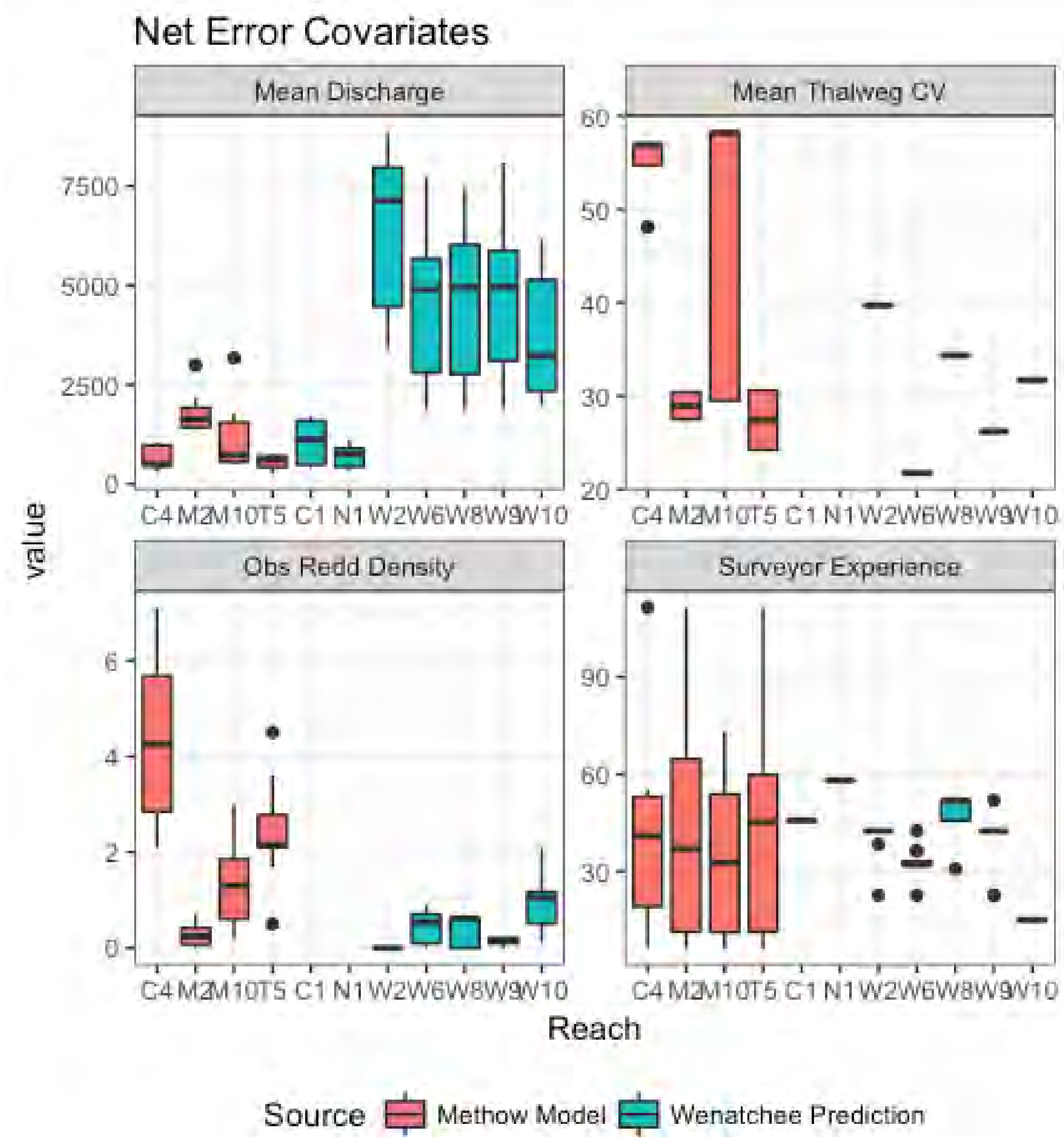
We have estimated the number of steelhead redds based on redd surveys, while incorporating potential observation error. After translating these to estimates of spawners by origin, we can then compare the spawner estimates to escapement estimates made using PIT tags, and estimate a pre-spawn mortality rate (Table 4). Taking the total PIT-tag based escapement estimate to the Wenatchee (after subtracting the 327 hatchery and 66 wild fish removed at Tumwater, as well as the 27 hatchery fish removed at Dryden, and the 56 and 8 deaths to hatchery and wild fish due to harvest), and subtracting the total estimate of spawners, including the tributaries, then dividing by the total escapement estimate provides an estimate of pre-spawn mortality across the entire Wenatchee population. We did this for natural and hatchery origin fish, and found that natural fish had a higher pre-spawn mortality rate this year.

Table 4: Wenatchee pre-spawn mortality rates.

Origin	Pre-spawn_Mort	CV
Natural	0.26	0.0009
Hatchery	0.09	0.0077

Caveats

The predictions of surveyor net error were made using a model that had been fit to data in the Methow. Most covariates in the Wenatchee were within the range of values in the Methow study, but mean discharge was higher in all reaches in the Wenatchee than in the modeled reaches in the Methow (Figure 3). The mean discharge in the Methow study was 1069.2, while it was 3837.5 in the Wenatchee reaches in 2016. That difference alone would change net error predictions by 0.5, not an insignificant amount. However, the observed covariate values in the Wenatchee did not lead to unrealistic estimates of net error. The ranges of net error estimates for the Methow study and the Wenatchee in 2016 were very similar.



Net error covariate values from the study in the Methow and the predicted reaches in the Wenatchee.

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Appendix E

Genetic Diversity of Wenatchee Summer Steelhead

Examining the Genetic Structure of Wenatchee Basin Steelhead and Evaluating the Effects of the Supplementation Program

Developed for

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17 January 2012

Table of Contents

Table of Contents 2
Executive Summary 3
Introduction 5
Materials and methods 7
  Sample collections 7
  Sample processing 8
  Evaluation of loci 9
  Allele frequencies, genetic distances and population differentiation 10
  Effective spawning population 11
Results and Discussion 13
    Collections and samples received 13
    Evaluation of loci 13
  Objective 3.1, 3.2 – Allele frequencies and Genetic distances 14
    Allele frequencies 14
    Analysis of Molecular Variance 14
    Pair-wise F_{ST} estimates 14
    Principal Components 16
  Objective 3.3 – Effective spawning population 18
  Summary 19
Acknowledgements 20
Literature Cited 21
Figures 25
Tables 38

Executive Summary

In 1997, Wenatchee River summer steelhead, as part of the upper Columbia River evolutionarily significant unit (ESU), were listed as threatened under the Endangered Species Act (ESA). To address concerns about effects of hatchery supplementation, the hatchery program for hatchery produced (HOR) summer steelhead to be planted in the Wenatchee River changed from using mixed ancestry broodstock collected in the Columbia River to using Wenatchee River broodstock collected in the Wenatchee River. Three monitoring and evaluation (M&E) indicators were developed to measure the genetic effects of hatchery production on wild fish populations. To address these indicators, temporal collections of tissue samples from Wenatchee River hatchery-produced (HOR) and natural origin (NOR) adults captured and sampled at Dryden and Tumwater dams and from NOR juveniles from three Wenatchee River tributaries and the Entiat River were surveyed for genetic variation with 132 genetic (SNPs) markers. Peshastin Creek (a Wenatchee River tributary) and the Entiat River served as no-hatchery-outplant controls, meaning they have stopped receiving HOR juvenile outplants. As per the M&E plan, we interrogated these data for the presence or absence of spatial and temporal trends in allele frequencies, genetic distances, and effective population size.

Allele frequencies – Changes to the summer steelhead hatchery supplementation program had no detectable effect on genetic diversity of wild populations. On average, HOR adults had higher minor allele frequencies (MAF) than NOR adults, which may simply reflect the mixed ancestry of HOR adults. Both HOR and NOR adults had MAF similar to juveniles collected in spawning tributaries and in the Entiat River. There was no temporal trend in allele frequencies or observed heterozygosity in adult or juvenile collections and allele frequencies in control populations were no different than those still receiving hatchery outplants. This suggests that the hatchery program has had little effect on allele frequencies since broodstock sources changed in 1998.

Genetic distances – As intended, interbreeding of Wenatchee River HOR and NOR adults reduced the genetic differences between Wells Hatchery HOR adults and Wenatchee River NOR adults observed in the first few years after changing the broodstock collection protocol. Though there were detectable genetic differences between HOR and HOR adults, the magnitude of that difference declined over time. HOR adults were genetically quite different from NOR adults and juveniles based on pair-wise F_{ST} and principal components analysis (PCA), most likely because of the much smaller effective population size (N_b) in the hatchery population (see below). Pair-wise F_{ST} estimates and genetic distances between HOR and NOR adults collected the same year declined over time suggesting that the interbreeding of HOR and NOR adults in the hatchery (and presumably in the wild) is slowly homogenizing Wenatchee River summer steelhead. Analyses using brood year (the year fish were hatched, determined using scale-based age estimates) were inconclusive because of limitations of the data.

Effective population size (N_b) – Although the effective population size of the Wenatchee River hatchery summer steelhead program was consistently small, it does not appear to have caused a reduction in the effective population size of wild populations. On average, estimates of N_b were much lower and varied less for HOR adults than for NOR adults and juveniles. Estimates of N_b for HOR adults declined from the earliest brood years to a stable new low value after broodstock practices were changed in 1997. There was no indication that this had any effect on N_b in NOR adults and juveniles; N_b estimates for NOR adults and juveniles were, on average, higher and varied considerably over the time period covered by our dataset (1998 – 2010) and showed no temporal trend.

Introduction

The National Marine Fisheries Service (NMFS) recognizes 15 Evolutionary Significant Units (ESU) for west coast steelhead (*Oncorhynchus mykiss*). The Upper Columbia ESU, which contains steelhead in the Wenatchee Basin, was listed as endangered under the Endangered Species Act (ESA) in 1997. Included in this listing were the Wells hatchery steelhead (program initiated in the late 1960s) that originated from a mixed group of native steelhead and are considered to be genetically similar to natural spawning populations above Wells Dam. Juvenile steelhead from Wells Fish Hatchery was the primary stock released into the Wenatchee River (Murdoch et al. 2003). The 1998 steelhead status review identified several areas of concern for this ESU including the risk of genetic homogenization due to hatchery practices and the high proportion (65% for the Wenatchee River) of hatchery fish present on the spawning grounds (Good et al. 2005). The Biological Review Team (BRT) further identified the relationship between the resident and anadromous forms of *O. mykiss* and possible changes in the population structure ('genetic heritage of the naturally spawning fish') in the basin as two areas requiring additional study. Furthermore, the West Coast Steelhead BRT (2003) recommended that stocks in the Wenatchee, Entiat, and Methow rivers, within the Upper Columbia ESU, be managed as separate populations.

A review of the presence of resident *O. mykiss* in the Upper Columbia ESU (Good et al. 2005) shows that rainbow trout are relatively abundant in upper Columbia River tributaries currently accessible to steelhead as well as in upriver tributaries unavailable to anadromous access by Chief Joseph and Grand Coulee dams (Kostow 2003). U.S. Fish and Wildlife Service (USFWS) biologists surveyed the abundance of trout and steelhead juveniles in the Wenatchee, Entiat, and Methow river drainages in the mid-1980s and found adult trout (defined as those with fork length > 20 cm) in all basins (Mullan et al. 1992). The results also supported the hypothesis that resident *O. mykiss* are more abundant in tributary or mainstem areas upstream of the areas used by steelhead for rearing. No samples of rainbow trout from the Wenatchee were available for this study.

In addition to the mixed ancestry Wells Hatchery steelhead, Skamania Hatchery (Washougal River steelhead ancestry) steelhead were also released into the Wenatchee River basin for several years in the late 1980s (L. Brown, Washington Dept. of Fish and Wildlife [WDFW], personal communication). In 1996, broodstock for the Wenatchee River steelhead program were collected from Priest Rapids Dam and Dryden (rkm 24.9) and Tumwater (rkm 52.6) dams on the Wenatchee River. Because of the ESA listing, broodstock collection after 1996 was restricted to the Wenatchee River in an effort to develop a localized broodstock (Murdoch et al. 2003). Thus, starting in 1998, all juvenile steelhead released into the Wenatchee River and Wenatchee River tributaries were offspring of only Wenatchee River captured broodstock.

In response to the need for evaluation of the supplementation program, both a monitoring and evaluation plan (Murdoch and Peven 2005) and the associated analytical framework (Hays et al. 2006) were developed for the Habitat Conservation Plans Hatchery Committee through the joint effort of the fishery co-managers (Confederated Tribes of the Colville Reservation [CCT], NMFS, USFWS, WDFW, and Yakama Nation [YN]) and Chelan County, Douglas County, and Grant County Public Utility Districts (PUD). These reports outline 10 objectives to be applied to various species assessing the impacts of hatchery operations mitigating the operation of Rock Island and Rocky Reach Dams. This report pertains to Wenatchee River basin steelhead (*O. mykiss*) and the steelhead supplementation program as addressed by objective 3, specifically the first three evaluation indicators.

> **Objective 3:** Determine if genetic diversity, population structure, and effective population size have changed in natural spawning populations as a result of the hatchery program. Additionally, determine if hatchery programs have caused changes in phenotypic characteristics of natural populations.

3.1 Allele Frequency

3.2 Genetic Distances Between Populations

3.3 Effective Spawning Population

To address these evaluation indicators the WDFW Molecular Genetics Lab (MGL) obtained pertinent tissue collections and samples, surveyed genetic variation with SNP markers using our standard laboratory protocols, and calculated the relevant genetic metrics and statistics. We used collections from both the Entiat River and Wenatchee River basins. Both have received hatchery plants from non-local stocks [i.e. Entiat was stocked with both Wenatchee and Wells program juveniles averaging 12K and 18K respectively during 1995-2001, and Wenatchee received on average 177K juveniles from the Wells program during 1995-2001; (Good et al. 2005)], and both have all or some part of the basin designated as natural production "reference" drainage – no hatchery outplanting (i.e., the entire Entiat Basin, and Peshastin Creek in the Wenatchee River basin) (Good et al. 2005).

Materials and methods

Sample collections

To address objectives 3.1 through 3.3, we obtained samples from hatchery (HOR, adipose fin clipped) and natural origin (NOR, adipose fin intact) adult summer steelhead captured at Dryden or Tumwater diversion dams in the summer and fall of 1997 through 2009 (excepting 2004 and 2005; Table 1). All or some fraction of these fish was later used as hatchery broodstock the calendar year following the sampling year. In order to keep things simple we have reported years as the spawning year, i.e., the calendar year the fish were spawned, not the calendar year they were captured.

To address objective 3.2, it was necessary to have samples from natural origin fish from each of the spawning populations in the basin. It is difficult to obtain adult samples from known spawning populations due to the life history and behavior of steelhead, without tributary weirs or some other blocking method of collection. The NOR adult samples used as broodstock collected from Dryden and Tumwater Dams were a mixed collection representing all of the spawning populations located upstream. Therefore to determine population substructure within the basin we obtained collections of juvenile fish from smolt traps located within tributaries representing three major populations in the basin and from the Entiat River (Chiwawa River, Nason Creek, and Peshastin Creek; Table 2). We also obtained two collections of juvenile fish caught in a smolt trap in the lower Wenatchee River. These, like the NOR adult collections, were a mixed collection presumably representing all populations located upstream. Fin tissue was taken from each fish and preserved in 95% ethanol.

Sample processing

Fin tissue samples were processed for 1468 HOR and NOR adult steelhead broodstock (Table 1) and for 1542 juvenile *O. mykiss* from the Wenatchee and Entiat Rivers (Table 2). Samples were genotyped at 152 single nucleotide polymorphism loci (SNPs, Tables 3, 4). We originally proposed to use microsatellites, but WDFW MGL and other regional genetic laboratories (Columbia River Inter-Tribal Fish Commission [CRITFC], Idaho Fish and Game [IDFG], USFWS) are moving toward using SNPs and they provide the same kinds of information with faster processing. Twenty SNP loci were developed to discriminate among trout species; 14 distinguish *O. mykiss* from coastal cutthroat trout (*O. clarkii clarkii*) and westslope cutthroat (*O. clarkii lewisi*), and 6 distinguish steelhead and coastal cutthroat from westslope cutthroat (Table 4). The remaining 132 SNP loci were developed to be used for population structure, parentage assignment, or other population genetic studies of *O. mykiss* (Table 3). These markers comprised the current standard set of SNP markers used for genetic studies of *O. mykiss* at WDFW MGL.

We used Qiagen DNEasy ® kits (Qiagen Inc., Valencia, CA), following the recommended protocol for animal tissues, to extract and isolate DNA from fin tissue. SNP genotypes were obtained through PCR and visualization on Fluidigm EP1 integrated fluidic circuits (chips). Protocols followed Fluidigm's recommendations for TaqMan SNP assays as follows: Samples were pre-amplified by Specific Target Amplification (STA) following Fluidigm's recommended protocol with one modification. The 152 assays were pooled to a concentration of 0.2X and mixed with 2X Qiagen Multiplexing Kit (Qiagen, Inc., Valencia CA), instead of TaqMan PreAmp Master Mix (Applied Biosystems), to a volume of 3.75µl, to which 1.25µl of unquantified sample DNA was added for a total reaction volume of 5µl. Pre-amp PCR was conducted on a MJ Research or Applied Biosystems thermal cycler using the following profile: 95°C for 15 min followed by 14 cycles of 95°C for 15 sec and 60°C for 4 minutes. Post-PCR reactions were diluted with 20µl dH_2O to a final volume of 25µl.

Specific SNP locus PCRs were conducted on the Fluidigm chips. Assay loading mixture contained 1X Assay Loading Reagent (Fluidigm), 2.5X ROX Reference Dye (Invetrogen) and 10X custom TaqMan Assay (Applied Biosystems); sample loading mixture contains 1X TaqMan Universal PCR Master Mix (Applied Biosystems), 0.05X AmpliTaq Gold DNA polymerase (Applied Biosystems), 1X GT sampling loading reagent (Fluidigm) and 2.1 µL template DNA. Four µL assay loading mix and 5 µL sample loading mix were pipetted onto the chip and loaded by the IFC loader (Fluidigm). PCR was conducted on a Fluidigm thermal cycler using a two step profile. Initial mix thermal profile was 70°C for 30min, 25°C for 5 min, 52.3° for 10 sec, 50.1°C for 1 min 50sec, 98°C for 5 sec, 96°C for 9 min 55 sec, 96°C for 15 sec, 58.6°C for 8 sec, and 60.1°C for 43 sec. Amplification thermal profile was 40 cycles of 58.6°C for 10 sec, 96°C for 5 sec, 58.6°C for 8 sec and 60.1°C for 43 sec with a final hold at 20°C.

The SNP assays were visualized on the Fluidigm EP1 machine using the BioMark data collection software and analyzed using Fluidigm SNP genotyping analysis software. To ensure all SNP markers were being scored accurately and consistently, all data were scored by two researchers and scores of each researcher were compared. Disputed scores were called missing data (i.e., no genotype).

Evaluation of loci

A two-tailed exact test of Hardy–Weinberg equilibrium (HWE) was performed for each locus in each collection or population using the Markov Chain method implemented in GENEPOP v4.1 (dememorization number 1000, 100 batches, 1000 iterations per batch; Raymond and Rousset 1995; Rousset 2008). Significance of probability values was adjusted for multiple tests using false discovery rate (Verhoeven et al. 2005). F_{IS}, a measure of the fractional reduction in heterozygosity due to inbreeding in individuals within a subpopulation and an additional indicator of scoring issues, was calculated according to Weir and Cockerham (1984) using GENEPOP v4.1. Allele frequencies were calculated using CONVERT v1.0 (Glaubitz 2004). Expected and observed heterozygosities were calculated using GDA v1.1 (Lewis and Zaykin 2001).

Allele frequencies, genetic distances and population differentiation

To evaluate Q1 of Objective 3.1 and 3.2, we evaluated trends and patterns in allele frequencies, genetic distances and population differentiation. To test for temporal patterns in allele frequencies, we compared sample or spawn year to two diversity metrics, allele frequency and observed heterozygosity, from each adult and juvenile collection. Each SNP locus had only one or two alleles, so we used the minor allele frequency (MAF) of each SNP locus for each adult collection and averaged across loci. We also calculated the average observed heterozygosity (Ho) for each SNP locus within each adult and juvenile collection. We examined the presence or absence of a temporal trend in average allele frequency and observed heterozygosity with logistic regression analysis in R (R Development Core Team 2009).

To partition genetic variance into temporal, spatial (juvenile) and origin (adult) fractions, we performed hierarchical analysis of molecular variance (AMOVA) using ARLEQUIN v3.0 (Excoffier et al. 2005) with 1,000 permutations. We performed this analysis separately for juvenile and adult collections. Juveniles were grouped by sampling location (tributary) and adults were grouped by origin (HOR or NOR). To estimate the magnitude of genetic differences among temporal and spatial collections we calculated pairwise F_{ST} estimates among collections using FSTAT (Goudet 1995) with 1000 permutations. Statistical significance was adjusted using false discovery rate (Verhoeven et al. 2005).

To evaluate the temporal changes in genetic relationships, we compared spawn year to within spawn year pairwise F_{ST} estimates between NOR and NOR adults using beta regression (Simas and Rocha 2010). We used beta regression because the dependent variable was bound by zero and one but not binomial. Analysis was performed in R (package "betareg", Cribari-Neto and Zeileis 2010), with a loglog link.

We used principal component analyses (PCA) to explore the relationship between the covariation among the SNP loci within each collection and genetic differentiation between HOR and NOR collections, and to determine if the degree of differentiation has changed with time. Since each SNP is represented by only two alleles, only one allele per SNP is necessary to fully describe the covariation among all SNPs. We used MATLAB® scripts (2007a, The Mathworks, Natlick, MA) to calculate the principal components from SNP allele frequencies using only the major allele (1-MAF) for each SNP. We defined the major allele as the allele with the higher mean frequency across all collections, regardless of its status within any individual collection. We conducted three PCA analyses using: (1) all adult samples, aggregated based on origin (HOR versus NOR) and spawn year (i.e., the year the adult fish were used as broodstock) (N = 1437, 22 collections), (2) same as #1, but with the addition of all juvenile samples (N = 2938, 37 collections), and (3) only those adults samples with available age information (Mike Hughes, WDFW, personal communication) aggregated based on origin, and spawn year or brood year (i.e., the year the fish were hatched) (N = 1313, 20 spawn-year or 25 brood-year collections).

Molecular differentiation between HOR and NOR adults within a year was calculated based on principal component scores using Euclidian distances. We calculated pair-wise Euclidian distances between HOR and NOR fish within a spawn year or brood year using the first three principal components, and standardized each distance by subtracting from it the mean Euclidian distance calculated across all pair-wise distances. We used Mahalanobis distances to calculate the variation among HOR and NOR collections (calculated separately), again using the first three principal components. Here, we calculated Mahalanobis distances as the Euclidian distances between each collection and the centroid of all collections (HOR and NOR combined), but the Euclidian distances are scaled based on the dispersion of collections around the centroid (i.e., the variance). Euclidian and Mahalanobis distances were calculated using MATLAB scripts.

Effective spawning population

To evaluate Q1 of Objective 3.3, we estimated N_e using the single-sample linkage disequilibrium methods implemented in the program LDNE (Waples and Do 2008). This method requires that you input the P_{crit} value, the minimum frequency at which alleles were included in the analysis, since results can be biased depending on this setting (Waples and Do 2010). SNP markers typically have only one or two alleles; if one of two alleles is excluded based on its frequency in the collection it essentially excludes the locus, reducing the overall dataset. Therefore, we used P_{crit} values ranging from 0.1 to 0.001 to evaluate whether trends in N_e changed given which loci were used. Confidence intervals were calculated using a jackknife procedure.

We calculated an estimate of N_e for all adult and juvenile collections individually. However, the intention of an integrated hatchery program such as the Wenatchee River steelhead hatchery program is that HOR and NOR fish are integrated and progress as a single population through intentional interbreeding in the hatchery and presumed natural interbreeding in the wild. Thus, we also combined annual HOR and NOR collections to calculate an overall N_e estimate as has been done in other genetic monitoring and evaluation analyses (e.g., Small et al. 2007, [Chinook salmon, *O. tshawytscha*]).

Estimates of N_e from linkage refer to the generations that produced the sample. To calculate the ratio of effective population size to census size (N_e/N), we obtained the number of fish spawned in the hatchery (1993 through 2006, i.e., those that produced the adipose fin clipped adults that returned to spawn in the Wenatchee River 1998 through 2010) and the estimated escapement of fish spawning naturally (HOR and NOR separately) for the same time period. Estimates of census population size in spawning tributaries was obtained by multiplying the fraction of redds counted within tributaries (Chad Herring ,WDFW, unpublished data) by the total Wenatchee River census population estimate (Andrew Murdoch, WDFW, unpublished data). To calculate N_e/N, we performed two analyses. First, for adults, we assumed a five year generation time for natural origin adults and a four year generation time for hatchery origin adults and divided the N_e estimate by the census population estimate from four or five years earlier. For juveniles, we assumed an age at outmigration of two years and divided the N_e estimates by the estimate of census population size for the appropriate tributary. Second, we used available adult age data to parse individuals into cohorts originating in brood years (rather than spawn years) and then used LDNE to estimate N_e from cohort collections. We performed both analyses to make full use of all available data; age data were not available for many adults, and because of variable survival and sampling not all cohorts had sufficient numbers of HOR and NOR adults. According to Luikart et al. (2010), estimates produced using linkage disequilibrium should be interpreted as something between effective population size (N_e) and the effective number of breeders (N_b). Using cohorts, the estimate produced by LDNE is clearly an estimate of N_b rather than N_e. In order to keep things simple, we have referred to all estimates as N_b.

Results and Discussion

Collections and samples received

From 1468 samples from HOR and NOR adult steelhead broodstock, 1437 produced sufficient genetic data for further analysis (Table 1). From 1542 samples from NOR juvenile steelhead from Wenatchee River tributaries and the Entiat River, 1501 produced sufficient genetic data for further analysis and were genetically identified as *O. mykiss* (Table 2). Samples genetically identified as *O. clarki* (2 samples from the Chiwawa River, 1 from the Entiat River) or *O. clarki*/*O. mykiss* hybrids (4 – lower Wenatchee River, 4 – Nason Creek, 4 – Chiwawa River, and 1 – Entiat River) were omitted from further analysis.

Evaluation of loci

Three loci showed deviations from HWE in 10 or more of 37 Wenatchee steelhead collections before correcting for multiple tests (AOmy016, AOmy051, AOmy252, Table A1) indicating possible scoring issues. These loci were omitted from further analysis. Nine of the remaining loci were monomorphic or nearly monomorphic in all collections (average MAF < 0.1, AOmy023, AOmy028, AOmy123, AOmy129, AOmy132, AOmy209, AOmy229, AOmy270, AOmy271, Table A1) contributing little or nothing to analytical power. These loci were also omitted from further analysis. No genetic data was available for collection 10FD due to poor PCR amplification at locus AOmy213 for the entire collection. AOmy213 had a relatively low MAF in most collections so rather than re-processing this collection at this locus or running different sets of loci for different tests, we omitted this locus from further analysis. Only six tests of deviation from HWE were significant after correcting for 4348 tests using false discovery rate. Two of these tests were in loci already omitted. The remaining four tests were spread among the remaining loci, indicating no more loci needed to be omitted from further analysis.

Objective 3.1, 3.2 – Allele frequencies and Genetic distances

Allele frequencies

Average MAF of SNP loci ranged from 0.00 to 0.60 in HOR adult collections and from 0.00 to 0.61 in NOR adult collections (Table A1). Observed heterozygosity ranged from 0.00 to 0.75 in HOR adult collections and from 0.01 to 0.67 in NOR adult collections. Juvenile collections produced similar ranges of MAF and Ho (Table A1). Average MAF and Ho of HOR adult collections appeared to be greater than those of natural origin collections. However, logistic regression analysis indicated there was no significant temporal trend in either diversity statistic (Figure 1). Similarly, there was no consistent temporal trend in MAF or Ho of juvenile collections (Figure 2). Both the Chiwawa River and Nason Creek, the two tributaries that currently still receive hatchery juvenile outplants, both appeared to have declining allele frequencies, but neither was statistically significant ($P > 0.90$). However, the power to detect significant trends was limited by the small sample sizes (n = 3 sample years).

Analysis of Molecular Variance

Analysis of molecular variance (AMOVA) of adult collections (i.e., temporal and origin structure) indicated most of the genetic variance was among individuals or among individuals within populations (99.04%). Most of the remaining variance was temporal variation within hatchery and natural origin groups (0.61%) with the remaining variation from origin (0.35%). AMOVA of juvenile collections (i.e., spatial structure) indicated most of the genetic variance was among individuals (98.44%) or among individuals within populations (0.94%). Most of the remaining variance existed among temporal collections within tributary collections (0.37%) with the smallest fraction as among tributary variance (0.24%). Thus, overall, there was more variability among years than among tributaries or origins, but no trend in the temporal variability.

Pair-wise F_{ST} *estimates*

HOR adults were genetically different that NOR adults as estimated by F_{ST} (full pair-wise table in Table A2, all pair-wise F_{ST} estimates with P-values ≤ 0.05 before correcting for multiple tests were significantly different from zero after correcting for multiple tests using false discovery rate). On average, HOR adult collections were as different from one another (mean F_{ST} = 0.011) as they were from NOR adult collections among years (mean F_{ST} = 0.009) or from NOR adult collections within years (mean F_{ST} = 0.010). Among year comparisons of NOR adult collections were, on average, nearly an order of magnitude lower (mean = 0.002). These patterns held whether spawn year or brood year (data not shown) was used to group individuals. Over time, within spawn year pair-wise F_{ST} estimates between HOR and NOR adults declined over time (β = -0.014, P = 0.0185; Figure 3), suggesting that the integration of hatchery and wild fish is slowly genetically homogenizing the groups. That relationship disappeared when adults were grouped by brood year (i.e., comparing fish produced the same year) and all brood years were used (β = -0.009, P = 0.615, data not shown). However, when the dataset was restricted to just those brood years when all typical (age at maturation frequency among all years > 0.10) age classes were present in the dataset (HOR = age 3, 4; NOR = age 4, 5, 6; brood years 1996-1998, 2004-2005) a non-significant (P = 0.278) negative relationship (β = -0.12) of F_{ST} and brood year was apparent. When the data were further restricted to just the years after the hatchery program changed to only collecting broodstock in the Wenatchee River (brood years 1998, 2004-2005), the slope was also negative (β = -0.09), but the relationship was not statistically significant (P = 0.962).

Within tributary among sample year pair-wise comparisons of juvenile collections were, on average, only very slightly smaller than comparisons among tributaries (0.005 vs. 0.006, respectively, Table 5, all pair-wise F_{ST} estimates with P-values ≤ 0.05 before correcting for multiple tests were significantly different from zero after correcting for multiple tests using false discovery rate). Nason Creek and Peshastin Creek on average showed higher among sample year F_{ST} estimates (0.010 and 0.007, respectively) than the Chiwawa or Entiat Rivers (0.004 and 0.002, respectively). The pair-wise comparison of the two collections of lower Wenatchee River smolts, presumably a mix of Chiwawa, Nason, Peshastin smolts and smolts from other spawning tributaries, was an order of magnitude smaller (F_{ST} = 0.0002), and not significantly different than zero (Table 5). There was no temporal trend in pair-wise comparisons of juvenile collections. However with, at most, four annual collections, detecting any temporal trend was unlikely. We also had no collections from years prior to 1998 (the first year of new hatchery program broodstock collecting protocols) with which to compare contemporary data, nor could we find any reports or papers containing pre-hatchery-program-change genetic comparisons among Wenatchee River tributary populations, making it impossible to determine whether or not changing the hatchery program has had any effect at all on population structure. However, these data will be useful for future studies.

Principal Components

Each principal component analysis (Figures 4, 5) indicated that the genetic structure among HOR collections differed from that among NOR collections, and that this difference has decreased with time. When adult fish were aggregated based on origin and spawn-year, there was a clear differentiation between HOR and NOR adult collections along PC 1, and a separation among HOR collections, differentiating the early spawn-years (1998 – 2003) from the later spawn-years (2004 – 2010) along PC 2 and PC 3, respectively (Figure 4). The pair-wise genetic distances between HOR and NOR collections from the same spawn year (i.e., the HOR and NOR fish used as broodstock within the same year) decreased from the largest distance in 1998 to small distances in 2009 and 2010, although the smallest distance occurred in 2004 (Figure 4, top right). That is, within hatchery broodstock, the genetic difference between HOR and NOR fish decreased, on average, from 1998 to 2010, and the decrease appeared to be a mutual convergence of NOR fish shifting right along PC 1 and HOR fish shifting downward along PC 2 and PC 3. This increasing similarity in adult fish mirrored that seen in within year pair-wise F_{ST} estimates between HOR and NOR adults which also declined over time (Figure 3).

Overall, there was considerably more genetic variation among the HOR collections than there was among the NOR collections with average Mahalanobis distances (distance between each collection and the overall centroid [0,0,0]) among the HOR and NOR collections being 4.2 and 1.5, respectively. Since each NOR collection was generally composed of 3-4 brood-years, while HOR collections rarely were composed of more than two brood-years, we attributed the lower year-to-year genetic variability of the NOR broodstock to the greater homogenizing effect of including four or more brood-years compared with only two brood years for the HOR broodstock.

Including the 15 juvenile collections, along with the 22 adult collections, did not materially alter the principal component structure (Figure 6), although the total genetic variation accounted for by the three principal components decreased from 44% using only the adults to 33% when juveniles were included. For the most-part, the juvenile fish appeared intermediate between HOR and NOR fish, but there was greater overlap in principal component scores (and therefore greater genetic similarity) of the juvenile and NOR collections, than of the juvenile and HOR collections. The average Euclidian distance between the juvenile and HOR collections was 0.49, compared to 0.23 between the juvenile and NOR collections, which was no different than 0.23 and 0.22 for the within juvenile and NOR collections, respectively.

By using the available adult age data, we were able to compare the genetic differentiation among the same set of fish when they are aggregated by origin (hatchery versus natural) and brood-year (year fish were hatched) with aggregates based on origin and spawn-year (year adult fish were spawned). A brood-year analysis compares within a year the genetic diversity generated from hatchery broodstock with that naturally produced in the spawning grounds. A spawn-year analysis compares the HOR and NOR genetic diversity that was mixed among cohorts of the parental generations. The same basic pattern of genetic structure that we have seen in spawn-year analyses (Figure 4, Figure 6, and the right side of Figure 5) also occurred in the brood-year analysis (left side of Figure 5). That is, from Figure 5 we saw (1) that HOR and NOR fish were differentiated from each other; (2) there was considerably more genetic variation (temporal variation) among the hatchery-origin collections than there was among the natural-origin collections (for brood-year, Mahalanobis distances = 5.18 and 0.75, respectively; for spawn-year, Mahalanobis distances = 4.25 and 1.25, respectively), and (3) that the genetic distances between HOR and NOR collections were lower in the more recent brood- and spawn-years, than in the earlier brood- and spawn-years (Figure 7; $R^2 = 0.41$ or 41%, $P < 0.05$). This indicated that the HOR and NOR fish used as broodstock in 2010 were more similar to each other than they were at the inception of the new hatchery program.

The relationship between genetic distance and brood-year was not the same as the relationship between genetic distance and spawn-year. For brood-year, although the slope was negative (i.e., trending downward or decreased differentiation with time) and the two most-recent brood years (2005-2006) showed relatively small HOR and NOR adult differentiation, the negative slope was not significantly different from zero and the regression accounted for only 7% of the variation. This was likely the result of insufficient sampling of certain age classes from many brood years (especially from NOR adults) due to two un-processed sample years (2005 and 2006).

Objective 3.3 – Effective spawning population

There was no difference in the temporal trends in estimates of N_b with P_{crit} set from 0.1 to 0.001 (Figure 8, data not shown for all collections), so we have reported only results with $P_{crit} = 0.001$, i.e., the full genetic dataset. Using either spawn-year or brood year, estimates of NOR adult N_b were higher and varied more than those of HOR adults (Figures 9, 10), concordant with the PCA analysis. Estimates for HOR adults ranged from 17 to 174 (by spawn year, mean = 65) or from 6 to 130 (by brood year, mean = 39). Estimates for NOR adults ranged from 36 to 982 (by spawn year, mean = 405) or from 59 to 2966 (by brood year, mean = 645). Many N_b estimates for NOR adults had confidence intervals extending to infinity on the upper bound. This reflected the difficulty in obtaining precise estimates of N_b for large populations (Waples and Do 2010).

Estimates of N_b for HOR steelhead dropped by approximately half from 1994, when broodstock were still collected at Wells Hatchery, to 1998, when the program used Wenatchee River trapped adults only, suggesting an effect of changing broodstock collection practices, which began in 1997 (Figures 8, 9). Since 1997, the hatchery population N_b remained at a relatively stable lower level (Figures 8, 9, and 10). There was no obvious change in N_b for NOR steelhead since 1993; the N_b estimate for 1993 was the largest, however the confidence interval overlapped estimates from many other years. The temporal trend in N_b estimates from combined collections mirrored those of the HOR collections alone, though estimates using combined collections were slightly larger (Figure 11).

As with N_b estimates, estimates of the ratio of N_b/N for NOR adults varied more than those of HOR adults (Figures 12, 13). However, using spawn year, i.e., mixtures of cohorts, the average N_b/N ratio for HOR adults was equal to that of NOR adults (mean $N_b/N = 0.26$), whereas when using brood year, the average N_b/N ratio for NOR adults was double that of HOR adults (NOR average =0.40, HOR average = 0.20). This is likely a consequence of the homogenizing effect of mixed cohorts. Estimates of N_b for HOR adults using spawn year were close to those estimated using brood year because of the lower diversity in age at maturation, whereas for NOR, grouping by brood year produces different estimates than when grouping by spawn year because of higher diversity in age at maturation. Regardless of which estimate was used, there was no temporal trend in N_b/N for either NOR or HOR adults.

Summary

On average, HOR adults had higher minor allele frequencies (MAF) than NOR adults, and both had similar MAF as juveniles collected in spawning tributaries and in the Entiat River. There was no temporal trend in allele frequencies or observed heterozygosity in adult or juvenile collections and allele frequencies in control populations were no different than those still receiving hatchery outplants suggesting that the hatchery program has had little effect on allele frequencies since 1998.

HOR adults were genetically quite different from NOR adults and juveniles based on pair-wise F_{ST} and principal components analysis (PCA), most likely because of the much smaller effective population size (N_b) in the hatchery population. Pair-wise F_{ST} estimates and genetic distances between HOR and NOR adults collected the same year declined over time suggesting that the interbreeding of HOR and NOR adults in the hatchery (and presumably in the wild) is slowly homogenizing Wenatchee River summer steelhead. Analyses using brood year (the year fish were hatched, determined using scale-based age estimates) were inconclusive because of limitations of the data.

On average, estimates of N_b were much lower and varied less for HOR adults than for NOR adults and juveniles. Estimates of N_b for HOR adults declined from the earliest brood years to a stable new low value after broodstock practices were changed in 1997. There was no indication that this had any effect on N_b in NOR adults and juveniles; N_b estimates for NOR adults and juveniles were, on average, higher and varied considerably over the time period covered by our dataset (1998 – 2010) and showed no temporal trend. Small N_b sizes increase the risk of loss of genetic diversity due to inbreeding and random effects (genetic drift). The N_b of the hatchery component of the population may be increased by spawning more families, using specific mating designs, and minimizing variance in reproductive success. However, given the apparent lack of effects overall, changes to the hatchery protocol may not be necessary.

Overall, hatchery practices appear to have had little effect on natural origin Wenatchee summer steelhead neutral genetic diversity or N_b. We cannot accurately assess their effects on population structure at this time. However, it is interesting to note that when juvenile collections are analyzed separately from adult collections, Peshastin Creek, which has received fewer hatchery outplants in the past and is currently a refuge from hatchery outplants, is genetically different than other tributaries and the Entiat River (data not shown). On the other hand, the Entiat River, which is also a refuge from hatchery outplants and is not a tributary of the Wenatchee River, is genetically very similar to Nason Creek and the Chiwawa River, both Wenatchee River tributaries. This suggests, though it does not conclude, that within basin population structure may have existed before summer steelhead hatchery production began in the upper Columbia River and that the population structure was eliminated by hatchery influence long before 1998.

Acknowledgements

We thank Chad Herring, Clint Deason, John Walters and the numerous technicians that sampled these thousands of fish. We thank Sonia Peterson and Sarah Bell for help in the laboratory and thank Maureen Small for help with some analyses. The project was implemented with funding from the Chelan Co. PUD and Washington State general funds.

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Figures

Figure 1. Observed average minor allele frequencies (MAF) and observed heterozygosities (Ho) of 119 SNP loci from 11 annual collections of hatchery-produced (HOR) and natural origin (NOR) adult steelhead from the Wenatchee River. Trend lines are from a logistic regression. Note the X axis does not cross the Y axis at the origin. Neither the slopes nor the intercepts were statistically significant.

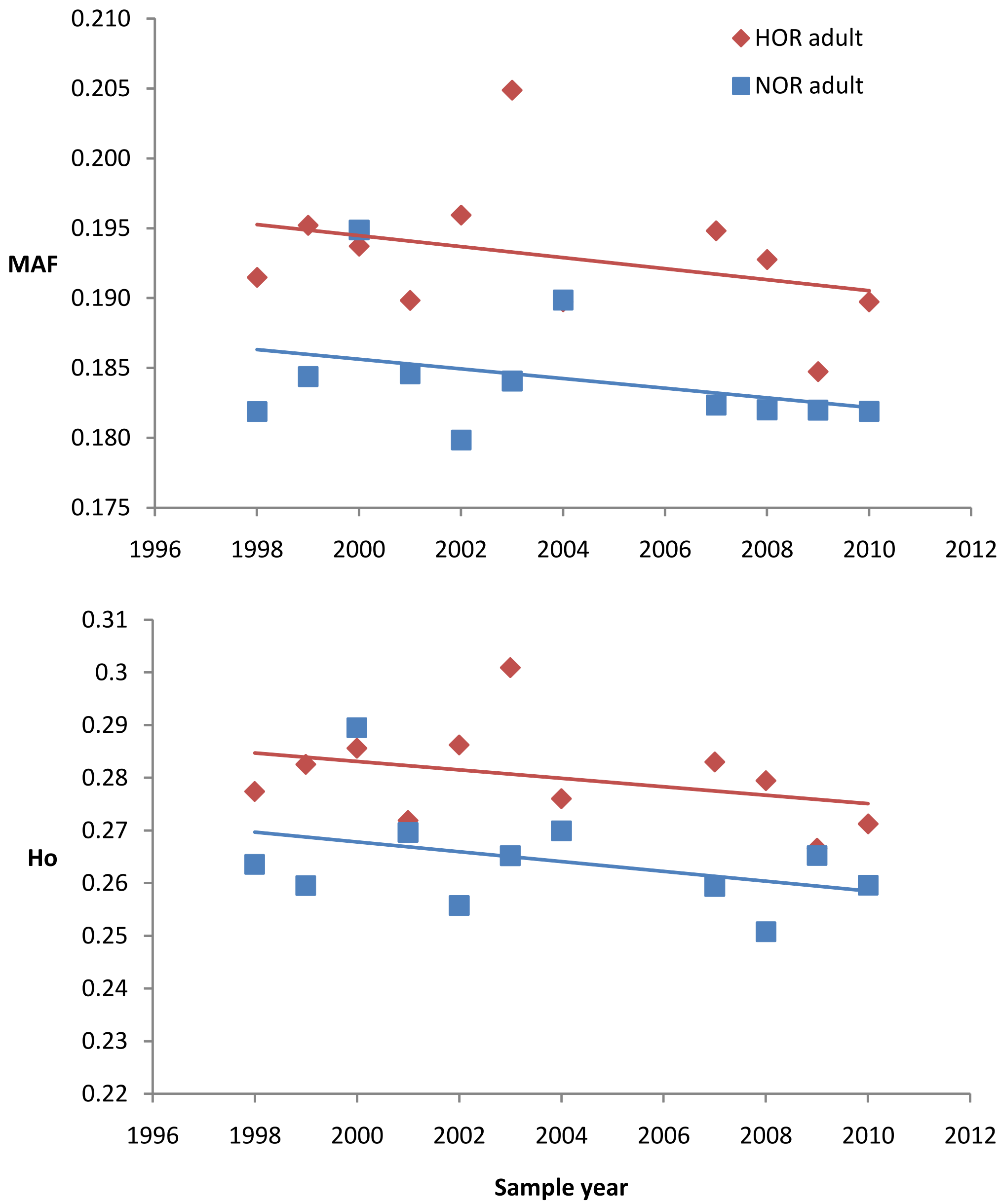


Figure 2. Observed average minor allele frequencies (MAF) and observed heterozygosities (Ho) of 119 SNP loci from 15 collections of natural origin juvenile steelhead from Wenatchee River tributaries, the lower Wenatchee River and the Entiat River. There were no consistent temporal trends in MAF or Ho in these collections.

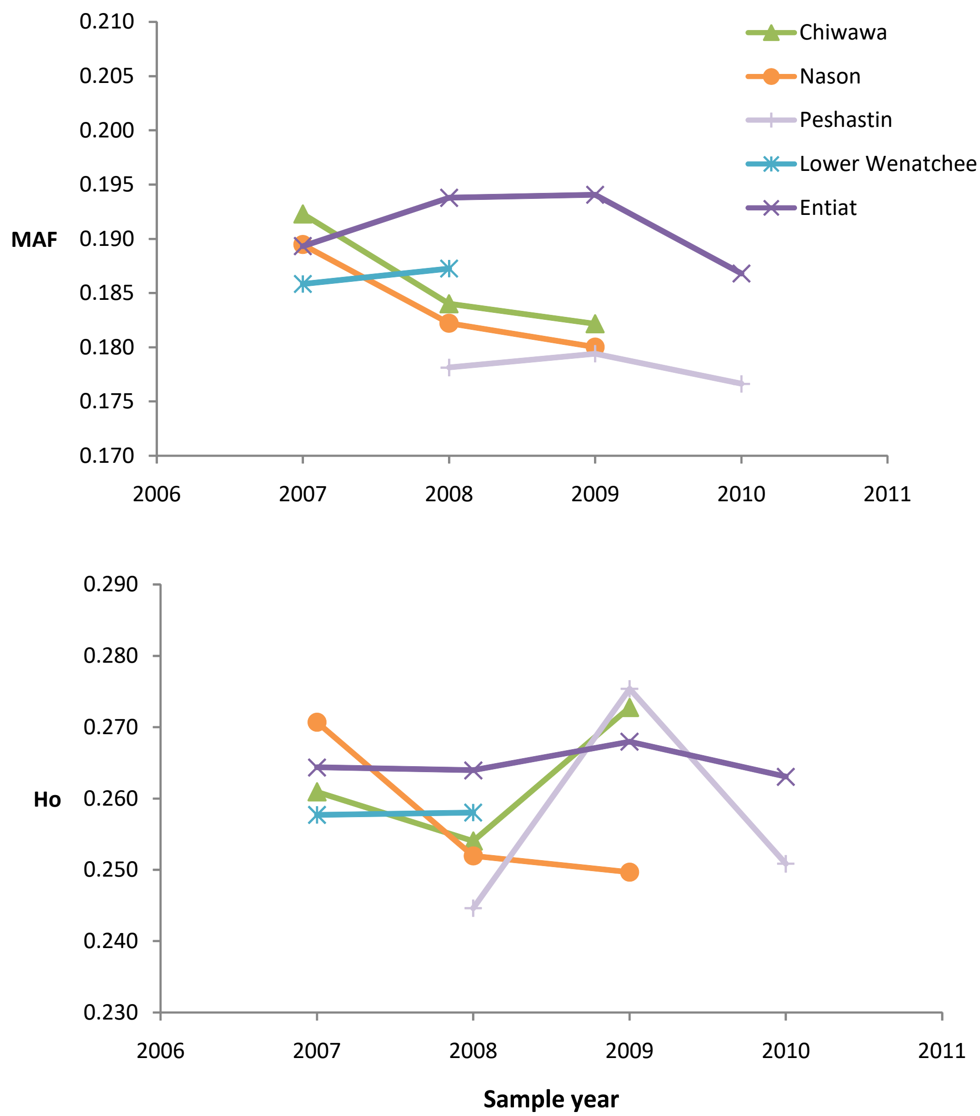


Figure 3. The relationship of time with pairwise F_{ST} estimates between hatchery-produced (adipose fin clipped) and natural origin (unclipped) adults of the same sample year. The line is the prediction based on beta regression.

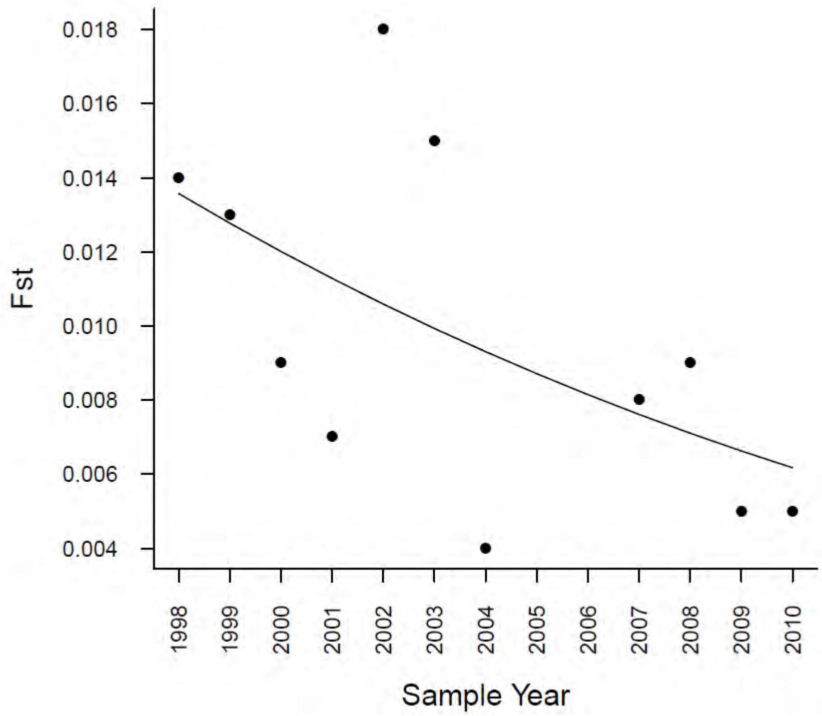


Figure 4. Principal component (PC) 1 versus 2 (top left), PC 1 versus 3 (bottom left), and PC 2 versus 3 (bottom right) based on an analysis using all adults aggregated into origin and spawn-year collections. Natural-origin spawn-years are shown in italicized typeface. The percentage within the label of each axis convey the percent of total genetic variance that is accounted for by that axis. Taken together, the three principal components account for 44% of the total SNP variation. Top right shows pairwise Euclidian distances versus spawn-year, with zero distance equal to average distance across all pairwise distances. Blue line is least-squares fit with $R^2 = 0.45$.

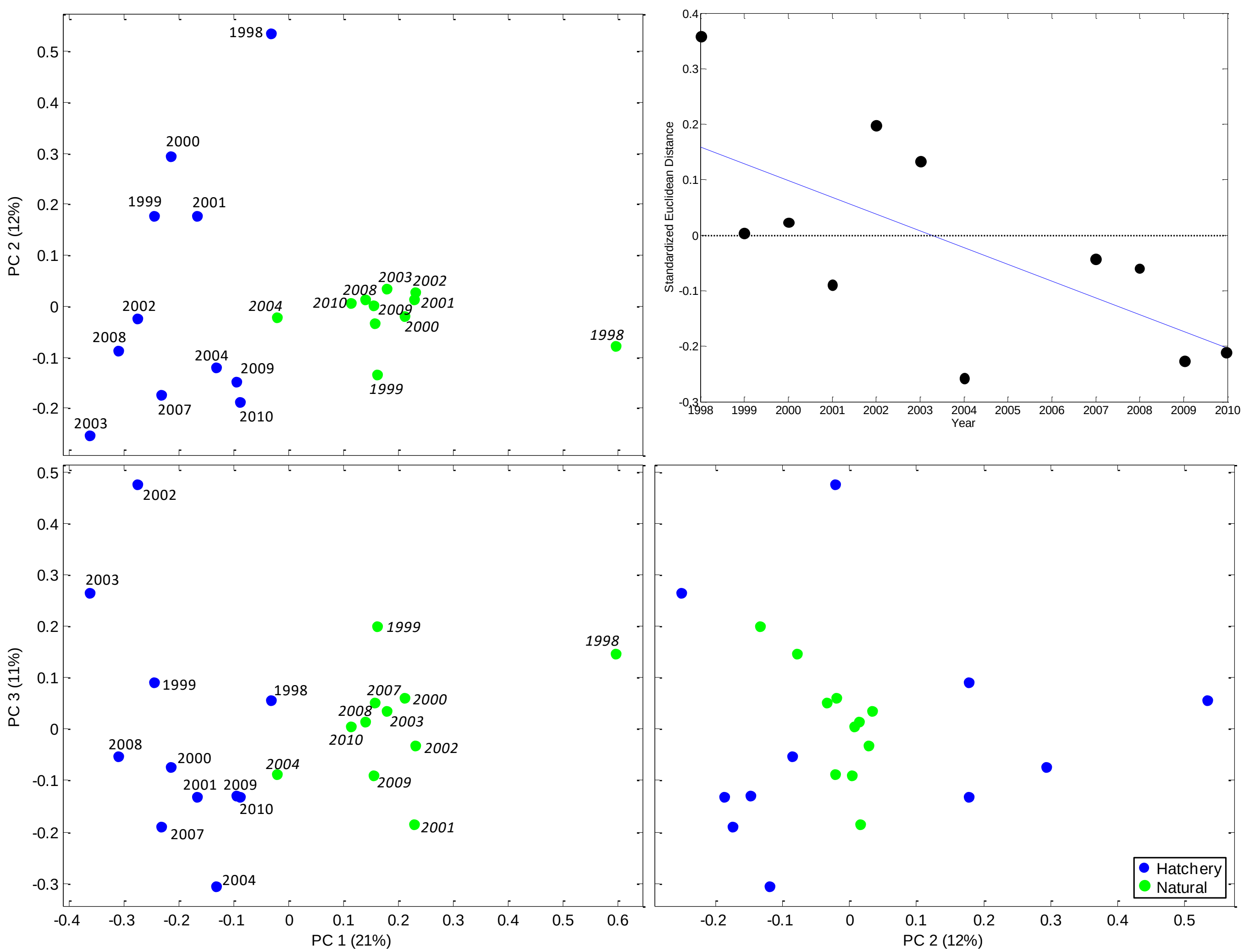


Figure 5. Principal components (PC) 1 versus 2 (top) and 3 (bottom) for adults aggregated into brood-year (BY; left) and spawn-year (SY; right). Spawn-year analysis is the same as in Figure x1, except fewer individuals per collection were included (see methods). Note that for the SY analysis here PC 2 and 3 are similar to PC 3 and 2, respectively, in Figure x1. Only BY1995 (earliest year with paired hatchery-natural data), BY2000 (extreme PC 1 score), and BY2006 (latest year with paired hatchery-natural data) are labeled. Hatchery- and natural-origin individuals from BY1995, BY2000, and BY2006, returned to spawn (spawn-year) in 1999 (hatchery)/1999-2001 (natural), 2003-2004 (hatchery)/2004 and 2007 (natural), and 2009-2010 (hatchery)/2010 (natural), respectively. These years are labeled in the upper right figure. Only 4 year-old BY 2006 natural-origin fish are represented in the SY 2010 collection.

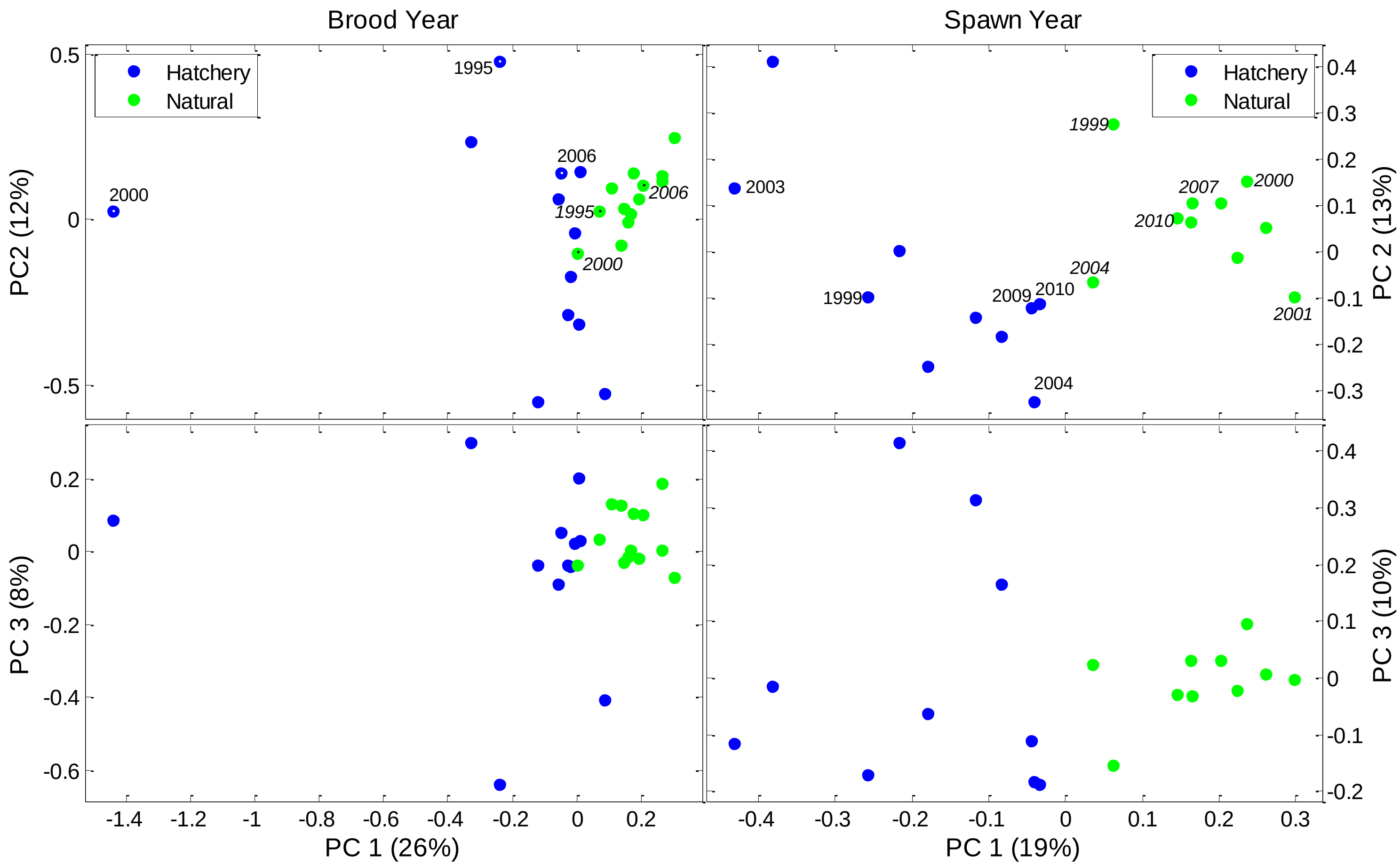


Figure 6. Principal component (PC) 1 versus 2 (top) and PC 1 versus 3 (bottom) based on an analysis using all adult and juvenile fish aggregated into age (juvenile versus adult), origin (hatchery versus adult) and spawn-year collections.

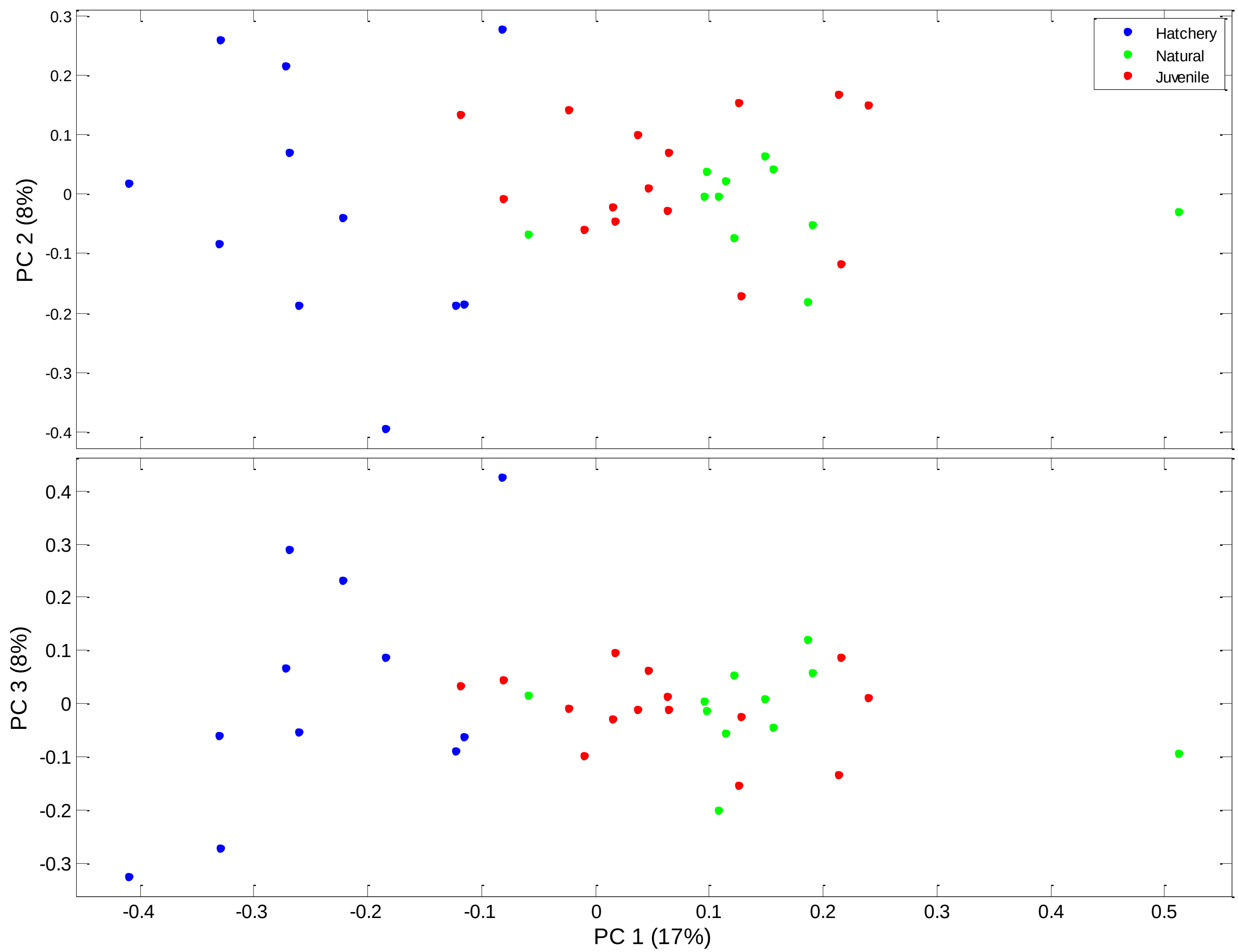


Figure 7. Pairwise Euclidian distances versus brood-year (top) and spawn-year (bottom), with zero distance equal to average distance across all pairwise distances. Blue lines are least-squares fits, which is not significant (slope = 0) for brood-year, but significant (slope > 0) for spawn-year.

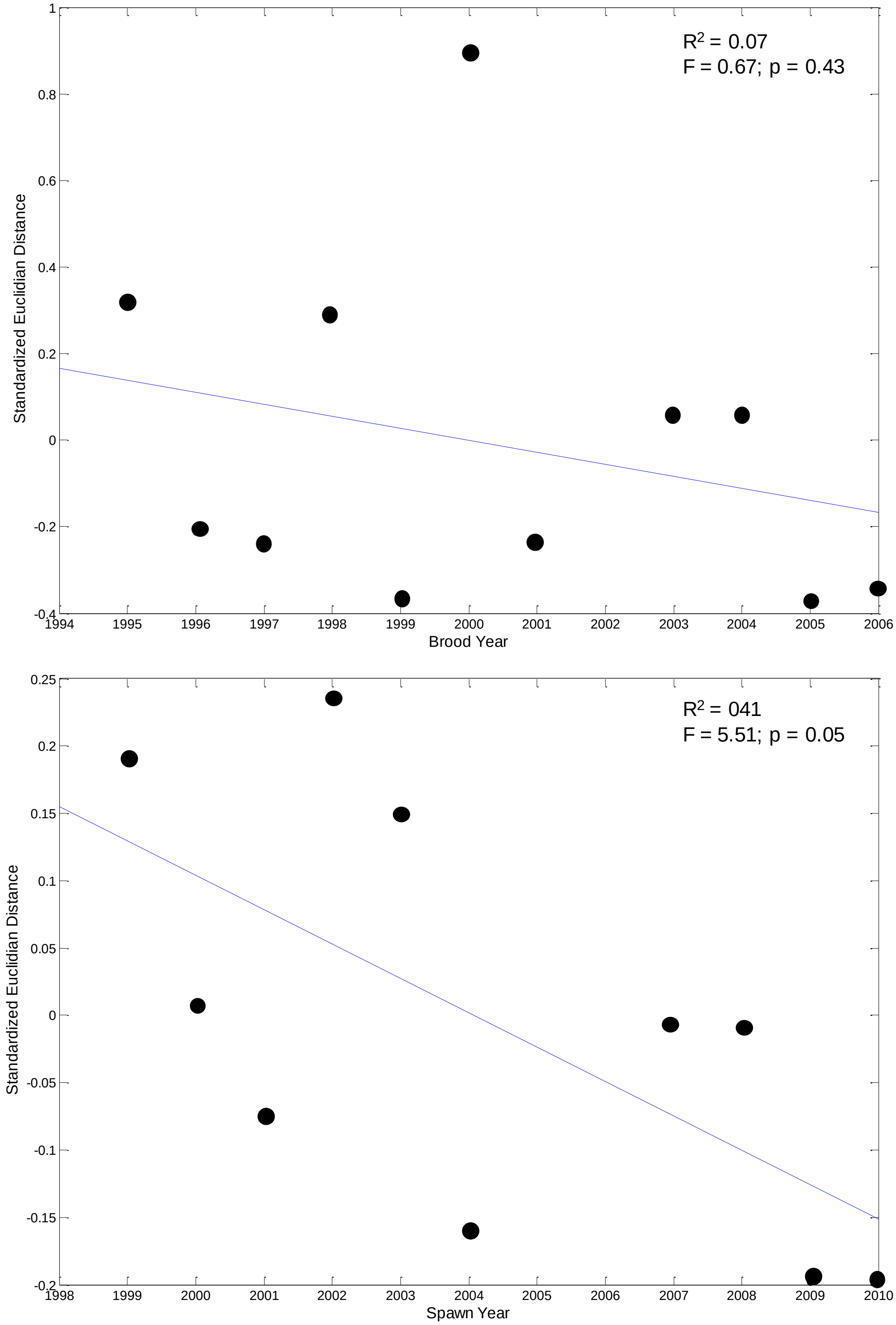


Figure 8. Effective population size estimates (N_b) from Wenatchee River adult hatchery-produced steelhead annual collections calculated using single sample methods implemented in the program LDNE (Waples and Do 2008). Each line connects annual estimates of N_b estimated with a different value of P_{crit}, the smallest allelic proportion allowed during analysis. With SNP data, omitting an allele omits the locus. Estimates of N_b changed very little when P_{crit} varied from 0.1 to 0.001. Setting P_{crit} = 0.001 forced the use of all available loci.

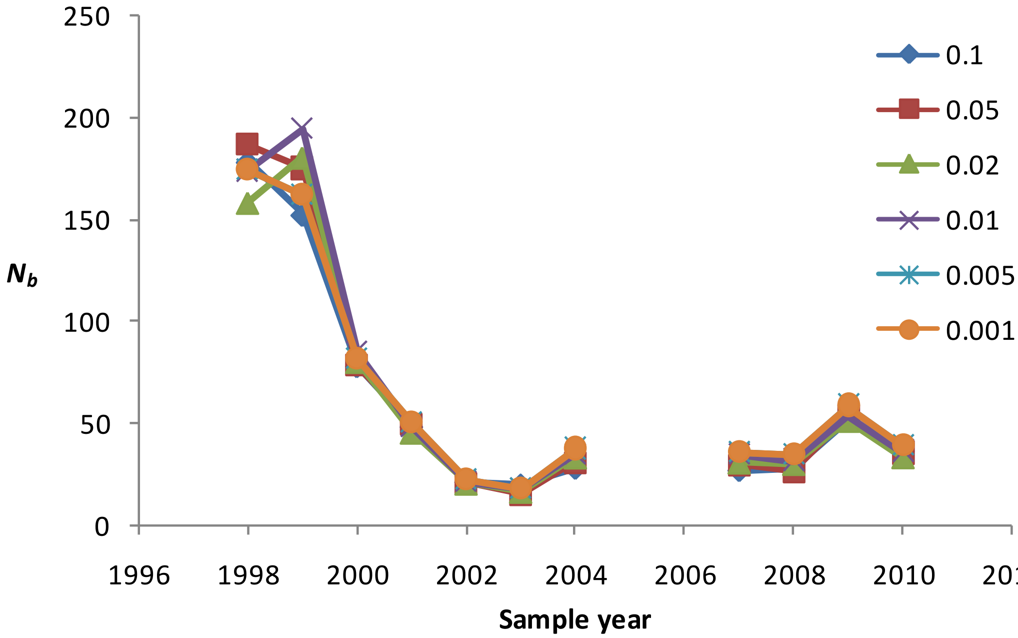


Figure 9. Estimates of Wenatchee River steelhead effective number of breeders (N_b) estimated using the single sample methods incorporated in the program LDNE (Waples and Do 2008). Estimates of N_b refer to parental (and even grantparental) generations. N_b data were plotted against their estimated parental brood year. We assumed a 5 year generation time for natural origin adults (NOR), a 4 year generation time for hatchery-produced adults (HOR) and an age of smolt outmigration of age 2 for smolt collections from Wenatchee River tributaries (Chiwawa River, Nason Creek, Peshastin Creek), the lower Wenatchee River, and the Entiat River. Bars represent the 95% confidence interval estimated by jackknife procedure. Bars that exceed the upper limit of the Y axis are labeled with the upper bound (Inf. = infinity).

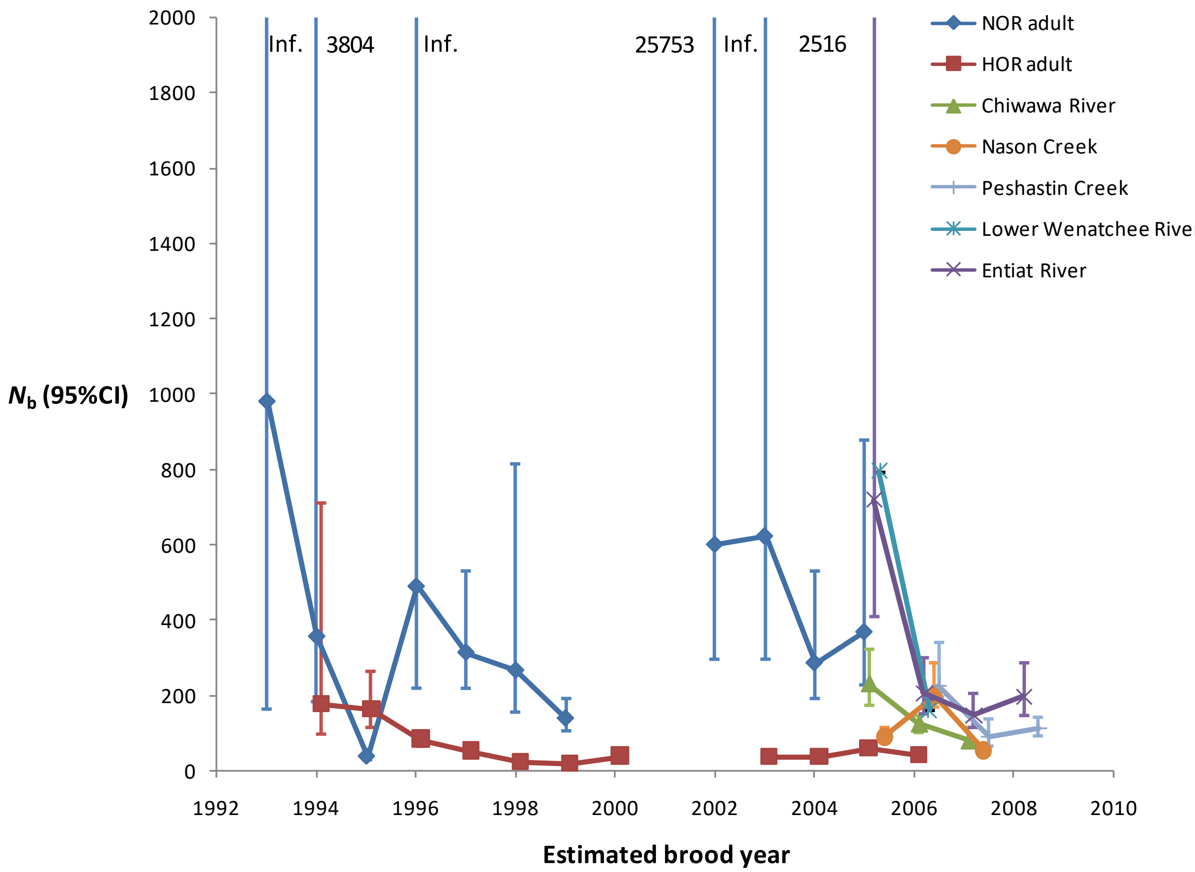


Figure 10. Estimates of N_b for collections of hatchery-produced (HOR) and natural origin (NOR) Wenatchee River summer steelhead grouped by brood year rather than spawn year. Brood year was estimated using scale-based age data. Error bars that extend past the top of the chart are all bounded by infinity.

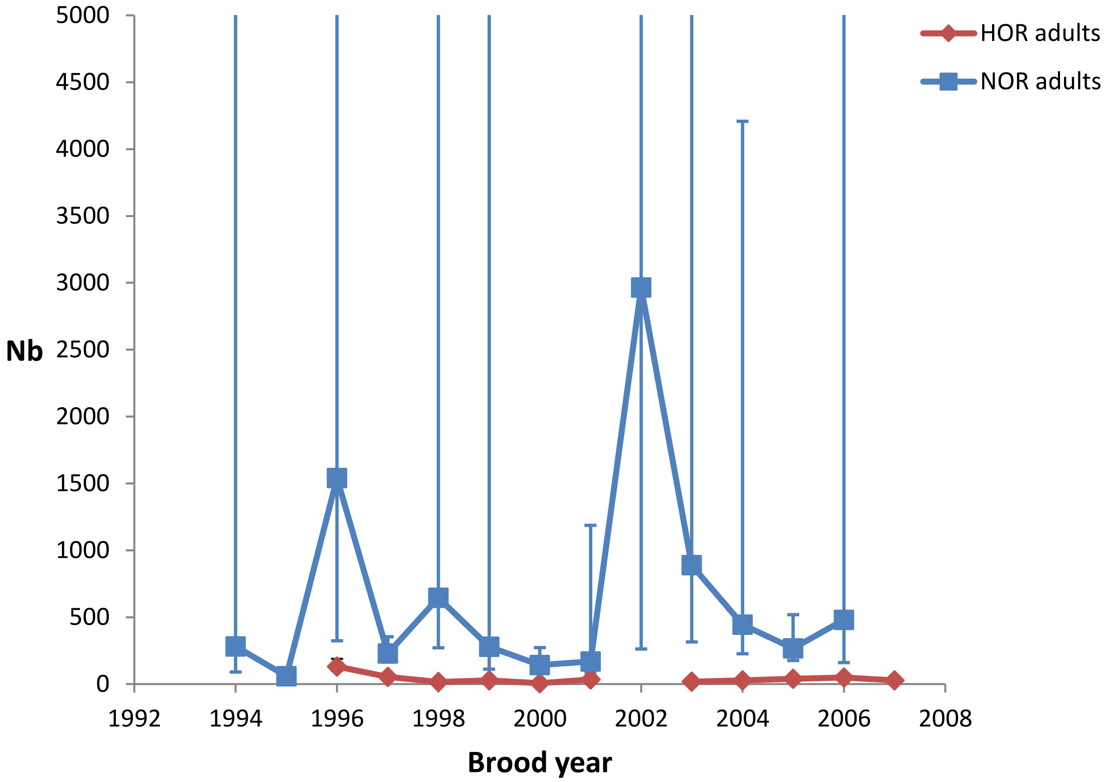


Figure 11. Estimates of N_b for combined annual adult hatchery-produced (HOR) and natural origin (NOR) steelhead and for HOR adults alone. The temporal patterns are similar, though estimates from combined collections are larger than those from HOR collections alone.

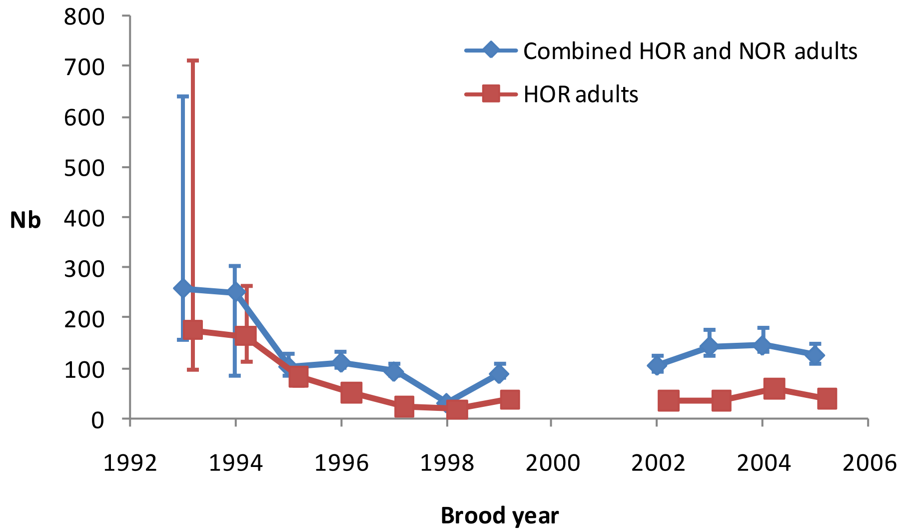


Figure 12. N_b/N ratios for hatchery-produced (HOR) and natural origin (NOR) adult Wenatchee River summer steelhead grouped by spawn year. The average N_b/N ratios are not different, though in later years NOR adults appear to have lower N_b/N ratios.

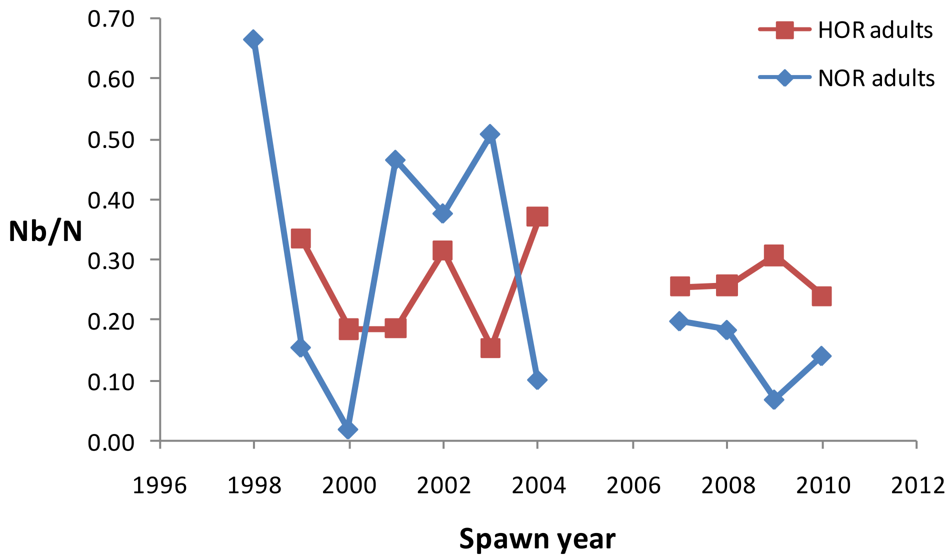
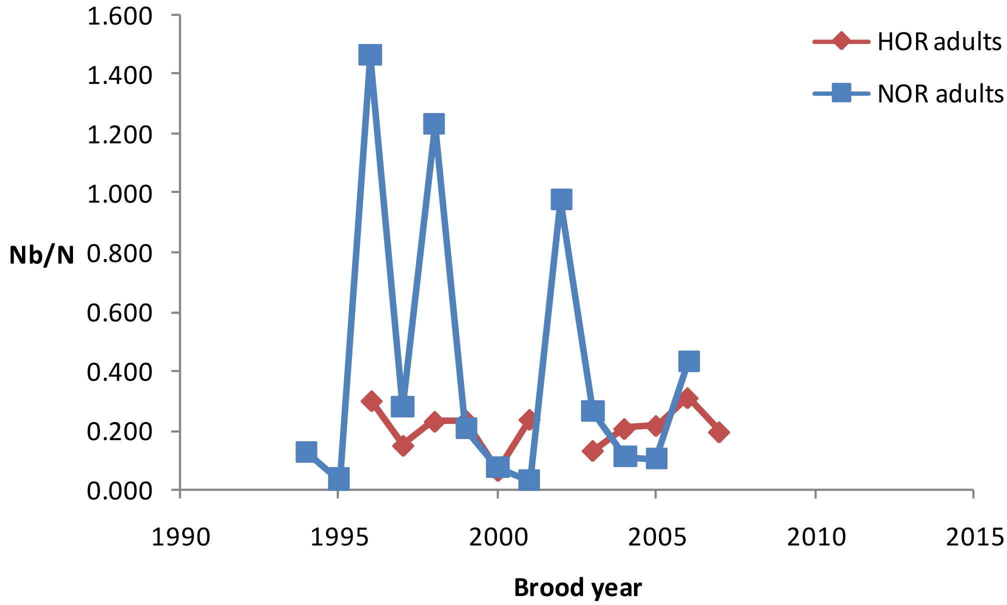


Figure 13. N_b/N ratios for hatchery-produced (HOR) and natural origin (NOR) adult Wenatchee River summer steelhead collections with individuals grouped in brood years rather than spawn years. Individual brood year was estimated using scale-based age data.



Tables

Table 1. Samples of adult steelhead collected for Wenatchee Program broodstock and used for genetic monitoring and evaluation.

Origin	Sampling Location	Year spawned	WDFW Collection code	Samples (N)	Unused Samples[a]
Hatchery	Dryden/Tumwater Dams	1998	98AE	32	4
		1999	98LJ	62	2
		2000	99NE	60	5
		2001	00DQ	99	1
		2002	01MS	64	
		2003	02NP	89	
		2004	03KW	61	
		2007	06CW	64	1
		2008	08AG	56	
		2009	09AV	74	
		2010	10FE	76	1
			Total	737	14
Natural	Dryden/Tumwater Dams	1998	98AF	30	5
		1999	99AA	51	1
		2000	99ND	33	3
		2001	00DP	50	
		2002	01MR	95	
		2003	02NO	50	
		2004	03KV	71	3
		2007	06CX	74	
		2008	08AF	74	1
		2009	09AU	82	2
		2010	10FD	90	2
			Total	700	17

[a]Samples were not used if they had incomplete (≤ 80% or 95 of 119 loci) or duplicate genotypes.

Table 2. Samples of natural origin juvenile steelhead and rainbow trout collected from four Wenatchee basin rivers or creeks and the Entiat River.

Sampling Location	Collection Year	WDFW Collection Code	Samples (N)	Unused samples[a]
Chiwawa River	2007	07AO	127	5
	2008	08CG	143	1
	2009	09NF	35	2
Entiat River	2007	07AL	134	4
	2008	08CI	82	4
	2009	09NC	74	1
	2010	10OX	82	1
Lower Wenatchee River	2007	07AM	139	5
	2008	08CE	98	2
Nason Creek	2007	07AN	81	4
	2008	08CF	133	6
	2009	09NG	103	2
Peshastin Creek	2008	08CH	142	2
	2009	09NE	34	1
	2010	10OY	94	1
		Total	1501	41

[a]Samples were not used if they were genetically identified as cutthroat trout or cutthroat/rainbow trout hybrids, or if they had incomplete (≤ 80% or 95 of 119 loci) or duplicate genotypes.

Table 3. List of 132 general use, diploid single nucleotide polymorphic (SNP) loci genotyped in Wenatchee River basin and Entiat River steelhead.

WDFW Name	Locus Name	Allele 1	Allele 2	Reference
AOmy005	Omy_aspAT-123	T	C	(Campbell et al. 2009)
AOmy014	Omy_e1-147	G	T	(Sprowles et al. 2006)
AOmy015	Omy_gdh-271	C	T	(Campbell et al. 2009)
AOmy016	Omy_GH1P1_2	C	T	(Aguilar and Garza 2008)
AOmy021	Omy_LDHB-2_e5	T	C	(Aguilar and Garza 2008)
AOmy023	Omy_MYC_2	T	C	(Aguilar and Garza 2008)
AOmy027	Omy_nkef-241	C	A	(Campbell et al. 2009)
AOmy028	Omy_nramp-146	G	A	(Campbell et al. 2009)
AOmy047	Omy_u07-79-166	G	T	WDFW - S. Young unpubl.
AOmy051	Omy_121713-115	T	A	(Abadía-Cardoso et al. 2011)
AOmy056	Omy_128693-455	T	C	(Abadía-Cardoso et al. 2011)
AOmy059	Omy_187760-385	A	T	(Abadía-Cardoso et al. 2011)
AOmy061	Omy_96222-125	T	C	(Abadía-Cardoso et al. 2011)
AOmy062	Omy_97077-73	T	A	(Abadía-Cardoso et al. 2011)
AOmy063	Omy_97660-230	C	G	(Abadía-Cardoso et al. 2011)
AOmy065	Omy_97954-618	C	T	(Abadía-Cardoso et al. 2011)
AOmy067	Omy_aromat-280	A	T	WSU - J. DeKoning unpubl.
AOmy068	Omy_arp-630	G	A	(Campbell et al. 2009)
AOmy071	Omy_cd59-206	C	T	WSU - J. DeKoning unpubl.
AOmy073	Omy_colla1-525	C	T	WSU - J. DeKoning unpubl.
AOmy079	Omy_g12-82	T	C	WSU - J. DeKoning unpubl.
AOmy081	Omy_gh-475	C	T	(Campbell et al. 2009)
AOmy082	Omy_gsdf-291	T	C	WSU - J. DeKoning unpubl.
AOmy089	Omy_hsp90BA-193	C	T	(Campbell and Narum 2009)
AOmy094	Omy_inos-97	C	A	WSU - J. DeKoning unpubl.
AOmy095	Omy_mapK3-103	A	T	CRITFC - N. Campbell unpubl.
AOmy096	Omy_mcsf-268	T	C	WSU - J. DeKoning unpubl.
AOmy100	Omy_nach-200	A	T	WSU - J. DeKoning unpubl.

AOmy107	Omy_Ots249-227	C	T	(Campbell et al. 2009)
AOmy108	Omy_oxct-85	A	T	WSU - J. DeKoning unpubl.
AOmy110	Omy_star-206	A	G	WSU - J. DeKoning unpubl.
AOmy111	Omy_stat3-273	G	Deletion	WSU - J. DeKoning unpubl.
AOmy113	Omy_tlr3-377	C	T	WSU - J. DeKoning unpubl.
AOmy117	Omy_u09-52-284	T	G	WDFW - S. Young unpubl.
AOmy118	Omy_u09-53-469	T	C	WDFW - S. Young unpubl.
AOmy120	Omy_u09-54.311	C	T	WDFW - S. Young unpubl.
AOmy123	Omy_u09-55-233	A	G	WDFW - S. Young unpubl.
AOmy125	Omy_u09-56-119	T	C	WDFW - S. Young unpubl.
AOmy129	Omy_BAMBI4.238	T	C	WDFW - S. Young unpubl.
AOmy132	Omy_G3PD_2.246	C	T	WDFW - S. Young unpubl.
AOmy134	Omy_Il-1b-028	T	C	WDFW - S. Young unpubl.
AOmy137	Omy_u09-61.043	A	T	WDFW - S. Young unpubl.
AOmy151	Omy_p53-262	T	A	CRITFC - N. Campbell unpubl.
AOmy173	BH2VHSVip10	C	T	Pascal & Hansen unpubl.
AOmy174	OMS00003	T	G	(Sánchez et al. 2009)
AOmy176	OMS00013	A	G	(Sánchez et al. 2009)
AOmy177	OMS00018	T	G	(Sánchez et al. 2009)
AOmy179	OMS00041	G	C	(Sánchez et al. 2009)
AOmy181	OMS00052	T	G	(Sánchez et al. 2009)
AOmy182	OMS00053	T	C	(Sánchez et al. 2009)
AOmy183	OMS00056	T	C	(Sánchez et al. 2009)
AOmy184	OMS00057	T	G	(Sánchez et al. 2009)
AOmy185	OMS00061	T	C	(Sánchez et al. 2009)
AOmy186	OMS00062	T	C	(Sánchez et al. 2009)
AOmy187	OMS00064	T	G	(Sánchez et al. 2009)
AOmy189	OMS00071	A	G	(Sánchez et al. 2009)
AOmy190	OMS00072	A	G	(Sánchez et al. 2009)
AOmy191	OMS00078	T	C	(Sánchez et al. 2009)
AOmy192	OMS00087	A	G	(Sánchez et al. 2009)

AOmy193	OMS00089	A	G	(Sánchez et al. 2009)
AOmy194	OMS00090	T	C	(Sánchez et al. 2009)
AOmy195	OMS00092	A	C	(Sánchez et al. 2009)
AOmy196	OMS00094	T	G	(Sánchez et al. 2009)
AOmy197	OMS00103	A	T	(Sánchez et al. 2009)
AOmy198	OMS00105	T	G	(Sánchez et al. 2009)
AOmy199	OMS00112	A	T	(Sánchez et al. 2009)
AOmy200	OMS00116	T	A	(Sánchez et al. 2009)
AOmy201	OMS00118	T	G	(Sánchez et al. 2009)
AOmy202	OMS00119	A	T	(Sánchez et al. 2009)
AOmy203	OMS00120	A	G	(Sánchez et al. 2009)
AOmy204	OMS00121	T	C	(Sánchez et al. 2009)
AOmy205	OMS00127	T	G	(Sánchez et al. 2009)
AOmy206	OMS00128	T	G	(Sánchez et al. 2009)
AOmy207	OMS00132	A	T	(Sánchez et al. 2009)
AOmy208	OMS00133	A	G	(Sánchez et al. 2009)
AOmy209	OMS00134	A	G	(Sánchez et al. 2009)
AOmy210	OMS00153	T	G	(Sánchez et al. 2009)
AOmy211	OMS00154	A	T	(Sánchez et al. 2009)
AOmy212	OMS00156	A	T	(Sánchez et al. 2009)
AOmy213	OMS00164	T	G	(Sánchez et al. 2009)
AOmy215	OMS00175	T	C	(Sánchez et al. 2009)
AOmy216	OMS00176	T	G	(Sánchez et al. 2009)
AOmy218	OMS00180	T	G	(Sánchez et al. 2009)
AOmy220	Omy_1004	A	T	(Hansen et al. 2011)
AOmy221	Omy_101554-306	T	C	(Abadía-Cardoso et al. 2011)
AOmy222	Omy_101832-195	A	C	(Abadía-Cardoso et al. 2011)
AOmy223	Omy_101993-189	A	T	(Abadía-Cardoso et al. 2011)
AOmy225	Omy_102505-102	A	G	(Abadía-Cardoso et al. 2011)
AOmy226	Omy_102867-443	T	G	(Abadía-Cardoso et al. 2011)
AOmy227	Omy_103705-558	T	C	(Abadía-Cardoso et al. 2011)

AOmy228	Omy_104519-624	T	C	(Abadía-Cardoso et al. 2011)
AOmy229	Omy_104569-114	A	C	(Abadía-Cardoso et al. 2011)
AOmy230	Omy_105075-162	T	G	(Abadía-Cardoso et al. 2011)
AOmy231	Omy_105385-406	T	C	(Abadía-Cardoso et al. 2011)
AOmy232	Omy_105714-265	C	T	(Abadía-Cardoso et al. 2011)
AOmy233	Omy_107031-704	C	T	(Abadía-Cardoso et al. 2011)
AOmy234	Omy_107285-69	C	G	(Abadía-Cardoso et al. 2011)
AOmy235	Omy_107336-170	C	G	(Abadía-Cardoso et al. 2011)
AOmy238	Omy_108007-193	A	G	(Abadía-Cardoso et al. 2011)
AOmy239	Omy_109243-222	A	C	(Abadía-Cardoso et al. 2011)
AOmy240	Omy_109525-403	A	G	(Abadía-Cardoso et al. 2011)
AOmy241	Omy_110064-419	T	G	(Abadía-Cardoso et al. 2011)
AOmy242	Omy_110078-294	A	G	(Abadía-Cardoso et al. 2011)
AOmy243	Omy_110362-585	G	A	(Abadía-Cardoso et al. 2011)
AOmy244	Omy_110689-148	A	C	(Abadía-Cardoso et al. 2011)
AOmy245	Omy_111005-159	C	T	(Abadía-Cardoso et al. 2011)
AOmy246	Omy_111084-526	A	C	(Abadía-Cardoso et al. 2011)
AOmy247	Omy_111383-51	C	T	(Abadía-Cardoso et al. 2011)
AOmy248	Omy_111666-301	T	A	(Abadía-Cardoso et al. 2011)
AOmy249	Omy_112301-202	T	G	(Abadía-Cardoso et al. 2011)
AOmy250	Omy_112820-82	G	A	(Abadía-Cardoso et al. 2011)
AOmy252	Omy_114976-223	T	G	(Abadía-Cardoso et al. 2011)
AOmy253	Omy_116733-349	C	T	(Abadía-Cardoso et al. 2011)
AOmy254	Omy_116938-264	A	G	(Abadía-Cardoso et al. 2011)
AOmy255	Omy_117259-96	T	C	(Abadía-Cardoso et al. 2011)
AOmy256	Omy_117286-374	A	T	(Abadía-Cardoso et al. 2011)
AOmy257	Omy_117370-400	A	G	(Abadía-Cardoso et al. 2011)
AOmy258	Omy_117540-259	T	G	(Abadía-Cardoso et al. 2011)
AOmy260	Omy_117815-81	C	T	(Abadía-Cardoso et al. 2011)
AOmy261	Omy_118175-396	T	A	(Abadía-Cardoso et al. 2011)
AOmy262	Omy_118205-116	A	G	(Abadía-Cardoso et al. 2011)

AOmy263	Omy_118654-91	A	G	(Abadía-Cardoso et al. 2011)
AOmy265	Omy_120255-332	A	T	(Abadía-Cardoso et al. 2011)
AOmy266	Omy_128996-481	T	G	(Abadía-Cardoso et al. 2011)
AOmy267	Omy_129870-756	C	T	(Abadía-Cardoso et al. 2011)
AOmy268	Omy_131460-646	C	T	(Abadía-Cardoso et al. 2011)
AOmy269	Omy_98683-165	A	C	(Abadía-Cardoso et al. 2011)
AOmy270	Omy_cyp17-153	C	T	WSU - J. DeKoning unpubl.
AOmy271	Omy_ftzf1-217	A	T	WSU - J. DeKoning unpubl.
AOmy272	Omy_GHSR-121	T	C	CRITFC - N. Campbell unpubl.
AOmy273	Omy_metA-161	T	G	CRITFC - N. Campbell unpubl.
AOmy274	Omy_UBA3b	A	T	(Hansen et al. 2011)

Primer and probe sequences for unpublished loci available by request.

Table 4. List of 20 species identification single nucleotide polymorphic (SNP) loci genotyped in Wenatchee River basin and Entiat River steelhead.

		Expected genotype			
WDFW Name	Locus Name	*O. mykiss*	*O. clarkii clarkii*	*O. clarkii lewisi*	Reference
ASpI001	Ocl_Okerca	T	C	C	(McGlauflin et al. 2010)
ASpI002	Ocl_Oku202	A	C	C	(McGlauflin et al. 2010)
ASpI003	Ocl_Oku211	G	T	T	(McGlauflin et al. 2010)
ASpI004	Ocl_Oku216	C	C	A	(McGlauflin et al. 2010)
ASpI005	Ocl_Oku217	C	C	A	(McGlauflin et al. 2010)
ASpI006	Ocl_SsaHM5	A	A	G	(McGlauflin et al. 2010)
ASpI007	Ocl_u800	T	C	C	(McGlauflin et al. 2010)
ASpI008	Ocl_u801	A	T	T	(McGlauflin et al. 2010)
ASpI009	Ocl_u802	C	C	T	(McGlauflin et al. 2010)
ASpI010	Ocl_u803	C	T	T	(McGlauflin et al. 2010)
ASpI011	Ocl_u804	G	G	C	(McGlauflin et al. 2010)
ASpI012	Omy_B9_228	A	A	C	(Finger et al. 2009)
ASpI013	Omy_CTDL1_243	C	A	A	(Finger et al. 2009)
ASpI014	Omy_F5_136	C	G	G	(Finger et al. 2009)
ASpI016	Omy_myclarp404-111	T	G	G	CRITFC - S. Narum - unpubl.
ASpI017	Omy_myclgh1043-156	C	T	T	CRITFC - S. Narum - unpubl.
ASpI018	Omy_Omyclmk436-96	A	C	C	CRITFC - S. Narum - unpubl.
ASpI019	Omy_RAG11_280	T	A	A	(Sprowles et al. 2006)
ASpI020	Omy_URO_302	T	C	C	(Finger et al. 2009)
ASpI021	Omy_BAC-F5.238	C	G	G	WDFW - S. Young unpubl.

Primer and probe sequences for unpublished loci available by request.

Table 5. Pairwise F_{ST} estimates for collections from Wenatchee River tributaries and the Entiat River (below diagonal) and associated bootstrap estimated *P*-values (above diagonal).

		Chiwawa River			Nason Creek			Peshastin Creek			Lower Wenatchee River		Entiat River			
Population	Year	2007	2008	2009	2007	2008	2009	2008	2009	2010	2007	2008	2007	2008	2009	2010
Chiwawa	2007		**0.000**	**0.003**	**0.000**	**0.000**	**0.000**	**0.000**	**0.002**	**0.000**	**0.001**	**0.001**	**0.000**	**0.001**	**0.000**	**0.000**
River	2008	0.004		**0.004**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**
	2009	0.004	0.003		**0.000**	**0.001**	0.061	**0.000**	**0.001**	**0.000**	0.086	**0.050**	**0.022**	0.108	**0.005**	**0.045**
Nason	2007	0.011	0.010	0.007		**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**
Creek	2008	0.007	0.007	0.005	0.009		**0.003**	**0.000**	**0.002**	**0.000**	0.079	**0.000**	**0.001**	**0.000**	**0.000**	**0.000**
	2009	0.007	0.007	0.003	0.014	0.006		**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**
Peshastin	2008	0.010	0.011	0.008	0.013	0.010	0.013		**0.001**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**
Creek	2009	0.005	0.005	0.006	0.010	0.007	0.008	0.003		**0.002**	**0.002**	**0.047**	**0.028**	**0.004**	**0.005**	**0.001**
	2010	0.010	0.011	0.008	0.015	0.008	0.011	0.003	0.003		**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**
Lower Wenatchee	2007	0.003	0.003	0.000	0.005	0.008	0.007	0.009	0.010	0.008		0.112	**0.020**	**0.012**	**0.002**	**0.017**
River	2008	0.002	0.005	0.002	0.003	0.004	0.005	0.007	0.009	0.006	0.000		**0.049**	0.459	**0.047**	**0.002**
Entiat	2007	0.005	0.006	0.002	0.005	0.006	0.005	0.005	0.007	0.006	0.001	0.002		0.451	0.173	**0.000**
River	2008	0.004	0.004	0.000	0.007	0.005	0.007	0.008	0.009	0.011	0.002	0.001	0.000		0.644	**0.002**
	2009	0.005	0.006	0.002	0.003	-0.001	0.003	0.002	0.003	0.004	0.003	0.002	0.002	0.000		**0.028**
	2010	0.005	0.006	0.003	0.006	0.004	0.006	0.006	0.008	0.009	0.002	0.003	0.003	0.003	0.002	

P-values in bold were significant at $\alpha = 0.05$ after correcting for multiple tests using false discovery rate.

Appendix F

NPDES Hatchery Effluent Monitoring, 2016

NPDES MONITORING FOR WDFW FACILITIES

All WDFW hatcheries monitor their discharge in accordance with the National Pollutant Discharge Elimination System (NPDES) permit. This permit is administered in Washington by the Washington Department of Ecology under agreement with the United States Environmental Protection Agency. The previous permit was extended until March 31, 2016. The current permit was renewed effective April 1, 2016 and will expire March 31, 2021.

Facilities are exempted from sampling during any month that pounds of fish on hand fall below 20,000 lbs and pounds of feed used fall below 5,000 lbs, with the exception of offline settling basin discharges which are to be monitored once per month when ponds are in use and discharging to receiving waters. Inactive permitted facilities retain a permit but are not required to monitor discharges because the pounds of fish and pounds of feed remain below monitoring guideline set by the permit.

Sampling at permitted facilities includes the following parameters:

<FLOW	Measured in millions of gallons per day (MGD) discharge.
<SS EFF	Average net settleable solids in the hatchery effluent, measured in ml/L.
<TSS COMP	Average net total suspended solids, composite sample (6 x/day) of the hatchery effluent, measured in mg/L.
<TSS MAX	Maximum daily net total suspended solids, composite sample (6 x/day) of the hatchery effluent, measured in mg/L.
<SS PA	Maximum settleable solids discharge from the pollution abatement pond, measured in ml/L.
<SS %	Removal of settleable solids within the pollution abatement pond from inlet to outlet, measured as a percent. No longer required under permit effective June 1, 2000.
<TSS PA	Maximum total suspended solids effluent grab from the pollution abatement pond discharge, measured in mg/L.
<TSS %	Removal of suspended solids within the pollution abatement pond from inlet to outlet, measured as a percent. No longer required under permit effective June 1, 2000.
<SS DD	Settleable solids discharged during drawdown for fish release. One sample per pond drawdown, measured in ml/L.
<TRC	Total residual chlorine discharge after rearing vessel disinfection and after neutralization with sodium thiosulfate. One sample per disinfection, measured in ug/L.

In addition, at Similkameen Hatchery only, the following sampling was conducted at the request of Washington Department of Ecology, but is not required under NPDES permit:

<SS IW	Settleable solids influent grab taken as wastes are pumped into the pollution abatement pond, measured in mg/L. No longer monitored as of January 2008.
<TSS IW	Total suspended solids influent grab as wastes are pumped into the pollution abatement pond, measured in mg/L. No longer monitored as of January 2008.

Eastbank Hatchery

NPDES Permit Number WAG13-5011

		FLOW	SS EFF	TSS COMP	TSS MAX	FLOW PA	SS PA	SS %	TSS PA	TSS %	Lbs of Fish	Lbs of Feed
2016	JAN	29.72	0	0	0	5000	0.01		14.2		24405	6167
	FEB	29.72	0	0	0	7000	0.01		18		34129	6724
	MAR	31.02	0	0	0	15000	0		27.5		44129	7136
	APR	14.87	0	0.2	0.2	5000	0.01		6		34824	5588
	MAY	19.39	0	0.2	0.2	7500	0.01		13		28243	8931
	JUN	29.09	0	0.2	0.2	15000	0		14.4		36506	9347
	JUL	29.09	0	0.8	0.8	12000	0.01		30.2		42904	7331
	AUG	29.09	0	0.5	1	7500	0.01		12.6		38218	7227
	SEP	29.09	0	0	0	10000	0.01		19.8		35629	11396
	OCT	29.72	0	0.6	0.6	7000	0.6		21.2		46349	12083
	NOV	29.72	0	0	0	7000	0		17.2		46363	3241
	DEC	15.51	0	0	0	5000	0		27.3		18401	4101

Wells Hatchery

NPDES Permit Number WAG13-5009

		FLOW	SS EFF	TSS COMP	TSS MAX	FLOW PA	SS PA	SS %	TSS PA	TSS %	Lbs of Fish	Lbs of Feed
2016	JAN	17.38	0.01	0	0	**	**		**		68738	14203
	FEB	19.59	0.01	1.2	1.2	**	**		**		86459	18204
	MAR	24.67	0.01	1.4	1.4	**	**		**		102881	18878
	APR	6.62	0	-10.4	9.4	**	**		**		10038	286
	MAY	6.62	0	0.4	1.6	**	**		**		10708	1660
	JUN	6.62	-0.1	-0.2	8.4	**	**		**		15118	3432
	JUL	3.97	0.01	1	1	**	**		**		5613	2481
	AUG	4.19	0.01	0	0	**	**		**		9105	3393
	SEP	6.06	0	1.4	1.4	**	**		**		13849	4538
	OCT	7.39	0	0.8	0.8	9288	0.1		2.4		22216	5753
	NOV	8.61	0.03	3.4	3.4	15309	0.05		1.2		28056	9830
	DEC	8.68	0.02	1	1	17573	0.06		1.4		46313	13557

** PA pond - No discharge. PA pond system down during hatchery rebuild.

Chiwawa Ponds - Chiwawa River
NPDES Permit Number WAG13-5015

		FLOW	SS EFF	TSS COMP	TSS MAX	Lbs of Fish	Lbs of Feed	SS DD	TSS DD
2016	JAN	3.67	0	2	2	9716	353		
	FEB	2.87	0	-0.4	-0.4	9323	518		
	MAR	3.22	0	0	0	17838	2848	0.05	5.2
	APR	2.32	0	1	1	17477	1320	0.03	14.4
	MAY		No Monitoring			0	0		
	JUN		No Monitoring			0	0		
	JUL		No Monitoring			0	0		
	AUG		No Monitoring			0	0		
	SEP	4.6	0.03	-0.4	-0.4	6553	132		
	OCT	4.49	0	-2	-0.2	6553	619		
	NOV	4.22	0	0.4	0.4	7865	750		
	DEC	3.71	0	0.8	0.8	8288	241		

Chiwawa Ponds - Wenatchee River
NPDES Permit Number WAG13-5015

		FLOW	SS EFF	TSS COMP	TSS MAX	Lbs of Fish	Lbs of Feed	SS DD	TSS DD
2016	JAN	No Monitoring				0	0		
	FEB	No Monitoring				0	0		
	MAR	No Monitoring				0	0		
	APR	2.18	0	0.8	0.8	18309	2746		
	MAY	2.25	0			7500	0	0.05	50.6
	JUN		No Monitoring			0	0		
	JUL		No Monitoring			0	0		
	AUG		No Monitoring			0	0		
	SEP		No Monitoring			0	0		
	OCT		No Monitoring			0	0		
	NOV	3	0	-1.4	-1.4	11778	1316		
	DEC	6.91	0	0.2	0.2	14254	1150		

Methow Hatchery

NPDES Permit Number WAG13-5000

		FLOW	SS EFF	TSS COMP	TSS MAX	FLOW PA	SS PA	SS %	TSS PA	TSS %	Lbs of Fish	Lbs of Feed	SS DD	TSS DD
2016	JAN	7.98	0	0.2	0.2	14400	0.1		0.2		11800	850		
	FEB	7.98	0	0	0	14400	0.1		0		12400	925		
	MAR	6.4	0	0.5	1	14400	0.1		0.2		13000	970		
	APR	6.4	0	-1.6	-1.6	14400	0.1		0.2		15000	1000	0.1	7.6
	MAY	6.4	0	0	0	14400	0.1		0.2		16000	1100	0.1	1.2
	JUN	6.2	0	0.2	0.2	14400	0.1		0.4		4000	240		
	JUL	6.4	0	0	0	14400	0		0		4400	1700		
	AUG	6.4	0	0	0	14400	0		0.2		4900	2100		
	SEP	6.4	0	0.2	0.2	14400	0		0.4		6300	3150		
	OCT	5.83	0	0	0	14400	0		0		7200	1200		
	NOV	5.83	0	0	0	14400	0		0		9100	1560		
	DEC	9.86	0	0	0	14400	0		0		10300	1100		

Similkameen Hatchery

NPDES Permit Number WAG13-5007

		FLOW	SS EFF	TSS COMP	TSS MAX	FLOW PA	SS IW	TSS IW	Lbs of Fish	Lbs of Feed	SS DD	TSS DD
2016	JAN	6.62	0	-10.4	-10.4				10038	286		
	FEB	6.62	0	0.4	0.4				10708	1660		
	MAR	6.62	-0.1	-0.2	0.2				15118	3432		
	APR	6.62	0	-14.2	-14.2				17224	2322	0	13.8
	MAY		No Monitoring						0	0		
	JUN		No Monitoring						0	0		
	JUL		No Monitoring						0	0		
	AUG		No Monitoring						0	0		
	SEP		No Monitoring						0	0		
	OCT	6.48	0	-1	-1				5730	528		
	NOV	6.84	0	-1.6	-1.6				6624	1584		
	DEC	6.48	0	0.8	0.8				7548	0		

Chelan Hatchery

NPDES Permit Number WAG13-5006

		FLOW	SS EFF	TSS COMP	TSS MAX	FLOW PA	SS PA	SS %	TSS PA	TSS %	Lbs of Fish	Lbs of Feed
2016	JAN	5.2	0.05	0.4	0.4	68000	0.05		3.2		14000	5163
	FEB	7.2	0.05	0.2	0.2	68000	0.05		1		16000	7936
	MAR	7.2	0.05	1.2	1.2	68000	0.05		4.6		27000	6417
	APR	5.2	0.05	0.7	1	68000	0.05		2.6		10332	2324
	MAY	7.2	0.05	1.2	1.2	68000	0.05		7		5400	2076
	JUN	7.2	0.05	1.2	1.2	68000	0.05		2		4200	2105
	JUL	9.5	0.04	0.4	0.4	68000	0.05		2.8		4196	4137
	AUG	9.8	0.05	-0.8	-0.8	68000	0.05		2.2		5325	5766
	SEP	9.8	0.05	0.4	0.4	68000	0.05		1.8		9374	8256
	OCT	8.9	0.05	1.4	1.4	68000	0.05		2.8		32535	10733
	NOV	8.9	0.05	0	0	68000	0.05		1.8		20152	4236
	DEC	6.23	0.05	0.2	0.2	68000	0.05		1.6		9000	3420

Chelan Falls Hatchery

NPDES Permit Number WAG13-7019

		FLOW	SS EFF	TSS COMP	TSS MAX	FLOW PA	SS PA	SS %	TSS PA	TSS %	Lbs of Fish	Lbs of Feed
2016	JAN	12.8	0.05	-6.6	-6.6	857	0.05		0.8		23897	2475
	FEB	12.8	0.05	-2	-2	857	0.05		0.2		23595	1919
	MAR	12.8	0.05	-14	-14	857	0.05		0.8		24208	5895
	APR	12.8	0.05	-1.6	-1.6	857	0.05		1.2		27623	2409
	MAY		No Monitoring								0	0
	JUN		No Monitoring								0	0
	JUL		No Monitoring								0	0
	AUG		No Monitoring								0	0
	SEP		No Monitoring								0	0
	OCT		No Monitoring								0	0
	NOV	6.9	0.04	-0.6	-0.6	3000	0.05		0.6		25846	3779
	DEC	6.9	0.04	-0.4	-0.4	3000	0.05		1.4		28196	3344

Dryden Acclimation Pond
NPDES Permit Number WAG13-5014

		FLOW	SS EFF	TSS COMP	TSS MAX	Lbs of Fish	Lbs of Feed	SS DD	TSS DD
2016	JAN		No Monitoring			0	0		
	FEB		No Monitoring			0	0		
	MAR	14.2	0	0.2	0.2	35272	484		
	APR	14.08	0.01	-0.2	-0.2	43929	2024	-0.01	12.4
	MAY		No Monitoring			0	0		
	JUN		No Monitoring			0	0		
	JUL		No Monitoring			0	0		
	AUG		No Monitoring			0	0		
	SEP		No Monitoring			0	0		
	OCT		No Monitoring			0	0		
	NOV		No Monitoring			0	0		
	DEC		No Monitoring			0	0		

Priest Rapids
NPDES Permit Number WAG13-7013

		FLOW	SS EFF	TSS COMP	TSS MAX	FLOW PA	SS PA	TSS PA	Lbs of Fish	Lbs of Feed	SS DD	TSS DD
2016	JAN	22.8	0	0.9	1	**	**	**	5054	0		
	FEB	26.6	0	0.2	0.2	**	**	**	6759	539		
	MAR	40.73	0	-0.8	-0.8		0.01	55.2	15217	5674		
	APR	26.1	0	0.2	0.2		0	17	36203	21076		
	MAY	38.03	0	1.4	1.4		0	33.8	72648	33627		
	JUN	30.25	0	0.6	0.6		0	32	108095	37585	0	1.9
	JUL		No Monitoring						0	0		
	AUG		No Monitoring						0	0		
	SEP	57.24	0			**	**	**	3280	0		
	OCT	60.39	0			**	**	**	39030	0		
	NOV	62.67	0			**	**	**	25050	0		
	DEC	34.85	0	0.6	0.6	**	**	**	7062	0		

**PA pond - No discharge this month

Appendix G

Steelhead Stock Assessment at Priest Rapids Dam, 2014-2015

Priest Rapids Dam 2014-2015 Adult Upper Columbia River Steelhead Run-Cycle Stock Assessment Report

Introduction

Upper Columbia River (UCR) steelhead stock assessment sampling at Priest Rapids Dam (PRD) is authorized through the Endangered Species Act (ESA) Section 10 Permit 1395 (NMFS 2003). Permit authorizations include interception and biological sampling of up to 10 percent of the UCR steelhead passing PRD to determine upriver population size, estimate hatchery to wild ratios, determine age-class contribution and evaluate the need for managing hatchery steelhead consistent with ESA recovery objectives, which include fully seeding spawning habitat with naturally produced UCR steelhead supplemented with artificially propagated enhancement steelhead (NMFS 2003).

Stock Assessment

The 2014 steelhead sampling at Priest Rapids Dam began on 7 July and concluded 8 November. Sampling consisted of operating the Priest Rapids Off Ladder Fish Trap (OLAFT), located on the left-bank fishway at Priest Rapids Dam, 8 hours per day, up to three days per week, for a total of 53 sampling days. Steelhead were trapped, handled, and released in accordance with Section 2.1 and 2.2.1 of the National Marine Fisheries Service (NMFS) Biological Opinion for ESA Permit 1395 (NMFS 2003). The cumulative sample rate attained during 2014 totaled 17.3%.

The Washington Department of Fish and Wildlife (WDFW) sampled 3,428 steelhead of the 2014/2015 run-cycle passing PRD, totaling 19,766 steelhead, for an overall sampling rate of 17.3%. Of the 3,428 steelhead sampled, 2,262 (70.0%) were hatchery origin and 1,166 (30.0%) were wild origin. The estimated 2014-2015 run-cycle total wild steelhead return was 5,930 representing 207.2% of the 1986-2013 average and about 106.2% of the most recent 5-year average (Table 1).

Based on external marks and external and internal tags, 2,217 hatchery-origin steelhead were sampled at Priest Rapids Dam during the 2014 return cycle and included 30.4% Wenatchee hatchery-origin steelhead and 47.1% “above Wells Dam” hatchery-origin steelhead[1] (Table 2), while 11.0% of the hatchery-origin steelhead sampled could not be assigned to a specific hatchery program. Ringold FH origin steelhead represented about 11.5% of the hatchery sample (Table 2).

[1] Defined as “above Wells Dam” because hatchery origin, adipose-clipped steelhead released into the Methow and Okanogan rivers from the Wells FH and Winthrop NFH have the same marks and are indistinguishable from one another.

Table 1. Priest Rapids Dam adult steelhead returns and stock composition, 1974-2013.

Run-cycle[1/]	Hatchery	Wild	Wild percent	Total run
1974				2,950
1975				2,560
1976				9,490
1977				9,630
1978				4,510
1979				8,710
1980				8,290
1981				9,110
1982				10,770
1983				32,000
1984				26,200
1985				34,010
1986	20,022	2,342	10.5	22,364
1987	9,955	4,058	29.0	14,013
1988	7,530	2,670	26.2	10,200
1989	8,033	2,685	25.1	10,718
1990	6,252	1,585	20.2	7,837
1991	11,169	2,799	20.0	13,968
1992	12,102	1,618	11.8	13,720
1993	4,538	890	16.4	5,428
1994	5,880	855	12.7	6,735
1995	3,377	993	22.7	4,370
1996	7,757	843	9.8	8,600
1997	8,157	785	8.8	8,942
1998	4,919	928	15.9	5,847
1999	6,903	1,374	16.6	8,277
2000	9,023	2,341	20.6	11,364
2001	24,362	5,715	19.0	30,077
2002	12,884	2,983	18.8	15,867
2003	14,890	2,837	16.0	17,729
2004	15,670	2,985	16.0	18,655
2005	10,352	3,127	23.2	13,479
2006	8,738	1,677	16.1	10,415
2007	12,160	3,097	20.3	15,257
2008	13,528	3,030	18.3	16,558
2009	32,557	7,439	18.6	39,996
2010	18,784	7,647	28.9	26,431
2011	15,910	4,896	23.5	20,806
2012	13,908	3,284	19.1	17,192
2013	10,415	4,657	30.9	15,072
2014	13,836	5,930	30.0	19,766
1986-2013 average	**11,778**	**2,862**	**19.1**	**14,204**
2009-2013 average	**18,317**	**5,583**	**24.2**	**23,899**

[1/] A return cycle is the combined total of steelhead passing PRD from 1 June – 30 November during year (x), plus steelhead passing PRD between 15 April and 31 May on year (x+1).

Table 2. Origin classification of steelhead sampled at Priest Rapids Dam, 7 July – 8 November 2014.

Steelhead origin																					
Wild			**Hatchery**																		
Wild			**Wenatchee**						**Above Wells**				**Ringold FH**			**Unk. Hat.**					
Criteria			**VIE**						**Criteria**				**Criteria**			**Criteria**			**Total**	**Total**	**Total**
NS	**NM**	**Total**	**LTGR**	**RTGR**	**RTOR**	**CWT**	**AD**	**Total**	**AD**	**Ped**	**LV**	**Total**	**AD**	**RV**	**Total**	**SD**	**NM**	**Total**	**Wild**	**Hatchery**	**Total**
x	x	1,166	x					0	x			997	x	x	255	x	x	243	1,166	2,217	3,383
				x				0		x		11									
					x			0			x	36									
						x		141													
							x	534													
Total		**1,166**						**675**				**1,044**			**255**			**243**	**1,166**	**2,217**	**3,383**
% Hatchery								**30.4**				**47.1**			**11.5**			**11.0**		**100.0**	
% Total		**34.4**						**20.0**				**30.9**			**7.5**			**7.2**	**34.5**	**65.5**	**100.0**

Reconciliation of saltwater age of wild and hatchery steelhead sampled at Priest Rapids Dam during 2014 was accomplished through scale analysis. Salt-age analysis of the 2014 UCR steelhead run-cycle provides an estimated hatchery-origin return dominated by 1-salt and 2-salt age composition of 34.1% and 65.8%, respectively (Table 3). Natural-origin steelhead salt ages were 31.1% and 68.8% for salt ages-1 and 2, respectively. Three-salt age fish represented less than 0.1% of the combined hatchery/wild sample (Table 3).

Table 3. Salt-water age composition of 2014 – 2015 return cycle Upper Columbia River steelhead sampled at Priest Rapids Dam, corrected by scale age/origin determination.

	Origin					
	Hatchery		Wild		Combined	
Salt-age	***N***	**%**	***N***	**%**	***N***	**%**
1-salt	791	35.7	370	31.1	1161	34.1
2-salt	1,422	64.3	817	68.8	2239	65.8
3-salt	0	0.0	1	0.1	1	>0.1
4-salt	0	0.0	0	0.0	0	0.0
Total	**2,213**		**1,188**		**3,401**	

Freshwater residency of naturally produced Upper Columbia River steelhead present in the 2014-2015 run-cycle were dominated by age-2 freshwater fish (78.9%), and was only slightly lower than the 1986-2013 average of 74.2% (Table 4).

Table 4. 2014 return year freshwater age of wild Upper Columbia River steelhead sampled at Priest Rapids Dam during steelhead stock assessment activities, compared to July – November 1986-2013 average.

Freshwater age	**2014-2015 run cycle**		**1986-2013 proportion**	
	N	**%**	***N***	**%**
1.x	53	4.9	489	7.9
2.x	851	78.9	4,581	74.2
3.x	168	15.6	1,046	17.0
4.x	7	0.6	51	0.8
5.x	0	0.0	3	>0.1
Total	**1,079**		**6,170**	

Wild and hatchery-origin steelhead exhibited similar saltwater growth in the 2014 run-cycle. Wild 1and 2-salt adults were slightly larger than their hatchery cohorts (Table 5). Age-1 salt hatchery and age-1 and 2 salt wild steelhead observed in the 2014-2015 adult run-cycle return past PRD were comparable in size to the 1986-2013 run-cycle average (Table 5).

Table 5. Average fork length of 1-salt and 2-salt, Upper Columbia River steelhead sampled at Priest Rapids Dam during July – November 2014 and the period between 1986-2013.

	Average fork length (cm)			
	2014-2015 run cycle		1986-2013 run cycle	
Salt age	Wild	Hatchery	Wild	Hatchery
x.1	57.4	55.8	59.7	58.7
x.2	71.1	70.2	72.5	71.6

Appendix H

Wenatchee Sockeye Salmon Spawning Escapement, 2016

PUBLIC UTILITY DISTRICT NUMBER 1 OF CHELAN COUNTY
Natural Resource Division
Fish and Wildlife Department
327 N. Wenatchee Ave., Wenatchee WA 98801 (509) 663-8121

March 28, 2017

To: HCP Hatchery Committee

From: Catherine Willard and Scott Hopkins

Subject: 2016 Wenatchee Sockeye Mark/Recapture-Based Sockeye Escapement Estimates to Tributaries

Introduction

In 2016, the Chelan County Public Utility District (District) estimated sockeye escapement to tributaries based on mark-recapture methodology. The purpose of this document is to report the spawning escapement estimates for the Little Wenatchee and White River subbasins. This information is used to track and/or estimate viable salmonid population parameters (VSP): abundance, productivity, spatial structure, and diversity (McElhaney et al. 2000).

Methods

Mark-Recapture Method:

Detection efficiencies of the in-stream arrays were calculated for the Little Wenatchee River and White River in 2016. The in-stream arrays include a series of upstream and downstream coils (Figure 1). Combined, these coils represented the upstream and downstream detection arrays, respectively. Overall detection efficiency P_{all} of the arrays was calculated based on observed detection probabilities of individual arrays:

$$P_{all} = 1 - \left(1 - P_{array\ 1}\right)\left(1 - P_{array\ 2}\right)$$

where the probability of missing a fish on both the upstream P_{array1} and downstream P_{array2} arrays were combined for an overall efficiency P_{all} (Connolly et al. 2008).

Adult sockeye salmon were tagged at adult fishways within the Columbia River and at Tumwater Dam. Additionally, adult returns that were PIT tagged as juveniles were used in the analyses. Total passage of adult sockeye salmon through Tumwater Dam was obtained from Columbia River Data Access in Real Time (DART 2016). Resulting tag files were queried in PTAGIS (2016), providing detection histories for each study fish.

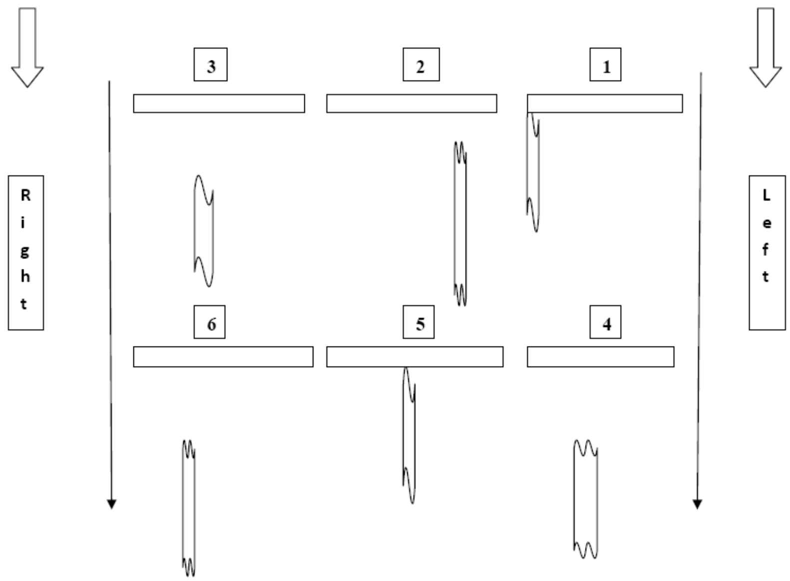


Figure 1. Schematic of a PIT array configuration.

Resulting data from passage at Tumwater Dam, mark and recapture using PIT tags, and detection efficiency estimates can provide estimation of escapement to spawning tributaries. Assumptions include: (1) the study population is "closed," i.e., no individuals die or emigrate between the initial mark and subsequent recaptures; (2) tags are not lost and detections are correctly identified; (3) all individuals have the same probability of being detected, and (4) the number of recapture events are proportional to the total population. Lastly, it was assumed that PIT-tagging efforts at Tumwater have negligible influence on fish behavior and tagged individuals behave similarly to untagged individuals. The resulting escapement rate, adjusted for detection efficiency, was then applied to the total population as such:

$$Escapement = \left(\frac{\left(\frac{Obs_{LWN}}{Eff_{LWN}} + \frac{Obs_{WTL}}{Eff_{WTL}} \right)}{PITs_{TUM}} \right) \times Counts_{TUM}$$

where the PIT tag detections (*Obs*) at the Little Wenatchee (*LWN*) and White River (WTL) were adjusted for detection efficiency (*Eff*), compared to the number released (*PITs*) at Tumwater Dam (*TUM*), and the resulting proportion was applied to the population observed (*Counts*) passing Tumwater Dam.

Results

Sockeye Salmon Mark-Recapture Method

Fishway enumeration at Tumwater Dam indicated that 73,697 adult sockeye salmon passed the facility during the 2016 migration, which was a sufficient return to open a recreational fishery in Lake Wenatchee for 2016. PIT tags were implanted in 790 fish at Tumwater and 630 fish were PIT-tagged before passing Tumwater; 130 fish were subsequently detected at the Little Wenatchee PIT tag array and 743 fish were subsequently detected at the White River PIT tag array (Table 1). Based on the recapture of PIT-tagged adult sockeye and assigned detection efficiency, total estimated escapement from Tumwater Dam to the Little Wenatchee River was 6,747 adult sockeye and 38,321 adult sockeye to the White River (Table 2).

Table 1. Number of adult sockeye salmon PIT-tagged, released, and detected upstream of Tumwater Dam in 2009 through 2016, and mark/recapture based tributary escapement estimates. Obs. = observed, D.E. = detection efficiency, Est = estimated (Obs./D.E.), and NA = not available.

Year	Number of PIT-tagged adults detected or tagged at Tumwater[1]	White River			Little Wenatchee River			Chiwawa River Obs.	Nason Creek Obs.
		Obs.	***D.E.* (p_{all})**	***Est***	Obs.	***D.E.* (p_{all})**	***Est***		
2009	1,085	381	0.406	*939*	38	0.971	*39*	37	7
2010	1,164	571	0.900[2]	*635*	67	1.000	*67*	3	1
2011	484	40	NA[3]	*NA*	84	--	*0*	0	0
2012	1,154	410	0.943	*435*	74	0.987	*75*	0	0
2013	719	152	NA[3]	*NA*	55	0.818	*67*	0	0
2014	1,729	848	0.999	*848*	76	1.000	*76*	0	3
2015[4]	950	371	0.999	*371*	50	1.000	*50*	69	4
2016	1,420	743	0.994	*738*	130	1.000	*130*	2	1

[1] Also includes fish detected downstream of release point (fallbacks).
[2] Detection efficiency p_{all} = 0.406 in 2009 was assigned from 2010 data.
[3] Technical difficulties with the White River PIT array prevented the calculation of detection efficiency and a mark-recapture based escapement estimate.
[4] In 2015, 45 sockeye salmon were detected in Chiwaukum Creek.

Table 2. Estimated escapement of adult sockeye salmon to Little Wenatchee and White rivers based on mark-recapture events, in-stream detection efficiency, and adult enumeration at Tumwater Dam, 2009-2016.

Year	Tumwater count	Recreational harvest	Little Wenatchee	White River	Combined	Escapement
2009	16,034	2,229	576	13,876	14,452	0.901
2010	35,821	4,129	2,062	19,542	21,604	0.603
2011[1]	18,634	0	2,431	14,582	17,013	0.913
2012	66,520	12,107	4,607	23,866	28,473	0.428
2013[1]	29,015	6,262	2,426	14,294	16,720	0.576
2014	99,898	16,281	4,319	49,021	53,340	0.534
2015	51,435	7,916	2,707	20,097	22,804	0.443
2016	73,697	14,630	6,747	38,321	45,068	0.612
Average	**48,882**	**7,944**	**3,234**	**24,200**	**27,434**	**0.626**

[1] Escapement was calculated using AUC counts for the Little Wenatchee River and a linear regression relationship to the Little Wenatchee River for the White River.

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Appendix I

Genetic Diversity of Wenatchee Sockeye Salmon

Assessing the Genetic Diversity of Lake Wenatchee Sockeye Salmon And Evaluating The Effectiveness Of Its Supportive Hatchery Supplementation Program

Developed for

Chelan County PUD

and the

Habitat Conservation Plan's Hatchery Committee

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March 2008

Executive Summary ………………………………………………… 1

Introduction

Lake Wenatchee Sockeye Salmon ………………………………………… 3
Sockeye Artificial Propagation In Lake Wenatchee ……………………….. 5
Previous Genetic Analyses ……………………………………………… 6
Study objectives ………………………………………………………… 7

Methods

Tissue collection ………………………………………………………… 9
Laboratory Analysis ..……………………………………………………. 9
Genetic Analysis
Assessing within collection genetic diversity ……………. 10
Assessing among-collection genetic differentiation ……… 10
Effective population size……………………………………. 11

Results/Discussion …………………………………………………… 12

Conclusions……………………………………………………………… 13

Acknowledgements …………………………………………………… 14

Literature Cited………………………………………………………… 15

Tables ………………………………………………………………… 19

Executive Summary

Nine spawning populations of sockeye (*Oncorhynchus nerka*) salmon have been identified in Washington, including stocks in the Lake Wenatchee basin (SaSI 5800) (Washington Department of Fisheries et al. 1993). Lake Wenatchee sockeye are classified as an Evolutionary Significant Unit (ESU), and consists of sockeye salmon that spawn primarily in tributaries above Lake Wenatchee (the White River, Napeequa River, and Little Wenatchee Rivers). Since 1990, the Wenatchee Sockeye Program has released juveniles into Lake Wenatchee to supplement natural production of sockeye salmon in the basin. The program's broodstock are predominantly natural-origin sockeye adults returning to the Wenatchee River captured at Tumwater Dam (Rkm 52.0), where a net-pen system is used to house both maturing adults and juveniles prior to release into Lake Wenatchee to over-winter.

Previous genetic studies have generally found a lack of concordance between population genetic relationships and their geographic distributions. These studies indicate that the nearest geographic neighbors of sockeye salmon populations are not necessarily the most genetically similar. Specifically for the Columbia River Basin, sockeye from Lake Wenatchee, Okanogan River, and Redfish Lake may be more closely related to a population from outside the Columbia River (depending on marker used) then to each other.

In this study we investigated the temporal and spatial genetic structure of Lake Wenatchee sockeye collections, without regard to sockeye populations outside of the Lake Wenatchee area. Our primary objective here was to determine if the Wenatchee Sockeye Program affected the natural Lake Wenatchee sockeye population. More specifically, we were tasked to determine if the genetic composition of Lake Wenatchee sockeye population had been altered by a supplementation program that was based on the artificial propagation of a small subset of that population. Using microsatellite DNA allele frequencies, we investigated population differentiation between temporally replicated collections of natural-origin Lake Wenatchee sockeye and program broodstock. We analyzed thirteen collections of Lake Wenatchee sockeye (Table 1), eight temporally replicated collections of natural-origin Lake Wenatchee sockeye (N=786) and five temporally replicated collections of Wenatchee Sockeye Program broodstock (N=248). Paired natural – broodstock collections were available from years 2000, 2001, 2004, 2006, and 2007.

Conclusions

We observed that allele frequency distributions were consistent over time, irrespective of collection origin, resulting in small and statistically insignificant measures of genetic differentiation among collections. We interpreted these results to indicate no year-to-year differences in allele frequencies among natural-origin or broodstock collections. Furthermore, there were no observed difference between pre- and post-supplementation collections. Therefore, we accepted our null hypothesis that the allele frequencies of the broodstock collections equaled the allele frequencies of the natural collections, which equaled the allele frequency of the donor population. Given the small differences in genetic composition among collections, the genetic model for estimating N_e produced estimates with extremely large variances, preventing the observation of any trend in N_e.

Introduction

A report titled "Conceptual Approach to Monitoring and Evaluating the Chelan County Public Utility District Hatchery Programs" was prepared July 2005 by Andrew Murdoch and Chuck Peven for the Chelan PUD Habitat Conservation Plan's Hatchery Committee. This report outlined 10 objectives to be applied to various species assessing the impact (positive or negative) of hatchery operations mitigating the operation of Rock Island Dam. This current study pertains only to Lake Wenatchee sockeye and objective 3:

> *Determine if genetic diversity, population structure, and effective population size have changed in natural spawning populations as a result of the hatchery program. Additionally, determine if hatchery programs have caused changes in phenotypic characteristics of natural populations.*

In order to evaluate cause and effect of hatchery supplementation, WDFW Molecular Genetics Lab surveyed genetic variation of Lake Wenatchee sockeye. The conceptual approach for this project follows that of a parallel study regarding the Wenatchee River spring Chinook supplementation program (Blankenship et al. 2007). We determined the genetic diversity present in the Lake Wenatchee sockeye population by analyzing temporally replicated collections spanning 1989 – 2007, which included collections from before and following the inception of the Wenatchee Sockeye Program. Documenting the genetic composition of the Lake Wenatchee sockeye population is necessary to assess the effect of the hatchery program on the Lake Wenatchee population. In addition, this work provides a genetic baseline for future projects requiring genetic data. See study objectives below for specific details about how this project addresses Murdoch and Peven (2005) objective 3.

Lake Wenatchee Sockeye Salmon

Nine spawning populations of sockeye (*Oncorhynchus nerka*) salmon have been identified in Washington (Washington Department of Fisheries et al. 1993): 1) Baker

River, 2) Ozette Lake, 3) Lake Pleasant, 4) Quinault Lake, and 5) Okanogan River (classified as native stock); 6) Cedar River (classified as non-native stock); 7) Lake Wenatchee, classified as mixed stock); 8) Lake Washington/Lake Sammamish tributaries; and 9) Lake Washington beach spawners (classified as unknown origin). Chapman et al. (1995) listed four additional spawning aggregations of sockeye salmon that appear consistently in Columbia River tributaries: the Methow, Entiat, and Similkameen Rivers; and Icicle Creek in the Wenatchee River drainage.

Located in north central Washington, the Wenatchee River basin drains a portion of the eastern slope of the Cascade Mountains, including high mountainous regions of the Cascade crest. The headwater area of the Wenatchee River is Lake Wenatchee, a typical low productivity oligotrophic or ultra-oligotrophic sockeye salmon nursery lake (Allen and Meekin 1980, Mullan 1986, Chapman et al. 1995). Sockeye salmon bound for Lake Wenatchee enter the Columbia River in April and May and arrive at Lake Wenatchee in late July to early August (Chapman et al. 1995; Washington Department of Fisheries et al. 1993). The run timing of Lake Wenatchee sockeye salmon, classified as an Evolutionary Significant Unit (ESU), appears to have become earlier by 6 - 30 days during the past 70 years (Chapman et al. 1995; Quinn and Adams 1996). Additionally, scale pattern analysis suggests Wenatchee sockeye migrate past Bonneville Dam earlier than the sockeye bound for the Okanogan River (Fryer and Schwartzberg 1994). The Wenatchee population spawns from mid-September through October in the Little Wenatchee, White, and Napeequa Rivers above Lake Wenatchee (Washington Department of Fisheries et al. 1993), peaking in late September (Chapman et al. 1995). Limited beach spawning is believed to occur in Lake Wenatchee (L. Lavoy pers. com.; Mullan 1986), although Gangmark and Fulton (1952) reported two lakeshore seepage areas in Lake Wenatchee that were used by spawning sockeye salmon. Sockeye salmon fry enter Lake Wenatchee between March and May (Dawson et al. 1973), and typically rear in the lake for one year before leaving as smolts (Gustafson et al. 1997; Peven 1987).

Both the physical properties of the habitat and ecological/biological factors of the sockeye populations differ between the Lake Wenatchee ESU and the geographically proximate Okanogan ESU. For example: 1) Different limnology is encountered by sockeye salmon in Lakes Wenatchee and Osoyoos; 2) Lake Wenatchee sockeye predominantly return at ages four and five (a near absence of 3-year-olds), where a large percentage of 3-year-olds return to the Okanogan population; and 3) the apparent one month separation in juvenile outmigration-timing between Okanogan- and Wenatchee-origin fish (Gustafson et al. 1997 and references therein).

Sockeye Artificial Propagation In Lake Wenatchee

The construction of Grand Coulee Dam completely blocked fish passage to the upper Columbia River, and 85% of sockeye salmon passing Rock Island Dam between 1935 and 1936 were estimated to be from natural stocks bound for areas up-river to Grand Coulee Dam (Mullan 1986; Washington Department of Fisheries et al. 1938). To compensate for loss of habitat resulting from Grand Coulee Dam, the federal government initiated the Grand Coulee Fish-Maintenance Project (GCFMP) in 1939 to maintain fish runs in the Columbia River above Rock Island Dam. Between 1939 and 1943, all sockeye salmon entering the mid-Columbia River were trapped at Rock Island Dam, and over 32,000 mixed Lake Wenatchee, Okanogan River, and Arrow Lake adult sockeye salmon were released into Lake Wenatchee (Gustafson et al. 1997 Appendix Table D-2). In addition to adult relocation, between 1941 and 1969 over 52.8 million fry descended from original spawners collected at Rock Island and Bonneville Dams, were released into Lake Wenatchee (Gustafson et al. 1997 Appendix Table D-2).

No releases of artificially-reared sockeye salmon occurred in the Wenatchee watershed during the years 1970 to 1989 (Gustafson et al. 1997 Appendix Table D-2). Since 1990, the Wenatchee Sockeye Program has released juveniles into Lake Wenatchee to supplement natural production of sockeye salmon in the basin. Sockeye adults returning to the Wenatchee River are captured at Tumwater Dam (Rkm 52.0) and transferred to Lake Wenatchee net pens until mature. The Wenatchee Sockeye Program goals are 260 adults with an equal sex ratio, <10% hatchery-origin returns (identified by coded wire tags), and the adults removed for broodstock account for <10% of the run size. Fish are spawned at Lake Wenatchee and their gametes are taken to Rock Island Fish Hatchery

Complex (i.e., Eastbank) for fertilization and incubation. Fry are returned to the Lake Wenatchee net -pens after they are large enough to be coded wire tagged, and are housed in the pens until fall (one year after spawning), when they are liberated into the lake to over-winter. For brood years 1991 – 2004 an average of 218,683 (std. dev. = 71,090) pen-reared Lake Wenatchee-origin juvenile sockeye salmon have been released yearly into Lake Wenatchee.

Previous Genetic Studies

Protein (allozyme) variation – Surveying genetic variation at 12 allozyme loci, Utter et al. (1984) reported moderate population structure among 16 sockeye collections from southeast Alaska through the Columbia River Basin, including Okanogan and Wenatchee stocks, with an apparent genetic association between upper Fraser River and Columbia River sockeye salmon. Winans et al. (1996) surveyed variation at 55 allozyme loci for 25 sockeye salmon and two kokanee collections from 21 sites in Washington, Idaho, and British Columbia, and reported the lowest level of allozyme variability of any species of Pacific salmon and a highest level of inter-population differentiation. Furthermore, these authors reported that there was no clear relationship between geographic and genetic differentiation among the populations within there study. Other studies corroborate the results of Winans et al. (1996), finding a lack of discernible geographic patterning for sockeye salmon populations in British Columbia, Alaska, and Kamchatka (Varnavskaya et al. 1994, Wood et al. 1994, Wood 1995). These studies indicate that the nearest geographic neighbors of sockeye salmon populations are not necessarily the most genetically similar, which contrasts with the other Pacific salmon species that exhibit concordance between geographic and genetic differentiation (Utter et al. 1989, Winans et al. 1994, Shaklee et al. 1991). As part of the comprehensive status review of west coast sockeye salmon (Gustafson et al. 1997), NMFS biologists collected new allozyme genetic information for 17 sockeye salmon populations and one kokanee population in Washington and combined these data for analysis with the existing Pacific Northwest sockeye salmon and kokanee data from Winans et al. (1996). Results of the updated study were consistent with Winans et al. (1996), with no clear concordance between geographic and genetic distances. Sockeye salmon from Lake Wenatchee, Redfish Lake, Ozette Lake, and Lake Pleasant are very distinct from other collections in the study, and Columbia River populations were not necessarily most closely related to each other. Gustafson et al. (1997) also examined between-year variability within a collection location and found low levels of statistical significance among the five Lake Wenatchee collections included in the study (For 10 pair-wise comparisons using sum-G test, five were statistically significant). Lake Wenatchee brood year 1987 accounted for three of the significant comparisons, which were driven by unusually high frequencies of two allozyme alleles (ALAT*95 and ALAT*108) (Winans et al. 1996). Nevertheless, Gustafson et al. (1997) conclude that, in general, temporal variation at a locale was considerably less than between-locale variation.

Nucleic acid variation - Beacham et al. (1995) reported levels of variation in nuclear DNA of *O. nerka* using minisatellite probes. They analyzed 10 collections, including a sample from Lake Wenatchee. Cluster analysis showed the Lake Wenatchee sample was different from all the other collections, including those from the Columbia River. Using a similar molecular technique, Thorgaard et al. (1995) examined the use of multi-locus DNA fingerprinting (i.e., banding patterns) to discriminate among 14 sockeye salmon and kokanee populations. Dendrograms based on analysis of banding patterns produced different genetic affinity groups depending on the probes used. While none of the five DNA probes showed a close relationship between Lake Wenatchee and Okanogan River sockeye salmon, if information from all probes were combined, *O. nerka* from Redfish Lake, Wenatchee, and Okanogan were separate from kokanee of Oregon and Idaho and a sockeye salmon sample from the mid-Fraser River.

Study Objective

We documented temporal variation in genetic diversity (i.e., heterozygosity and allelic diversity), and investigated population differentiation between temporally replicated collections of natural-origin Lake Wenatchee sockeye and program broodstock, using microsatellite DNA allele frequencies. Temporally replicated collections from the same location can also be used to estimate effective population size (N_e). If populations are "ideal", the census size of a population is equal to the "genetic size" of the population.

Yet, numerous factors lower the "genetic size" below census, such as, non-equal sex ratios, changes in population size, and variance in the numbers of offspring produced from parent pairs. N_e is thought to be between 0.10 and 0.33 of the estimated census size (Bartley et al. 1992; RS Waples pers. comm.), although numerous observations differ from this general rule. N_e can be calculated directly from demographic data, or inferred from observed differences in genetic variance over time. Essentially, when calculated from genetic data, N_e is the estimated size of an "ideal" population that accounts for the genetic diversity changes observed, irrespective of abundance.

We will address the hypotheses associated with Objective 3 in Murdock and Peven (2005) using the following four specific tasks:

Task 1 - Document the observed genetic diversity.

Task 2 - Test for population differentiation among Lake Wenatchee collections and the associated supplementation program.

Task 2 was designed to address two hypotheses listed as part of Objective 3 in Murdoch and Peven (2005):

- Ho: Allele frequency $_{\text{Hatchery}}$ = Allele frequency $_{\text{Naturally produced}}$ = Allele frequency $_{\text{Donor pop}}$.
- Ho: Genetic distance between subpopulations $_{\text{Year x}}$ = Genetic distance between subpopulations $_{\text{Year y}}$

Murdoch and Peven (2005) proposed these two hypotheses to help evaluate supplementation programs through a "Conceptual Process" (Figure 5 in Murdoch and Peven 2005). There are two components to the first hypothesis, which must be considered separately for Lake Wenatchee sockeye. The first component involves comparisons between natural-origin populations from Lake Wenatchee to determine if there have been changes in allele frequencies through time starting with the donor population. Documenting a change does not necessarily indicate that the supplementation program has directly affected the natural-origin fish, as additional tests would be necessary to support that hypothesis. The intent of the second component is to determine if the hatchery produced populations have the same genetic composition as the naturally produced populations.

Task 3 - Calculate N_e using the temporal method for multiple samples from the same location to document trend.

Task 4 - Compare N_e estimates with trend in census size for Lake Wenatchee sockeye.

Methods and Materials

Sampling

Thirteen collections of Lake Wenatchee sockeye were analyzed, eight temporally replicated collections of natural Lake Wenatchee sockeye (N=786) and five temporally replicated collections of Wenatchee Sockeye Program broodstock (N=248) (Table 1). Paired natural – broodstock collections were available from years 2000, 2001, 2004, 2006, and 2007 (Table 1). All collections were made at Tumwater Dam on the Wenatchee River. Note that collections classified as broodstock were predominantly natural-origin sockeye. A majority of the genetic samples were from dried scales. The tissue collections from 2006 and 2007 were fin clips stored immediately in ethanol after collection. DNA was extracted from stored tissue using Nucleospin 96 Tissue following the manufacturer's standard protocol (Macherey-Nagel, Easton, PA, U.S.A.).

Laboratory Analysis

Polymerase chain reaction (PCR) amplification was performed using 17 fluorescently end-labeled microsatellite marker loci, *One* 2 (Scribner et al 1996) *One* 100, 101, 102, 105, 108, 110, 114, and 115 (Olsen et al. 2000), *Omm* 1130, 1135, 1139, 1142, 1070, and 1085 (Rexroad et al. 2001), *Ots* 3M (Banks et al. 1999) and *Ots* 103 (Small et al. 1998). PCR reaction volumes were 10 μL, with the reaction variables being 2 μL 5x PCR buffer (Promega), 0.6 μL $MgCl_2$ (1.5 mM) (Promega), 0.2 μL 10 mM dNTP mix (Promega), and 0.1 μL *Go Taq* DNA polymerase (Promega). Loci were amplified as part of multiplexed sets, so primer molarities and annealing temperatures varied. Multiplex one had an annealing temperature of 55°C, and used 0.09 Molar (M) *One* 108, 0.06 M *One* 110, and 0.11 M *One* 100. Multiplex two had an annealing temperature of 53°C, and used 0.08 M *One* 102, 0.1 M *One* 114, and 0.05 M *One* 115. Multiplex three had an annealing temperature of 55°C, and used 0.08 M *One* 105 and 0.07 M *Ots* 103. Multiplex four had an annealing temperature of 53°C, and used 0.09 M *Omm* 1135 and 0.08 M *Omm* 1139. Multiplex five had an annealing temperature of 60°C, and used 0.2 M *Omm* 1085, 0.09 M *Omm* 1070, and 0.05 M *Ots* 3M. Multiplex six had an annealing temperature of 48°C, and used 0.06 M *One* 2, 0.08 M *Omm* 1142, and 0.08 M *Omm* 1130. *One* 101 was run in isolation with a primer molarity of 0.06. Thermal cycling was conducted on either PTC200 (MJ Research) or GeneAmp 9700 thermal cyclers as follows: 94°C (2 min); 30 cycles of 94°C for 15 sec., 30 sec. annealing, and 72°C for 1 min.; a final 72°C extension and then a 10°C hold. PCR products were visualized by denaturing polyacrylamide gel electrophoresis on an ABI 3730 automated capillary analyzer (Applied Biosystems). Fragment analysis was completed using GeneMapper 3.7 (Applied Biosystems).

Genetic data analysis

Assessing within collection genetic diversity - Heterozygosity measurements were reported using Nei's (1987) unbiased gene diversity formula (i.e., expected heterozygosity) and Hedrick's (1983) formula for observed heterozygosity. Both tests were implemented using the microsatellite toolkit (Park 2001). For each locus and collection FSTAT version 2.9.3.2 (Goudet 1995) was used to assess Hardy-Weinberg equilibrium, where deviations from the neutral expectation of random associations among alleles were calculated using a randomization procedure. Alleles were randomized among individuals within collections (4160 randomizations for this dataset) and the F_{IS} (Weir and Cockerham 1984) calculated for the randomized datasets were compared to the observed F_{IS} to obtain an unbiased estimation of the probability that the null hypothesis was true. The 5% nominal level of statistical significance was adjusted for multiple tests (Rice 1989). Genotypic linkage disequilibrium was calculated following Weir (1979) using GENETIX version 4.05 (Belkhir et al. 1996). Statistical significance of linkage disequilibrium results was assessed using a permutation procedure implemented in GENETIX for each locus by locus combination within each collection.

Assessing among collection genetic differentiation - The temporal stability of allele frequencies was assessed by the randomization chi-square test implemented in FSTAT version 2.9.3.2 (Goudet 1995). Multi-locus genotypes were randomized between collections. The G-statistic for observed data was compared to G-statistic distributions from randomized datasets (i.e., null distribution of no differentiation between collections). Population differentiation was also investigated using pairwise estimates of F_{ST}. Multi-locus estimates of pairwise F_{ST}, estimated by a "weighted" analysis of variance (Weir and Cockerham, 1984), were calculated using GENETIX version 4.05 (Belkhir et al.1996). F_{ST} was used to quantify population structure, the deviation from statistical expectations (i.e., excess homozygosity) due to non-random mating between populations. To determine if the observed F_{ST} estimate was consistent with statistically expectations of no population structure, a permutation test was implemented in GENETIX (1000 permutations).

Effective population size (N_e) – Estimates of the effective population size were obtained using a multi-collection temporal method (Waples 1990a). The temporal method assumes that cohorts are used, but we did not decompose the collection year samples into their respective cohorts using age data. Therefore, N_e estimates that pertain to individual year classes of breeders are not valid; however the harmonic mean over all samples will estimate an N_e that pertains to the time period from which the collections are derived. Comparing samples from years *i* and *j*, Waples' (1990a) temporal method estimates the effective number of breeders ($\hat{N}_{b(i,j)}$) according to:

$$\hat{N}_{b(i,j)} = \frac{b}{2(\hat{F} - 1/\tilde{S}_{i,j})}$$

The standardized variance in allele frequency ($\hat{F}$) is calculated according to Pollack (1983). The parameter b is calculated analytically from age structure information and the number of years between samples (Tajima 1992). The age-at-maturity information required to calculate b was obtained from ecological data (Hillman et al. 2007). The harmonic mean of sample sizes from years *i* and *j* is $\tilde{S}_{i,j}$. The harmonic mean over all pairwise estimates of $\hat{N}_{b(i,j)}$ is $\tilde{N}_b$. SALMONNb (Waples et al. 2007) was used to calculate $\tilde{N}_b$.

Results and Discussion

In this section we combine our presentation and interpretations of the genetic analyses. Additionally, this section is organized based on the task list presented in the study plan.

Task 1 - Document the observed genetic diversity.

Substantial genetic diversity was observed over all Lake Wenatchee sockeye collections analyzed (Table 1), with heterozygosity estimates over all loci having a mean of 0.79. Genetic diversity was consistent with expected Hardy-Weinberg random mating genotypic proportions for all collections. The F_{IS} observed for each collection was not statistically significant given the distribution of F_{IS} generated using a randomization procedure. Additionally, there were no statistically significant associations observed between alleles across loci (i.e., linkage equilibrium) (data not shown). We concluded from these results that the genetic data from each collection was consistent with statistical expectations for random association of alleles within and between loci. In other words, each collection represents samples from a single gene pool (i.e., populations), and the genetic diversity observed has no detectable technical artifacts or evidence of natural selection.

Task 2 - Test for differentiation among Lake Wenatchee collections and the associated supplementation program.

We explicitly tested the hypothesis of no significant differentiation within natural-origin or broodstock collections from Lake Wenatchee using a randomization chi-square test. The null hypothesis for these tests was that the allele frequencies from two different populations were drawn from the same underlying distribution. We show the results for the pairwise comparisons among eight temporally replicated natural-origin collections from Lake Wenatchee (28 pairwise tests), and report all tests were non-significant (Table 2A). Similarly, for five temporally replicated broodstock collections, 10 of 10 pairwise tests were non-significant (Table 2B). We also tested if natural-origin and broodstock collections were differentiated from each other over time, and report that 40 of 40 tests were non-significant (Table 2C). The nominal level of statistical significance ($\alpha = 0.05$) was adjusted for multiple comparisons using strict Bonferroni correction (Rice 1989). Yet, there are perhaps slight differences between paired natural-broodstock collections. Note that the p-values for comparisons regarding 2006 and 2007 paired collections are lower than for comparisons regarding 2000, 2001, and 2004. The small sample sizes for broodstock collections in 2006 and 2007 may not have been random samples from the Lake Wenatchee sockeye population.

Given the consistencies observed for allele frequency distributions over time, metrics of population structure were expected to be small. This was the case, as the estimated F_{ST} over all thirteen collections was 0.0003. This observed value fell within the distribution of F_{ST} values expected if there were no population structure present (permutation test p-value 0.12). Analysis of the paired natural-broodstock collections corroborated this result. Pairwise estimates of F_{ST} were 0.000 for years 2000, 2001, 2004, and 2007, and 0.002 for 2006. All five estimates were non-significant. Essentially, all 13 sockeye collections could be considered samples from the same population. Given these results, it is valid to combine all collections for statistical analysis. Therefore, we did not calculate genetic distances among any collections, as it is inappropriate to estimate distances that are effectively zero.

Conclusions

We interpret these data to indicate that there appears to be no significant year-to-year differences in allele frequencies among natural-origin or broodstock collections, nor are there observed differences between collections pre- and post-supplementation. As a result, we accept the null hypothesis that the allele frequencies of the broodstock collections equal the allele frequencies of the natural collections, which equals the allele frequency of the donor population. Furthermore, the observed genetic variance that can be attributed to among collection differences was negligible.

Task 3 - Calculate N_e using the temporal method for multiple samples from the same location to document trend.

The fundamental parameter for inferring N_e using genetic data is the standardized variance in allele frequency ($\hat{F}$) (Pollack 1983). Methods estimate N_e from observed changes in $\hat{F}$ over temporally replicated collections from the same location. Yet, as previously shown, there were no statistically significant differences detected in allele frequencies. The underlying model for estimating N_e produced estimates with extremely large variances, given small temporal differences in $\hat{F}$, which rendered any trend in N_e unobservable. Table 3 shows N_e estimates calculated using temporally replicated natural collections.

Task 4 - Compare N_e estimates with trend in census size for Lake Wenatchee sockeye.

See Task 3

Acknowledgements

We would like to thank Jeff Fryer (CRITFC) for providing critical collections of natural-origin sockeye from Lake Wenatchee. We would like to thank Norm Switzler for collection curation and Ken Warheit and Denise Hawkins for helpful comments regarding this project. This project was funded by Chelan County PUD and the Washington State General Fund.

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Table 1 Lake Wenatchee sockeye collections analyzed. MNA is the mean number of alleles per locus, Hz is unbiased heterozygosity, Obs Hz is observed heterozygosity, and HW is the p-value of the null hypothesis of random association of alleles (i.e., Hardy – Weinberg equilibrium). For reference, the nominal level of statistical significance at $\alpha = 0.05$ is 0.0002 after correction for multiple tests.

Year	Collection Code	Tissue Type	Source	N	MNA	Hz	Obs Hz	HW
1989	89[1]	Scales	Natural	96	14.35	0.792	0.791	0.424
1990	90[1]	Scales	Natural	96	13.19	0.793	0.779	0.131
2000	00AAE	Scales	Broodstock	96	12.31	0.787	0.776	0.213
2000	00[1]	Scales	Natural	96	11.76	0.801	0.826	0.868
2001	01AAS	Scales	Broodstock	53	9.47	0.788	0.793	0.392
2001	01[1]	Scales	Natural	96	14.35	0.786	0.794	0.456
2002	02[1]	Scales	Natural	96	14.53	0.794	0.777	0.780
2004	04[1]	Scales	Natural	96	14.65	0.798	0.803	0.704
2004	04AAV	Scales	Broodstock	43	14.35	0.796	0.795	0.051
2006	06CN	Tissue	Broodstock	38	14.59	0.793	0.785	0.688
2006	06CO	Tissue	Natural	96	14.53	0.806	0.803	0.408
2007	07EE	Tissue	Broodstock	18	14.00	0.790	0.790	0.221
2007	07EF	Tissue	Natural	96	14.35	0.789	0.800	0.347

[1] Samples taken from scale cards provided by Jeff Fryer (CRITFC)

Table 2 Allelic differentiation for Lake Wenatchee sockeye collections. A single analysis tested (pairwise) the allelic differentiation between all thirteen collections; however p-values for G-statistics are partitioned in the table by A) natural-origin, B) broodstock, and C) natural versus broodstock. Underlined values are for paired natural-broodstock collections from the same year. For reference, the nominal level of statistical significance at $\alpha = 0.05$ is 0.0006 after correction for multiple tests. No significant values were observed.

A) Natural-Origin Collections

	89	90	00	01	02	04	06CO	07EF
89		0.257	0.359	0.531	0.331	0.127	0.031	0.263
90			0.953	0.148	0.753	0.903	0.077	0.283
00				0.328	0.527	0.607	0.604	0.400
01					0.209	0.081	0.127	0.093
02						0.085	0.707	0.235
04							0.312	0.577
06CO								0.435
07EF								

B) Broodstock Collections

	00AAE	01AAS	04AAV	06CN	07EE
00AAE		0.189	0.090	0.008	0.058
01AAS			0.122	0.020	0.116
04AAV				0.008	0.031
06CN					0.326
07EE					

C) Natural vs. Broodstock

	89	90	00	01	02	04	06CO	07EF
00AAE	0.027	0.309	0.572	0.018	0.041	0.012	0.093	0.040
01AAS	0.115	0.471	0.160	0.219	0.519	0.049	0.654	0.133
04AAV	0.136	0.219	0.210	0.423	0.208	0.328	0.037	0.153
06CN	0.029	0.004	0.053	0.007	0.022	0.004	0.019	0.001
07EE	0.099	0.229	0.053	0.015	0.093	0.178	0.090	0.037

Table 3 Estimation of N_e for temporally replicated natural-original sockeye collections. Above the diagonal are pairwise estimates of N_e, where negative values mean sampling variance can account for genetic variance observed (i.e., genetic drift unnecessary). Below the diagonal are variances for pairwise estimates of N_e. Absent variance values (denoted by **-**) were too large for SalmonNb to display.

Collection	89	90	00	01	02	04	06CO	07EF
89		-3936.6	-1414	-2636.3	671.4	1871.1	1066.1	1951.2
90	2.59E+09		-1490.3	3649.1	-31144	-6808.4	817.6	93190.2
00	1.40E+09	4.45E+09		-592.2	-6842.2	-667.1	-1736.9	-1350.1
01	1.21E+09	1.47E+09	2.33E+09		977.1	6160.4	387.8	2531.5
02	1.91E+09	1.33E+09	1.16E+09	2.29E+09		1495.6	-848.5	3213.6
04	2.21E+09	3.62E+09	4.08E+09	1.27E+09	1.14E+09		896.6	2155.3
06CO	1.34E+09	1.39E+09	1.73E+09	**-**	4.51E+09	1.2E+09		3278.6
07EF	2.15E+09	1.51E+09	1.18E+09	1.68E+09	**-**	1.36E+09	2.65E+09	

Appendix J

Wenatchee Spring Chinook Redd Estimates, 2016

Spring Chinook Redd Estimates - 2016

Upper Wenatchee

Kevin See

December 22, 2016

Goals

Redd counts are an established method to provide an index of adult spawners (Gallagher et al. 2007). In the Wenatchee subbasin, spawning reaches are surveyed weekly during the spring Chinook spawning season (Jul 25, 2016 - Oct 03, 2016). The goals of this work are to:

- Estimate the true number of redds in each spawning reach with uncertainty.
- Summarize the number of redds at the tributary and population scale.

Methods

Data

Data were collected on the number of new redds during each survey (usually conducted about every week during the spawning season). Covariates such as surveyor experience, mean thalweg CV, and redd density (observed redds / km) were also collected on the reach scale to make predictions of surveyor error.

Surveyor Error

From the results of a previous study on spring Chinook, similar to the one outlined in Murdoch et al. (2014) for steelhead, we had a model that predicted surveyor net error (ratio of identified redds to true redds) based on covariates such as the surveyor's total experience with spawning ground surveys, the mean thalweg CV, and the observed redd density (redds/km). This model suggests that increasing experience and observed redd density lead to higher net error, while increasing the stream complexity (mean thalweg CV) leads to lower net error.

Because the net error model is a linear model, and therefore not constrained to be between 0 and 1 (less than 1 implies an underestimate of the number of redds, while net error greater than 1 implies an overestimate due to false identifications), we examined the values of the predictive covariates and compared them to the values used to fit the net error model. Several values were outside the range of the model dataset (See Figure 1). However, using those more extreme values did not result in absurd predictions of observer error, so we did not alter or constrain them.

Values of the covariates for the net surveyor error model, colored by stream. Dashed lines depict the range of values from the data set used to develop the net error model.

Total Redds

Estimates of total redds were made for each reach using the Gaussian area under the curve (GAUC) model described in Millar et al. (2012). The GAUC model was developed with spawner counts in mind. As it is usually infeasible to mark every individual spawner, only total spawner counts can be used, and an estimate of average stream life must be utilized to translate total spawner days to total unique spawners. However, in adapting this for redd surveys, individual redds can be marked, and therefore we fit the GAUC model to new redds only. The equivalent of stream life thus becomes the interval between surveys. However, this year surveys were unable to be conducted during several weeks coinciding with peak spawning in the Chiwawa. Therefore, to fit the GAUC model, we used survey number instead of Julian day, and set the survey interval to one. We fit these models to reach-scale data, which did pose several challenges for a few reaches. We did not make

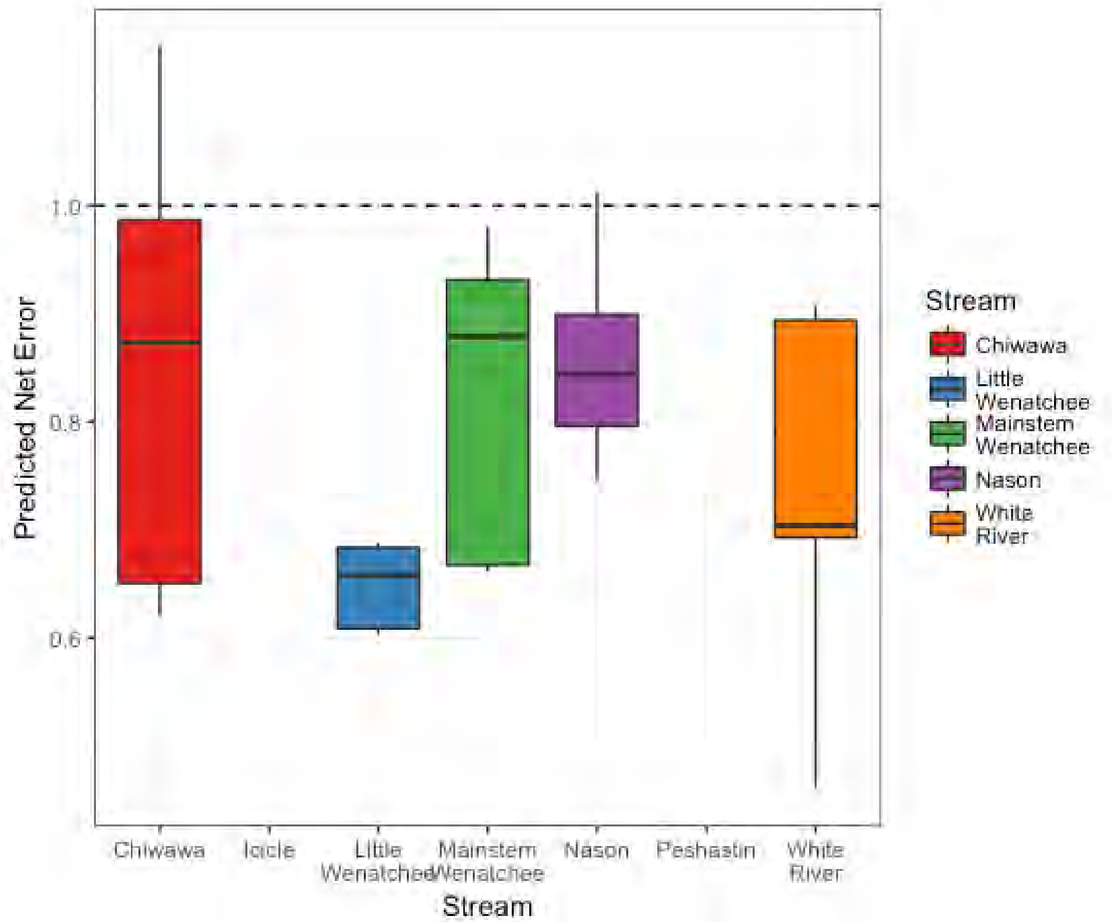
GAUC estimates for reaches that had fewer than 2 observed redds, or less than 3 weeks with at least one new redd observed.

When summing GAUC estimates at the reach-scale to obtain estimates at the stream scale, an attempt was made to incorporate the fact that the reaches within a stream are not independent. Estimates of correlation between the reaches within a stream were made based on weekly observed redds. This method may not be perfect, since spawners may use certain reaches preferentially at different times in the season, but it may be the best we can do. Because correlations are often quite high between reaches, this is a better alternative than to naively assume the standard errors between reaches are independent of one another. These estimates of correlation were combined with GAUC estimates of standard error for each reach to calculate a covariance matrix for the reaches within each stream, which was used when summing estimates of total redds to estimate the standard error at the stream-scale. Failure to incorporate the correlations between reaches would result in an underestimate of standard error at the stream scales. Different streams (and therefore reaches in different streams) were assumed to be independent.

Results

Surveyor Error

Predictions of net error are shown in Figure 2. Most predictions were less than one, implying some redds may have been missed. A few surveys had predictions of net error greater than one, implying some redds identified by surveyors were false redds.



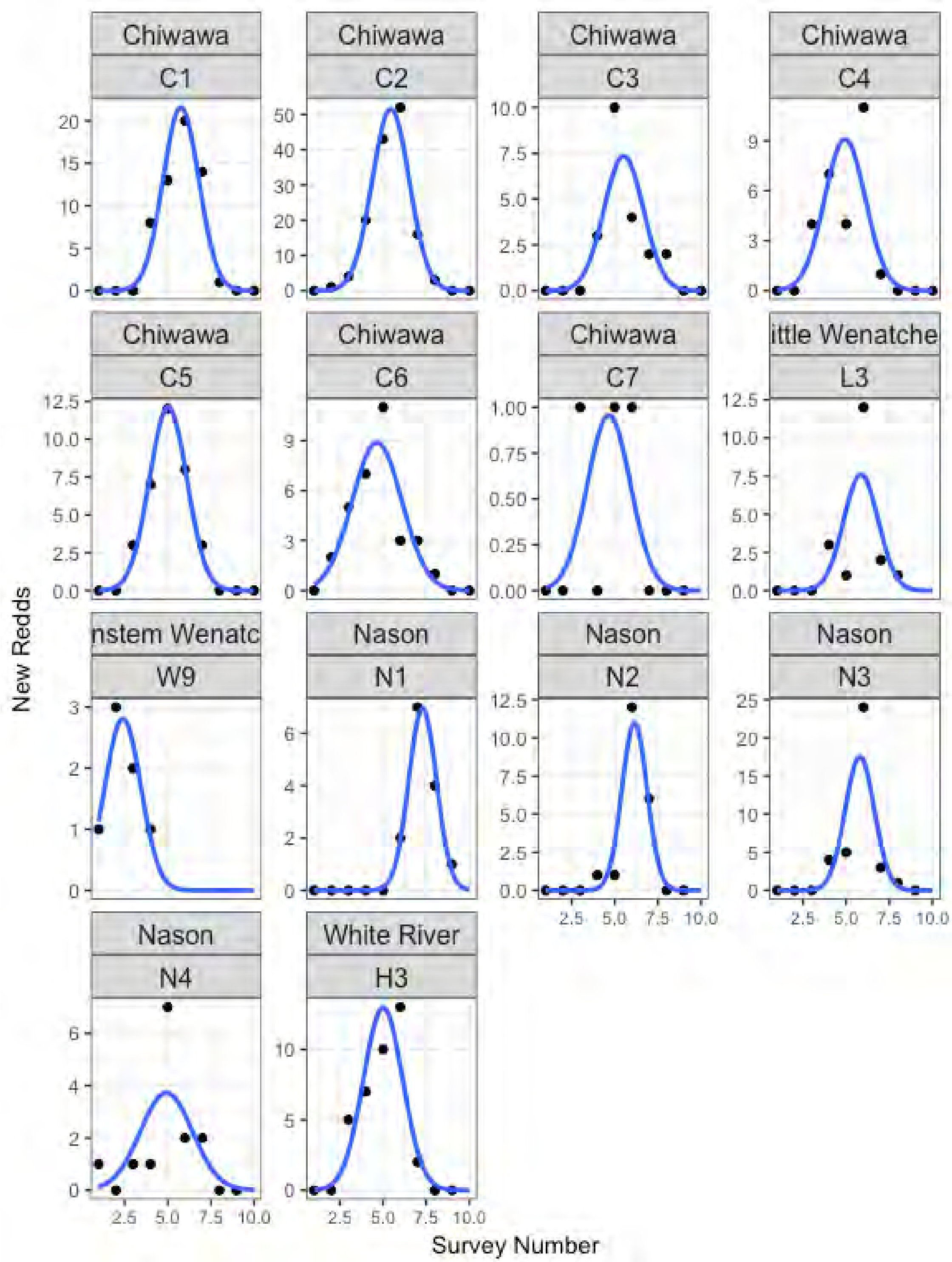
Boxplots showing predicted net error by stream. Dashed line shows no error.

Total Redds

Redds were estimated at the reach scale using the GAUC method whenever possible, and simply dividing the total number of observed redds by the predicted net error when not. For a few small tributary reaches, no estimates of observer error were made and instead the small number of observed redds was assumed to be observed without error. The estimates at the reach scale are displayed in Table 1. The curves that were fit in the GAUC process are shown in Figure 3. The results are summarized at the stream and population scale in Table 2.

Table 1: Estimates of total redds by reach.

Stream	Reach	Type	GAUC	Obs. Redds	Mean Net Error	Est. Redds	SE	CV
Chiwawa	C1	Major	Y	56	0.88	64	9.04	0.14
Chiwawa	C2	Major	Y	139	0.82	170	16.22	0.10
Chiwawa	C3	Major	Y	21	1.02	21	4.64	0.22
Chiwawa	C4	Major	Y	27	0.88	31	6.93	0.22
Chiwawa	C5	Major	Y	33	0.97	34	3.12	0.09
Chiwawa	C6	Major	Y	32	1.13	28	4.97	0.18
Chiwawa	C7	Major	Y	3	0.65	5	1.80	0.36
Chiwawa	K1	Minor	N	1	--	1	--	--
Chiwawa	R1	Minor	N	0	--	0	--	--
Chiwawa	S1	Minor	N	0	--	0	--	--
Icicle	I1	Minor	N	2	--	2	--	--
Icicle	I2	Minor	N	61	--	61	--	--
Icicle	I3	Minor	N	9	--	9	--	--
Little Wenatchee	L2	Major	N	3	0.69	4	1.33	0.33
Little Wenatchee	L3	Major	Y	19	0.61	31	13.43	0.43
Mainstem Wenatchee	A1	Minor	N	2	--	2	--	--
Mainstem Wenatchee	W10	Major	N	8	0.88	9	3.17	0.35
Mainstem Wenatchee	W9	Major	Y	7	0.67	11	2.30	0.21
Nason	N1	Major	Y	14	1.00	14	2.24	0.16
Nason	N2	Major	Y	20	0.85	23	5.94	0.26
Nason	N3	Major	Y	37	0.82	45	10.93	0.24
Nason	N4	Major	Y	14	0.76	18	7.17	0.40
Peshastin	D1	Minor	N	0	--	0	--	--
Peshastin	P1	Minor	N	0	--	0	--	--
Peshastin	P2	Minor	N	2	--	2	--	--
White River	H2	Major	N	4	0.69	6	1.86	0.31
White River	H3	Major	Y	37	0.85	43	8.14	0.19
White River	H4	Major	N	2	0.70	3	1.27	0.42
White River	Q1	Minor	N	1	--	1	--	--
White River	T1	Minor	N	0	--	0	--	--



Observed new redds by survey number and reach. Blue curve depicts the GAUC fitted curve.

Table 2: GAUC results at stream and population scale. Mean net error is the mean of net error estimates, weighted by the number of observed redds in each reach.

Stream	Obs. Redds	Mean Net Error	Est. Redds	Std. Err.	CV
Chiwawa	312	0.89	354	41.30	0.12
Icicle	72	--	72	0.00	0.00
Little Wenatchee	22	0.62	35	13.43	0.38
Mainstem Wenatchee	17	0.78	22	2.30	0.10
Nason	85	0.85	100	19.58	0.20
Peshastin	2	--	2	0.00	0.00
White River	44	0.83	53	8.14	0.15
Total	554	--	638	48.38	0.08

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Appendix K

Genetic Diversity of Chiwawa River Spring Chinook Salmon

Assessing the Genetic Diversity of Natural Chiwawa River Spring Chinook Salmon and Evaluating the Effectiveness of its Supportive Hatchery Supplementation Program

Developed for

Chelan County PUD

and the

Habitat Conservation Plan's Hatchery Committee

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Table of Contents

Executive Summary 3

Introduction

Reasons for evaluation project 7
History of artificial propagation 8
Previous genetic analyses 10
Study objectives 12

Methods

Tissue collection 13
Laboratory Analysis 13
Genetic Analysis
    Assessing within population genetic diversity 14
    Within- and among-population genetic differentiation 15
    Effective population size.. 17
    Individual assignment... 18

Results/Discussion 19

Conclusions.. 44

Acknowledgements 46

Literature Cited.. 47

Figures 52

Tables 59

Executive Summary

The main objective of this study was to determine the potential impacts of the Chiwawa River Supplementation Program on natural spring Chinook in the upper Wenatchee system. We did this by investigating population differentiation between temporally replicated Chiwawa River natural and hatchery samples from the Wenatchee River watershed using microsatellite DNA allele frequencies and the statistical assignment of individual fish to specific populations. Additionally, to assess the genetic effect of the hatchery program, we investigated the relationship between census and effective population sizes using collections obtained before and after the supplementation program. In this summary, we briefly describe the salient results contained within this report; however, each "Task" within the Results/Discussion section below contains extended coverage for each topic along with an expanded interpretation of each result.

Overall, we observed substantial genetic diversity within collections, with heterozygosities equal to roughly 80%, over thirteen microsatellite markers. Microsatellite allele frequencies among temporally replicated collections from the same population (i.e., location) were variable, resulting in significant genetic differentiation among these collections. However, these difference are likely the result of salmon life history in this area, as four-year-old Chinook comprise a majority of returns each year. That is, the genetic tests are detecting the differences of contributing parents from each cohort, rather than a hatchery effect.

Analysis of Chiwawa River Collections

To assess the multiple competing hypotheses regarding population differentiation within and among Chiwawa River collections, we found it necessary to organized the Chiwawa genetic data into three data sets: (1) fish origin (hatchery versus natural), (2) spawning location (hatchery broodstock versus in-river (natural) spawners), and (3) four "treatment" groups (1. hatchery-origin hatchery broodstock, 2. hatchery-origin natural spawner, 3. natural-origin natural spawner, and 4. natural-origin hatchery broodstock). We conducted separate analyses using each of the three data sets, with each analysis touching on some aspect of the components necessary to move through the Conceptual Process outlined by Murdoch and Peven (2005).

Origin Dataset – We report that allele frequencies within and between natural- and hatchery-origin collections are significantly different, but there does not appear to be a robust signal indicating that the recent natural-origin collections have diverged greatly from the pre- or early post-supplementation collections. Genetic drift will occur in all populations, but does not appear to be a major factor affecting allele frequencies within the Chiwawa collections.

Spawning Location Dataset – There are significant allele frequency differences within and between hatchery broodstock and natural spawner collections. However, in recent years the allele frequency differences between the hatchery broodstock and natural spawner collections have declined. Furthermore, based on linkage disequilibrium, there is a genetic signal that is consistent with increasing homogenization of allele frequencies within hatchery broodstock collections, but a similar homogenization within the natural spawner collection is not apparent. These data suggest that there exists consistent year-to-year variation in allele frequencies among hatchery and natural spawning collections, but there is a trend toward homogenization of the allele frequencies of the natural- and hatchery-origin fish that compose the hatchery broodstock.

Four Treatment dataset – Although there are signals of allelic differentiation among Chiwawa River collections, there are no robust signs that these collections are substantially different from each other. We used two different analyses to measure the degree of genetic variation that exists among individuals and collections within the Chiwawa River. First, we conducted a principal component analysis using all Chiwawa samples with complete genotypes (i.e., no missing alleles from any locus). Although the first two principal component axes account for only 10.5% of the total molecular variance, a substantially greater portion of that variance is among individual fish, regardless of their identity, rather than among hatchery and natural collections. The variances in principal component scores among individuals are 11 and 13 times greater than the variance in scores among collections.

Secondly, using an Analysis of Molecular Variance (AMOVA), we were able to determine how best to group populations, with "best" being defined as that grouping that accounts for the greatest proportion of among group (i.e., population) variance. Furthermore, by partitioning molecular variance into different hierarchical components, we are able to determine what level accounts for the majority of the molecular variance. The AMOVA results clearly show that nearly all molecular variation, no matter how the data are organized, resides within a collection. The percentage of total molecular variance occurring within collections ranged from 99.68% to 99.74%. These results indicate that the significant differences among collections of Chiwawa fish account for less than one percent of the total molecular variance, and these differences cannot be attributed to fish origin or spawning location.

Effective Population Size (N_e)

The contemporary estimate of N_e calculated using genetic data combined for Chiwawa natural-origin spawners (NOS) and hatchery-origin spawners (HOS) Chinook is N_e=386.8, which is slightly larger than the pre-hatchery N_e we estimated using demographic data from 1989 – 1992. Additionally, the N_e /N ratio calculated using 386.8 for N_e and the arithmetic mean yearly census of NOS and HOS Chinook from 1989 – 2005 for N is 0.40. These results suggest the N_e has not declined during the period of Chiwawa Hatchery Supplementation Program operation.

Analysis Of Upper Wenatchee Tributary Collections

We compared genetic data for spring Chinook collected from the major spawning aggregates of the Wenatchee River. We observed significant differences in allele frequencies among temporally replicated collections within populations, and among populations within the upper Wenatchee. However, these differences account for a very small portion of the overall molecular variance, and these populations overall are very similar to each other. Of all the populations within the Wenatchee River, the White River appears to be the most distinct. Yet, this distinction is more a matter of detail than of large significance, as the median F_{ST} between White River collections and all other collections (except the Little Wenatchee collection; see Results/Discussion) is less than 1.5% among population variance. We consider the implications of these results in the Conclusion section that follows the Results/Discussion section. Additionally, there is no evidence that the Chiwawa River Supplementation Program has changed the allele frequencies in the Nason Creek and White River populations, despite the presence of hatchery-origin fish in both these systems.

Introduction

Murdoch and Peven (2005) outlined 10 objectives to assess the impact (positive or negative) of hatchery operations mitigating the operation of Rock Island Dam. Two objectives relate to monitoring the genetic integrity of populations:

Objective 3: Determine if genetic diversity, population structure, and effective population size have changed in natural spawning populations as a result of the hatchery program. Additionally, determine if hatchery programs have caused changes in phenotypic characteristics of natural populations.

Objective 5: Determine if the stray rate of hatchery fish is below the acceptable levels to maintain genetic variation between stocks.

This study addresses Objective 3 (above), and documents analyses and results WDFW completed for populations of spring Chinook (*Oncorhynchus tshawytscha*) in the Wenatchee River watershed. This study was not intended to specifically address Objective 5 (above); however, genetic data provide results relevant to Objective 5. The critical component of Objective 3 is to determine if hatchery supplementation has effected change. Furthermore, change in this context means altering census size and/or genetic marker allele frequencies; we did not attempt to measure changes in fitness. Perhaps a more meaningful rewording of Objective 3 is, "Did the hatchery supplementation program succeed at increasing the census size of a target population while leaving genetic integrity intact?" In order to evaluate cause and effect of hatchery supplementation, we surveyed and compared genetic variation in samples collected before and after potential effects from the Chiwawa Hatchery Supplementation Program. Samples were acquired from the primary spawning aggregates in the upper Wenatchee River watershed: Nason Creek, Little Wenatchee River, White River, and Chiwawa River. Hatchery samples were acquired from programs that could potentially affect genetic composition of Wenatchee stocks, the integrated Chiwawa River stock (local stock), Leavenworth National Fish Hatchery spring Chinook (Carson Stock – non local), and Entiat NFH (Carson Stock – non local). Additionally, the genetic markers used were the Genetic Analysis of Pacific Salmonids (GAPS) (Seeb et al. in review) standardized microsatellites, so all data from the Wenatchee study will be available for inclusion in the GAPS Chinook coastwide microsatellite baseline.

History of Artificial Propagation

Artificial propagation in the upper Columbia River began in 1899 when hatcheries were constructed on the Wenatchee and Methow rivers (Mullan 1987). These initial operations were small, with the Tumwater Hatchery on the Wenatchee River releasing several hundred thousand fry, and the Methow River hatchery producing few Chinook salmon before it was closed in 1913 (Craig and Suomela 1941, Nelson and Bodle 1990). The Leavenworth State Hatchery operated in the Wenatchee River Basin between 1913 and 1931 using eggs from non-native stocks (Willamette River spring-run and lower Columbia Chinook hatchery fall-run). These early attempts at hatchery production were largely unsuccessful for spring-run Chinook (WDF 1934). Between 1931 and 1939, no Chinook salmon hatcheries were in operation above Rock Island Dam (Rkm 730).

In 1938, the last salmon was allowed to pass upstream through the uncompleted Grand Coulee Dam (Rkm 959). To mitigate the loss of habitat, adult Chinook salmon were trapped, under the auspices of the Grand Coulee Fish Maintenance Project (GCFMP), at Rock Island Dam beginning in May 1939, and relocated into three of the remaining accessible tributaries to the upper Columbia River: the Wenatchee, Entiat, and Methow Rivers. GCFMP transfers continued through the autumn of 1943. Spring- and summer/fall-run fish were differentiated at Rock Island Dam based on a 9 July cutoff date for Chinook arrivals at Rock Island Dam (Fish and Hanavan 1948). Spring-run adults collected at Rock Island Dam (pre 9 July fish) were either transported to Nason Creek on the Wenatchee River to spawn naturally (1939-43), or to the newly constructed Leavenworth NFH (1940) for holding and subsequent spawning (1940-43). Eggs were incubated on site or transferred to the Entiat NFH (1941) and Winthrop NFH (1941). In 1944 spring-run adults were allowed to freely pass Rock Island Dam. The GCFMP did not differentiate among late-run stocks (post 9 July fish) passing Rock Island Dam. Late-run offspring reared at the Leavenworth NFH, Entiat NFH, and Winthrop NFHs were an amalgamation of summer and fall upper Columbia River populations (Fish and Hanavan 1948). Late-run fish were transplanted into the upper and lower Wenatchee, Methow, and Entiat Rivers.

After 1943, the Winthrop NFH continued to use local spring-run Chinook for hatchery production, while the other NFHs largely focused on summer-run Chinook salmon. Renewed emphasis on spring run production in the mid-1970s saw the inclusion of local and non-local eggs (Carson NFH stock, Klickitat River stock, and Cowlitz River stock) to the NFHs. In the early 1980s, imports of non-native eggs were reduced significantly, and thereafter the Leavenworth, Entiat, and Winthrop NFHs have relied on adults returning to their facilities for their egg needs (Chapman et al. 1995). Regarding late-run Chinook, due to the variety of methods employed to collect broodstock at dams, hatcheries, or the result of juvenile introductions into various areas, Chinook populations and runs (i.e., summer and fall) have been mixed considerably in the upper Columbia system over the past five decades (reviewed in Chapman et al. 1994).

Washington Department of Fish and Wildlife (WDFW) operates two facilities producing spring-run Chinook, the Methow Fish Hatchery (MFH) owned by Douglas County PUD that began operation in 1992 and Eastbank Fish Hatchery (EFH) owned by Chelan County PUD that began operation in 1989. Both programs were designed to implement supplementation (supportive breeding) programs for naturally spawning populations on the Methow and Wenatchee Rivers, respectively (Chapman et al. 1995). As part of the Rock Island Mitigation Agreement between Chelan County Public Utility District and the fishery management parties (RISPA 1989), a supplementation (supportive breeding) program was initiated in 1989 on the Chiwawa River to mitigate smolt mortality resulting from the operation of Rock Island Hydroelectric Project. EFH uses broodstock collected at a weir on the Chiwawa River, although in recent years hatchery fish have been collected at Tumwater Dam. Similarly, the MFHC uses returning adults collected at weirs on the Methow River and its tributaries, the Twisp and Chewuch Rivers (Chapman et al. 1995; Bugert 1998). Although low run size and trap efficiency has resulted in most broodstock being collected from the hatchery outfall or in some years Wells Dam, progeny produced from these programs are reared at and released from satellite sites on the tributaries where the adults were collected. Numerous other facilities have reared spring-run Chinook salmon on an intermittent basis.

Previous Genetic Studies – Population differentiation

Waples et al. (1991a) examined 21 polymorphic allozyme loci in samples from 44 populations of Chinook salmon in the Columbia River Basin. These authors reported three major clusters of Columbia River Basin Chinook salmon: 1) Snake River spring- and summer-run Chinook salmon, and mid and upper Columbia River spring-run Chinook salmon, 2) Willamette River spring-run Chinook salmon, 3) mid and upper Columbia River fall- and summer-run Chinook salmon, Snake River fall-run Chinook salmon, and lower Columbia River fall- and spring-run Chinook salmon. Utter et al. (1995) examined allele frequency variability at 36 allozyme loci in samples of 16 upper Columbia River Chinook populations. Utter et al. (1995) indicated that spring-run populations were distinct from summer- and fall-run populations, where the average genetic distance between spring-run and late-run Chinook were about eight times the average of genetic distances between samples within each group. Additionally, allele frequency differences among spring-run populations were considerably greater than that among summer- and fall-run populations in the upper Columbia River. Utter et al. (1995) also reported hatchery populations of spring-run Chinook salmon were genetically distinct from natural spring-run populations, but hatchery populations of fall-run Chinook salmon were not genetically distinct from natural fall-run populations.

As part of an evaluation of the relative reproductive success for the Chiwawa River supplementation program, Murdoch et al. (2006), used eleven microsatellite loci to assess population differentiation among spring Chinook salmon population samples in the upper Wenatchee River. Murdoch et al. (2006) reported a >99% accuracy of correctly identifying spring-run and fall-run Chinook from the Wenatchee River. They also reported slight, but significantly different genetic variation among wild spring populations and between wild and hatchery stocks. Yet, since the spring-run populations are genetically similar, identifying individuals genetically from the upper tributaries of the Wenatchee River was difficult. This result is exemplified in their individual assignment results, where < 8% of spring-run individuals, hatchery or wild, were correctly assigned using their criterion of an LOD (log of odds) score greater than 2. Murdoch et al. (2006) also reported contemporary natural spring Chinook show heterozygote deficit and low linkage disequilibrium (LD), while contemporary hatchery spring Chinook show heterozygote excess and high LD.

Williamson et al. (submitted) have continued the work of Murdoch et al. (2006) by analyzing Chiwawa River demographic data from 1989 – 2005 to estimate the proportions of recruits that were produced by Chinook with hatchery or wild origin. In an "ideal" population, the genetic size (i.e., effective size or N_e) and the census size are equal; however various demographic factors such as unequal sex ratios and variance in reproductive success among individuals reduces the genetic size below the census size. It is generally thought that the genetic size is approximately 10-33% the census size (Bartley et al. 1992; RS Waples pers. comm.), although values have been reported outside this range (Araki et al. 2007; Arden and Kapuscinski 2003; Heath et al. 2002). Despite being difficult to estimate, the effective population size in many respects is a more important parameter to know than census size, because N_e determines how genetic diversity is distributed within populations and how the forces of evolution (i.e., forces that change genetic diversity over time) will affect the genetic variation present.

Williamson et al. (submitted) used demographic data to 1) investigate the effect of unequal sex ratio on genetic diversity, 2) investigate the effect of variation in reproductive success on genetic diversity, 3) investigate the effect of fluctuations in population size on genetic diversity, and 4) estimate the effective population size, using the inbreeding method (Ryman and Laikre 1991). Most importantly, they use demographic data from 1989 – 2000 to assess the impact of the Chiwawa Hatchery Supplementation Program on the effective population size of natural-origin Chiwawa River spring Chinook. They estimate that the N_e of naturally spawning Chiwawa Chinook (i.e., both hatchery- and wild-origin fish on the spawning grounds) from 1989 –

1992 was $N_e = 2683$ and in 1997 – 2000 was $N_e = 989$. They compare spawning ground N_e to estimates calculated from combined broodstock and naturally spawning Chinook demographic data. The combined inbreeding N_e estimate from 1989 – 1992 was $N_e = 147$ and in 1997 – 2000 was $N_e = 490$. Williamson et al. (submitted) argue that since the combined N_e estimate is lower than the naturally spawning estimate, the supplementation program has had a negative impact on the Chiwawa River N_e.

Williamson et al. (submitted) also present genetic data for Chinook recovered on spawning grounds in upper Wenatchee River tributaries in 2004 and 2005. These genetic data are derived from the Murdoch et al. (2006) study. They compare samples collected from Chiwawa River (i.e., hatchery and wild), White River, Nason Creek, and Leavenworth Hatchery. Additionally, they include a 1994 Chiwawa River wild smolt sample for comparison with the 2004 brood year. Williamson et al. (submitted) report statistically significant genetic differentiation among Chiwawa River, White River and Nason Creek. Additionally, they report that the 1994 and 2004 Chiwawa River wild samples are not statistically different, but the 2004 Chiwawa wild and hatchery collections are statistically different.

Study Objectives

This study investigated within and among population genetic diversity to assess the effect of the Chiwawa Hatchery's supplemental program on the natural Chiwawa River spring Chinook population. Differences among temporal population samples, the census size, heterozygosity, and allelic diversity were documented. We investigated population differentiation between the Chiwawa River natural and hatchery samples, and among all temporally replicated samples from the Wenatchee River watershed using microsatellite DNA allele frequencies and the statistical assignment of individual fish to specific populations. To assess the genetic effect of the hatchery program, correlation between census and effective population sizes were investigated using temporally replicated samples obtained before and after the supplementation program operation. To address the hypotheses associated with Objective 3 in Murdock and Peven (2005) we developed eleven specific “Tasks” (Blankenship and Murdoch 2006), to which we analyzed specific genetic data. We present the results from these analyses specific to each individual Task.

Methods and Materials

Tissue collection and DNA extraction

We analyzed thirty-two population collections of adult spring Chinook salmon (*Oncorhynchus tshawytscha*) obtained from the Wenatchee River between 1989 and 2006 (Table 1). Nine collections of natural Chinook adults from the Chiwawa River (n=501), and nine collections of Chiwawa Hatchery Chinook (n=595) were collected at a weir located in the lower Chiwawa River. The 1993 and 1994 Chiwawa Hatchery samples are smolt samples from the 1991 and 1992 hatchery brood years, respectively. Additional samples were collected from upper Wenatchee River tributaries, White River, Little Wenatchee River, and Nason Creek. Six collections of natural White River Chinook (n=179), one collection from the Little Wenatchee (n=19), and six collections from Nason Creek (n=268) were obtained. Single collections were obtained for Chinook spawning in the mainstem Wenatchee River and Leavenworth National Fish Hatchery. An additional out-of-basin collection from Entiat River was also included in the analysis. Samples collected in 1992 or earlier are scale samples. All other samples were either fin clips or operculum punches, stored immediately in ethanol after collection. DNA was extracted from stored tissue using Nucleospin 96 Tissue following the manufacturer’s standard protocol (Macherey-Nagel, Easton, PA, U.S.A.).

Laboratory analysis

We performed polymerase chain reaction (PCR) amplification on each fish sample using the 13 fluorescently end-labeled microsatellite marker loci standardized as part of the GAPS project (Seeb et al. in review). GAPS genetic loci are: *Ogo*2, *Ogo*4 (Olsen et al. 1998); *Oki*100 (unpublished); *Omm*1080 (Rexroad et al. 2001); *Ots*201b (unpublished); *Ots*208b, *Ots*211, *Ots*212, and *Ots*213 (Grieg et al. 2003); *Ots*3M, *Ots*9 (Banks et al.

1999); *Ots*G474 (Williamson et al. 2002); *Ssa*408 (Cairney et al. 2000). PCR reaction volumes were 10 µL, and contained 1 µL 10x PCR buffer (Promega), 1.0 µL MgCl2 (1.5 mM final) (Promega), 0.2 µL 10 mM dNTP mix (Promega), and 0.1 units/mL Taq DNA polymerase (Promega). Loci were amplified as part of multiplexed sets, so primer molarities and annealing temperatures varied. Multiplex one had an annealing temperature of 50°C, and used 0.37 Molar (M) *Oki*100, 0.35 M *Ots*201b, and 0.20 M *Ots*208b, and 0.20 M *Ssa*408. Multiplex two had an annealing temperature of 63°C, and used 0.10 M *Ogo*2, and 0.25 M of a non-GAPS locus (*Ssa* 197). Multiplex three had an annealing temperature of 56°C, and used 0.18 M *Ogo*4, 0.18 M *Ots*213, and 0.16 M *Ots*G474. Multiplex four had an annealing temperature of 53°C, and used 0.26 M *Omm*1080, and 0.12 M *Ots*3M. Multiplex five had an annealing temperature of 60°C, and used 0.30 M *Ots*212, 0.20 M *Ots*211, and 0.10 M *Ots*9. Thermal cycling was conducted on either a PTC200 thermal cycler (MJ Research) or GeneAmp 9700 (Applied Biosystems) as follows: 95°C (2 min); 30 cycles of 95°C for 30 sec., 30 sec. annealing, and 72°C for 30 sec.; a final 72°C extension and then a 10°C hold. PCR products were visualized by electrophoresis on an ABI 3730 automated capillary analyzer (Applied Biosystems). Fragment analysis was completed using GeneMapper 3.7 (Applied Biosystems). Standardization of genetic data to GAPS allele standards was conducted following Seeb et al. (in review).

Genetic data analysis

Assessing within population genetic diversity - Heterozygosity measurements are reported using Nei's (1987) unbiased gene diversity formula (i.e., expected heterozygosity) and Hedrick's (1983) formula for observed heterozygosity. Both tests are implemented using the microsatellite toolkit (Park 2001). We used GENEPOP version 3.4 (Raymond and Rousset 1995) to assess Hardy-Weinberg equilibrium (HWE), where deviations from the neutral expectation of random associations among alleles are calculated using a Markov chain method (5000 iterations in this study) to obtain unbiased estimates of Fisher's exact test. Global estimates of F_{IS} according to Weir and Cockerham (1984) were calculated using GENEPOP version 3.4. Genotypic linkage disequilibrium was calculated following Weir (1979) using GENEPOP version 3.4.

Linkage results for population collections are reported as the proportion of pairwise (locus by locus) tests that are significant (alpha = 0.01). Linkage disequilibrium is considered statistically significant if more than 5% of the pairwise tests based on permutation are significant for a collection.

Within- and among-population genetic differentiation – The temporal stability of allele frequencies within populations, and pairwise differences in allele frequencies among populations were assessed using several different procedures. First, we tested for differences in allele frequencies among populations defined in Table 1 using a randomization chi-square test implemented in GENEPOP version 3.4 (Raymond and Rousset 1995). This procedure tests for differences between pairs of populations where alleles are randomized between the populations (i.e., genic test). The null hypothesis for this test is that the allele frequency distributions between two populations are the same. A low p-value should be interpreted as the allele frequency distributions being compared are unlikely to be samples drawn from the same underlying distribution.

Second, to graphically describe allele frequency differences among populations we conducted a nonmetric multidimensional scaling analysis using allele-sharing distance matrices from two different data sets. Pairwise allele-sharing distances are calculated as 1 – (mean over all loci of the sums of the minima of the relative frequencies of each allele common to a pair of populations). To calculate the allele-sharing distances for each pair of populations we used PowerMarker v3.25 (Liu and Muse 2005). Nonmetric multidimensional scaling is a technique designed to construct an n-dimensional "map" of populations, given a set of pairwise distances between populations (Manly 1986). The output from this analysis is a set of coordinates along n-axes, with the coordinates specific to the number of n-dimensions selected. To simplify our analysis we selected a 2-dimensional analysis to represent the relative positions of each population in a typical bivariate plot. The goodness of fit between the original allele-sharing distances and the pairwise distances between all populations along the 2-dimensional plot is measured by a "stress" statistic. Kruskal (in Rohlf 2002) developed a five-tier guide for evaluating stress levels, ranging from a perfect fit (stress=0) to a poor fit (stress=0.40). We conducted the nonmetric multidimensional scaling analysis for one data set containing Chiwawa natural- and hatchery-origin collections, and another data set containing Chiwawa broodstock and in-river spawner collections. We used the mdscale module in MATLAB R2006b (The Mathworks 2006) to generate the nonmetric multidimensional scaling coordinates.

We examined the geographic and temporal structure of populations in the upper Wenatchee (Chiwawa River, Nason Creek, and White River, only) using a series of analyses of molecular variance (AMOVAs). Here, we defined an AMOVA as an analysis of variance of allele frequencies, as originally designed by Cockerham (1969), but implemented in Arlequin v2.1 (Schneider et al. 2000). These analyses permit populations to be aggregated into groups, and molecular variance is then partitioned into within collections, among collections, but within groups, and among group components. With this approach, we were able to determine how best to group populations, with "best" being defined as that grouping that accounts for the greatest proportion of among group variance. Furthermore, by partitioning molecular variance into three different hierarchical components, we are able to determine what level accounts for the majority of the molecular variance.

Finally, we explored the partitioning of molecular variance between among-individuals and among-populations using a principal component analysis and multi-locus estimates of pairwise F_{ST}, estimated by a "weighted" analysis of variance (Weir and Cockerham, 1984). Principal component analysis is a data-reduction technique whereby the correlation structure among variables can be used to combine variables into a series of multivariate components, with each original variable receiving a weighted value for each component based on its correlation with that component. Here, we used a program written by Warheit in MATLAB R2006b (The Mathworks 2006) that treats each allele for each locus as a single variable (13 loci = 26 alleles or variables), and these 26 "variables" were arranged into 26 components, with each component accounting for a decreasing amount of molecular variance. Estimates of F_{ST} were calculated using GENETIX version 4.05 (Belkhir et al.1996). To determine if the F_{ST} estimates were statistically different from random (i.e., no structure), 1000 permutations were implemented in GENETIX version 4.05 (Belkhir et al.1996).

Effective population size (N_e) – Estimates of the effective population size were obtained using two methods, a multi-collection temporal method (Waples 1990), and a single-collection method (Waples 2006) using linkage disequilibrium data. The temporal method assumes that cohorts are used, but we did not decompose the collection year samples into their respective cohorts using age data. Therefore, N_e estimates that pertain to individual year classes of breeders are not valid; however the harmonic mean over all samples will estimate the contemporary N_e. Comparing samples from years *i* and *j*, Waples' (1990) temporal method estimates the effective number of breeders ($\hat{N}_{b(i,j)}$) according to:

$$\hat{N}_{b(i,j)} = \frac{b}{2(\hat{F} - 1/\hat{S}_{i,j})}$$

The standardized variance in allele frequency ($\hat{F}$) is calculated according to Pollack (1983). The parameter b is calculated analytically from age structure information and the number of years between samples (Tajima 1992). The age-at-maturity information required to calculate b was obtained from Murdoch et al. (2006) for this analysis. They observed for Chiwawa Hatchery Chinook that 8.6% matured at age 2, 4% at age 3, 87% at age 4, and 0.4% at age 5. For Chiwawa natural Chinook, Murdoch et al. (2006) observed that 1.8% matured at age 3, 81.6% at age 4, and 16.7% at age 5. The harmonic mean of sample sizes from years *i* and *j* is $\tilde{S}_{i,j}$. Over all pairwise comparisons the harmonic mean of all $\hat{N}_{b(i,j)}$ is $\tilde{N}_b$, the contemporary estimate of the effective population size (N_e). SALMONNb (Waples et al. 2007) was used to calculate $\tilde{N}_b$. As suggested by authors, alleles with a frequency below 0.05 were excluded from the analysis to reduce potential bias.

The method of Waples (2006) uses linkage disequilibrium (i.e., mean squared correlation of allele frequencies at different gene loci) as a means of estimating effective population size (N_e) from a single sample. While this method is biased in some cases where N_e /N ratio is less the 0.1 and the sample size is less than the true N_e, it has been shown to produce comparable results to the temporal method. Burrows' delta method is used to estimate LD, and a bias corrected estimate of N_e is calculated after eliminating alleles with frequency less than 0.05. This test was implemented using LDN_e (Do and Waples unpublished). In age-structured species, N_e estimates based on LD are best interpreted as the effective number of breeders (N_b) that produced the sample (Waples 2006). N_b should be multiplied by the mean generation length (i.e., 4 in this case) to obtain an overall estimate of N_e based on an N_b estimate. We analyzed collections categorized by spawning location (i.e., hatchery broodstock or in-river) and did not analyze collections categorized by origin (i.e., hatchery or natural). Waples' (2006) method estimates N_e from observed LD, therefore the corresponding N_e estimates for the hatchery collections would be low and the estimates for the natural collections would be high. Yet, since the supplementation program is integrated, and hatchery fish can spawn naturally, we feel it inappropriate to analyze the hatchery and natural samples as if they were separate, which would essentially partition all the LD into the hatchery samples.

Each collection has an N_b estimate and an associated confidence interval. If the confidence interval includes infinity, it means that sampling error accounts for all the LD observed (i.e., empirical LD is less than expected LD). The usual interpretation is that there is no evidence for any disequilibrium caused by genetic drift in a finite number of parents. Since the LD method estimates the number of breeders that contributed to the sample being analyzed, in order to calculate an N_e /N ratio, the appropriate census size must be used. The census size used to derive a ratio was the estimate four years prior to the collection analyzed using LD, which assumed a strict four-year-old lifecycle, although the observed proportion of four-year-olds was approximately 85% each year. The census numbers (Table 2) used to calculate the ratios for Chiwawa broodstock and in-river spawners were combined NOS (natural-origin spawners) and HOS (hatchery-origin spawners) census estimates.

Individual assignment – A population baseline file was constructed containing all 1704 individual Chinook from 34 population collections (Table 1; Chiwawa origin data set plus all samples from other populations). All individuals in the baseline had geneotypes that included nine or more loci. Individual Chinook were assigned to their most likely population of origin based on the partial Bayesian criteria of Rannala and Mountain (1997), using a "jack-knife" procedure, where each individual to be assigned was removed from the baseline prior to the calculation of population likelihoods. This procedure was implemented in a program written by Warheit in MATLAB R2006b (The Mathworks 2006). Two assignment criteria were used, 1) the population with the largest posterior probability for an individual was the "most-likely" population of origin (i.e., all individuals assigned to a collection), and 2) an assignment was consider valid only if the posterior probability was greater than or equal to 0.9. Please note that while the analysis used 34 population collections to assign Rannala and Mountain likelihoods for each individual, these likelihoods were aggregated based on "population" (i.e., Chiwawa, Nason, White, and so on) and posterior probabilities were calculated for population location, rather than individual collections.

Results and Discussion

In this section we combine our presentation and interpretations of the genetic analyses. Additionally, this section will be organized based on the task list presented in the study plan. Overall conclusions are provided following this section.

<u>Task 1:</u> Determine trend in census size for Chiwawa River spring Chinook.

Census data from 1989 – 2005 are provided in Table 2 for the Chiwawa Hatchery broodstock and spring Chinook present in the Chiwawa River. The demographic data for naturally spawning Chinook are based on redd sampling and carcass surveys, while broodstock data are based on Chiwawa hatchery records. As the supplementation program is integrated by design, we also present the proportion of natural-origin broodstock (pNOB) incorporated into the hatchery, in addition to the number of natural-origin (NOS) and hatchery-origin (HOS) spawners present in Chiwawa River. The census size fluctuated yearly, and a general reduction in census size was observed in the mid to late 1990's. This trend was apparent in both the broodstock and in the river. The arithmetic mean census size from 1989 – 2005 for the Chiwawa Hatchery (i.e., broodstock) was N=87.5 per year. The arithmetic mean census size from 1989 – 2005 for the Chiwawa River (i.e., NOS and HOS combined) was N=961.9 per year. For collection years when adult Chiwawa hatchery-origin fish would have been absent in the Chiwawa River (1989 – 1992), the arithmetic mean of natural Chiwawa Chinook census size is N=962.7. We will use this number as the baseline census size to assess if census size has changed. We used two different values for the contemporary census size in the Chiwawa River, NOS only and NOS + HOS. Additionally, we used collection years 2002 – 2005 for the contemporary NOS and HOS estimates, as these are the most recent data and the number of years included for estimation is the same as the pre-hatchery estimate above (i.e., four years). For NOS only, the arithmetic mean census size from 2002 – 2005 was N=536.0. For total census size (i.e., NOS and HOS combined), the arithmetic mean census size from 2002 – 2005 was N=1324.0. For the demographic data presented here, the contemporary census size is larger than the census estimate derived from the years prior to hatchery operation.

<u>Task 2:</u> Document the observed genetic diversity.

Genetic Diversity Categorized By Origin

For Chiwawa River collections categorized by origin (Table 1A), substantial genetic diversity was observed, with heterozygosity estimates over all loci, having a mean of 0.80. Genetic diversity was consistent with expected Hardy-Weinberg random mating genotypic proportions for ten of the eighteen collections. Eight of the nine Chiwawa natural collections were consistent with HWE, and two of nine Chiwawa Hatchery collections were consistent with HWE. F_{IS} is observed to be slight for all Chiwawa population collections, suggesting individuals within collections do not show excessive homozygosity.

The deviations from HWE observed were generally associated with hatchery collections. The two smolt collections (i.e., 1993 and 1994) showed significant deviations from HWE, which may be a function of non-random hatchery practices involving the contributing natural-origin parental broodstocks (i.e., 1991 and 1992 cohort). Deviations from HWE in the remaining hatchery collections may be the result of few individuals being represented in the broodstock (see below).

Additionally, linkage disequilibrium (LD) was also common for Chiwawa hatchery-origin collections and minimal for Chiwawa natural-origin collections. The random association of alleles between loci (i.e., linkage equilibrium) is expected under ideal conditions. LD is observed when particular genotypes are encountered more than expected by chance. Laboratory artifacts (e.g. null alleles) or physical linkage of loci on the same chromosome can cause LD, but the LD we observed was not associated with certain locus combinations, which you would expect if either artifacts or physical linkage were the cause of LD. LD was observed for seven of the nine hatchery-origin collections. As with the deviations from HWE, the high LD in the 1993 and 1994 hatchery-origin collections may be a result of non-random hatchery practices. The substantial LD observed in the hatchery-origin adult collections (collection years 2000, 2001, 2004, and 2006) might be the result of small parental broodstock sizes contributing to those returning adults. During the mid 1990's, the Chiwawa broodstock size was low, with zero individuals collected in 1995 and 1999; so fewer individuals would be contributing to the hatchery adult returns than the natural. This idea is corroborated by the lower LD observed for the 2005 hatchery-origin collection, which had a contributing parental broodstock size in 2001 (i.e., the major contributing parental generation) approximately eight times as large as the previous few collection years (Table 2). LD reappears in the 2006 Chiwawa hatchery-origin collection, which had a contributing parental broodstock size (i.e., for the most-part, the 2002 hatchery brood year) five times lower (Table 2) than that of the 2005 collection.

While seven of nine hatchery-origin collections showed significant LD, only one natural origin collection showed LD, and for this collection, only 10% of the loci-pairs were in disequilibrium (Table 1). The fact that LD predominated in the hatchery samples, suggests that variance in reproductive success (i.e., overrepresentation of particular parents) is higher in the hatchery-origin than in natural-origin collections.

Genetic Diversity Categorized By Spawning Location

For upper Wenatchee River collections categorized by spawning location (Table 1B), substantial genetic diversity was observed, with heterozygosity estimates over all loci, having a mean of 0.79 and ranging from a low of 0.69 (1993 White River) to 0.85 (1993 Little Wenatchee). Genetic diversity was consistent with HWE for nineteen of twenty-nine population collections. For the collections that departed from HWE, seven were from the Chiwawa River, one was from Leavenworth Hatchery, one was the Wenatchee mainstem collection of hatchery-origin – naturally spawning fish, and one was from the White River. F_{IS} is observed to be slight for all population collections except the 1993 White River collection (10% heterozygote deficit) (Table 1B). Collections deviating with HWE generally correlated with collections having high LD. Twelve population collections showed a proportion of pairwise linkage disequilibrium tests (across all loci) greater than 5% (Table 1B), eight of which were Chiwawa collections.

Starting in 1996, spawning location collections are composed of both natural- and hatchery-origin samples. The LD seen in the later spawning location collections may be caused by an admixing effect (i.e., mixing two populations), where random mating has not had the chance to freely associate alleles into genotypes. Interestingly, there appears to be a trend of reducing LD through time within the broodstock collections (Table 1B), which suggests that a "homogenizing" effect is taking place within the Chiwawa River. This observation is discussed more fully in Task 3 below.

<u>Task 3:</u> Test for population differentiation among collections within the Chiwawa River and associated supplementation program.

Introduction

Task 3 was designed to address two hypotheses listed as part of Objective 3 in Murdoch and Peven (2005):

- Ho: Allele frequency $_{\text{Hatchery}}$ = Allele frequency $_{\text{Naturally produced}}$ = Allele frequency $_{\text{Donor pop}}$.
- Ho: Genetic distance between subpopulations $_{\text{Year x}}$ = Genetic distance between subpopulations $_{\text{Year y}}$

Murdoch and Peven (2005) proposed these two hypotheses to help evaluate the Chiwawa supplementation program through the "Conceptual Process" (Figure 5 in Murdoch and Peven 2005; repeated here as Figure 1). There are two components to the first hypothesis, which must be considered separately. The first component involves comparisons between natural-origin populations in the Chiwawa to determine if there have been changes in allele frequencies or genetic distances, through time starting with the donor population. Documenting a change does not necessarily indicate that the supplementation program has directly affected the natural origin fish, as additional tests would be necessary to support that hypothesis. The intent of the second component is to determine if the hatchery produced populations have the same genetic composition as the naturally produced populations.

Although on the surface these two components and their associated comparisons may appear simple, from a hypothesis-testing perspective the analyses are complicated by the fact that natural-origin fish may have had hatchery-origin parents, and hatchery-origin fish may have had natural-origin parents. As such, we organized the Chiwawa genetic data into three data sets: (1) fish origin (hatchery versus natural), (2) spawning location (hatchery broodstock versus in-river (natural) spawners), and (3) four "treatment" groups (1. hatchery-origin hatchery broodstock, 2. hatchery-origin natural spawner, 3. natural-origin natural spawner, and 4. natural-origin hatchery broodstock). We conducted separate analyses using each of the three data sets, with each analysis touching on some aspect of the components necessary to move through the Conceptual Process (Figure 1).

Hatchery- Versus Natural-Origin

We address the following questions with the origin data set:

1. Are there changes in allele frequencies and allele sharing distances in the natural-origin collections from pre-supplementation to today?
2. Are there changes in allele frequencies and allele sharing distances in the hatchery-origin collections from early supplementation to today?
3. Are there significant differences in allele frequencies and large allele sharing distances between hatchery- and natural-origin adults from a collection year, and has this pattern changed through time?

Genic Differentiation Tests – We explicitly tested the hypothesis of no significant differentiation within natural- or hatchery-origin collections from the Chiwawa River using a randomization chi-square test. We show the results for the pairwise comparisons among natural-origin collections from the Chiwawa River populations in the first block of the second page of Table 3. Ten of the 36 (28%) pairwise comparisons have highly significant allele frequency differences, while only 12 of the 36 comparisons (33%) showed no significant differences. Eight of these 12 comparisons involved the 1996 collection, which included only eight samples and therefore provided little power to differentiate allele frequencies. If we exclude the 1996 collection, only 14% of the pairwise comparisons showed no significant differences, and here all but one of these comparisons involved the 1989 collection. The 1989 collection appeared to be the least differentiated collection in the natural-origin data set in that all pairwise comparisons were either not significant, or only mildly significant at the nominal critical value. No comparisons involving the 1989 collection were significant using a Bonferroni-corrected critical value, and 1989 is the only natural-origin collection in our data set that can be classified as "pre-supplementation."

We can interpret these results to indicate that although there appears to be significant year-to-year differences in allele frequencies among post-supplementation collections, the allele frequencies between each post-supplementation collection and the 1989 pre-supplementation collection are not greatly different. However, the level of differentiation does increase from the early post-supplementation years to the more recent years (2001, 2004-2006), although the statistical level of this significance never exceeds the Bonferroni-corrected critical value. Finally, sample sizes were also small for the 1989 collection (n = 36) and we cannot eliminate a reduction in power as a contributing factor for the lack of significance for these tests.

As with the hatchery-origin collections, most pairwise comparisons of allele frequencies between hatchery-origin samples were significant (Table 3, first page, upper block). Out of the 36 pairwise comparisons, all but three are significant at some level, and most comparisons are highly significant. Similar to the natural-origin analysis, the non-significant results were limited to comparisons involving the 1996, which included only eight samples.

As a result of this analysis *we reject the hypothesis that there was no significant differentiation among natural- or hatchery-origin collections from the Chiwawa River*. Furthermore, the allele frequencies of the hatchery-origin collections are significantly different from those of natural-origin collections (Table 3, first page, second block). For those fish collected in the same year, allele frequencies are significantly different between hatchery- and natural-origin collections, although in 2005 the level of significance was below the Bonferroni critical value (Table 3). The next step is to examine the pattern of allelic differentiation to discover first if there is a trend among the data, and second, if this trend suggests that the allele frequency differences among Chiwawa River natural-origin fish collections has been affected by the hatchery-origin fish.

Allele-sharing and Nonmetric Multidimensional Scaling – We constructed a pairwise allele-sharing distance matrix for all hatchery- and natural-origin collections from the Chiwawa River and subjected this matrix to a nonmetric multidimensional scaling analysis, restricting the analysis to two dimensions (Figure 2). The stress statistic for this analysis is 0.09, a value Kruskal (in Rohlf 2002) listed as a good to excellent fit between the actual allele-sharing distances and the Euclidean (straight-line) distances in the plot.

In other words, Figure 2 is a good visual representation of the allele sharing distance matrix; collections with a high percentage of alleles shared will be closer to each other than collections with a lower percentage of alleles shared.

With the exception of the two outlier years (1996 and 1998) the Chiwawa natural-origin collections form a tight cluster indicating an overall common set of shared alleles among these collections. Even if we ignore the 1996 and 1998 hatchery-origin collections, there appears to be a greater variance in shared alleles among the Chiwawa hatchery-origin collections than the natural-origin collections (Figure 2). In fact, the median percentage of alleles shared among the Chiwawa natural-origin collections is 76% compared with 69% alleles shared among the Chiwawa hatchery-origin collections.

Also, there appears to be a convergence in allele sharing distances (i.e., a decrease in allele frequency differences) between the hatchery- and natural-origin fish from the late 1980s/early 1990s to 2006. The series of red arrows in Figure 2 represent the progression of change in hatchery-origin allele sharing distances from 1996 (first adult hatchery origin fish in our analysis) to 2006 and this progression is decidedly in the direction of the natural-origin cluster. However, the most recent natural-origin collections (2001, 2004-2006) appear to have pulled closer to the hatchery-origin collections, compared with the 1989 natural-origin collection (note the close proximity of the 2000 and 1989 natural-origin collections). Nevertheless, the cluster of natural-origin collections adjacent to the hatchery-origin collections in Figure 2 also includes the 1993 natural-origin collection. Qualitatively, it appears that the initial hatchery-origin and natural-origin collections were more different from each other in terms of the percentage of shared alleles than are the most recent hatchery- and natural-origin collections. This may have been a result of a non-random sample of natural-origin fish that was used as broodstock in the initial years of the supplementation program (see discussion in Task 2 concerning deviations from HWE and linkage disequilibrium).

That being said, we do need to emphasize that Figure 2 is dominated by five outlier collections (two each from the 1996 and 1998 collections, and the 1994 smolt collection).

The 1996 and 1998 collections are characterized by small samples sizes, and the 1994 smolt collection has nearly all pairs of loci in linkage disequilibrium (Table 1). If we eliminate these five outlier groups, both the hatchery- and natural-origin collections form a relatively tight cluster. Excluding the five outliers, the median percentage of shared alleles among all pairwise combinations of Chiwawa hatchery versus Chiwawa natural collections is 76%. This compares with a median pairwise percentage of 79% among only Chiwawa natural-origin collections. That is, there are nearly as many alleles shared between the hatchery-origin and natural-origin collections as there are among the natural-origin collections themselves. There is also a narrowing of differences between natural- and hatchery-origin fish from the same collection years from 1993 (76% shared alleles) through 2006 (83% shared alleles).

If allelic differentiation among collections is a function of genetic drift, we would expect a positive correlation between the number of years between two collections and the allele sharing distance. That is, if genetic drift is the primary cause of allele frequency differences between two collections, the greater the number of years between the two collections the larger the allele-sharing distance. For both the natural- and hatchery-origin collections we examined the relationship between the number of years between a pair of collections and the collections' allele-sharing distance (Figure 3). Although the relationship between time interval and allele distance appears to be a positive function in the natural collections, the slope of the regression line is 0.0017, and is not significantly different from zero. Furthermore, the correlation coefficient (r^2) equals 0.1068, which means that the time interval between collections accounts for only 10% of the pairwise differences in allelic distance. The hatchery-origin collections do show a significantly positive slope (0.0037; $p = 0.0254$) and a regression coefficient nearly three times greater than that for the natural-origin collections. However, the correlation coefficient is still relatively small ($r^2 = 0.3290$), indicating that the time interval between collections accounts for one-third of the pairwise differences in allelic distance. The results suggest that if genetic drift is a factor in allelic differentiation between collections, it is only a minor factor, and appears to have affected the hatchery-origin collections more than the natural-origin collections.

If four-year-old fish dominate each collection year, we would expect a closer relationship among collections that are spaced at intervals of four years. The average percentage of alleles shared between two natural-origin collections that are separated by four years or a multiple of four years is 81%, compared with 78% for natural-origin collections separated by years that are not divisible by four. Likewise, for hatchery-origin collections the average percentage of alleles shared is 80% and 75% for collections separated by years divisible and not divisible by four, respectively. Although the percent differences described above are relatively small, they are consistent with the idea that allelic differences between collections are a function of year-to-year variability among different cohorts of four year-old fish.

Summary – The allele frequencies within and between natural- and hatchery-origin collections are significantly different, but there does not appear to be a robust signal indicating that the recent natural-origin collections have diverged greatly from the pre- or early post-supplementation collections. Genetic drift will occur in all populations, but does not appear to be a major factor with the Chiwawa collections. We propose that the differences among collections are a function of differences in allele frequencies among cohorts of the four year-old fish that dominate each collection.

Hatchery Broodstock Versus Natural (In-River) Spawners

We address the following questions with the spawner data set:

1. Are there changes in allele frequencies and allele sharing distances in the natural spawning collections from pre-supplementation to today?
2. Are there changes in allele frequencies and allele sharing distances in the hatchery broodstock collections from early supplementation to today?
3. Are there significant differences in allele frequencies and large allele sharing distances between hatchery and natural spawning adults from a collection year, and has this pattern changed through time?

Genic Differentiation Tests – For the most part there are significant differences in allele frequencies among collections for both the hatchery broodstock and natural spawners (Table 4), and these differences are consistent with the origin data set (Table 3). There are four collection years with paired samples (2001, 2004-2006) where we can compare allele frequency differences between the hatchery broodstock and natural spawners, within the same year. The 2001 hatchery broodstock and natural spawner collections have significantly different allele frequencies, but the level of significance decreased from 2001 to 2004, and become non-significant in 2005 and 2006 (Table 4). This indicates that by 2005, the hatchery broodstock and natural spawners collections were effectively sampling from the same population of fish. Additionally, the percentage of alleles shared between the hatchery broodstock and the natural spawners increased from 76% in 2001 to 86% in 2006 (allele sharing distance matrix, not shown). From this analysis, we conclude that although there are year-to-year differences in allele frequencies within the natural and hatchery spawner collections, *there appears to be a convergence of allele frequencies within collection-year, between the natural and hatchery spawner populations*.

Linkage Disequilibrium – Linkage disequilibrium is the correlation of alleles between two loci, and can occur for several reasons. If two loci are physically linked on the same chromosome, than alleles from each of these loci should be correlated. However, linkage between two loci can occur as a result of population bottlenecks, small population sizes, and natural selection. If any of these conditions had occurred or were occurring within the Chiwawa River system, we would expect to find substantial linkage disequilibrium in many or perhaps all Chiwawa collections. However, many Chiwawa collections, especially the natural-origin collections, do not show linkage disequilibrium (Table 1), and it would appear that the linkage disequilibrium within certain Chiwawa collections is not a function of the processes listed above. Linkage disequilibrium can also result if the collection is composed of an admixture. That is, if two or more reproductively isolated populations are combined into a single collection, the collection will show linkage disequilibrium. Each broodstock and natural spawning collection is composed of natural- and hatchery-origin fish. If these hatchery- and natural-origin fish are drawn from the same population, the spawning collections should not show substantial linkage disequilibrium. However, if the hatchery- and natural-origin fish are from different populations (i.e., full hatchery – natural integration has not been achieved), the spawning collections should show substantial linkage disequilibrium.

There are only three Chiwawa spawning collections that are not composed of both hatchery- and natural-origin samples: 1989 (natural-origin, natural spawner), 1993 (natural-origin, hatchery broodstock), and 2001 (natural-origin, natural spawner). Of the 10 spawning collections with both hatchery- and natural-origin fish, seven show significant linkage disequilibrium. Two of the three collections that did not show linkage disequilibrium are the 1996 and 1998 hatchery broodstock collections, which are composed of only seven natural- and six hatchery-origin fish, and two natural- and 19 hatchery-origin fish, respectively. Within the hatchery broodstock collections with linkage disequilibrium, the percent of loci pairs showing linkage decreased from 32% in 2000 to 13% in 2001 and 2004, to only 1% and 5% in 2005 and 2006, respectively (Table 1). If the homogenization of allele frequencies of natural- and hatchery-origin fish was increasing from 2000 to 2006, we would expect a decrease in linkage disequilibrium among the broodstock collections. This is what occurred within the hatchery broodstock collections, but did not occur within the natural spawner collections, where the percent of loci pairs showing linkage was 18% in 2004, 6% in 2005, and 10% in 2006 (Table 1). Furthermore, the 2001 natural spawner collection, with no hatchery-origin component showed linkage disequilibrium with 9% of loci pairs.

There is no correlation between percent of loci pairs showing linkage disequilibrium and percent of broodstock composed of hatchery-origin fish ($r^2 = 0.0045$). Furthermore, the natural spawner and hatchery broodstock collections were each composed of roughly the same average percentage of hatchery-origin fish (57% and 53%, respectively). If the decrease in linkage disequilibrium among the hatchery broodstock collections from 2000 to 2006 was a result of a homogenization of allele frequencies of natural- and hatchery-origin fish in the broodstock, the same degree of homogenization did not occur within the natural spawner collections. This would occur if natural- and hatchery-origin fish spawning within the river remain segregated, either by habitat or by fish behavior.

Summary – As with the origin data set, there are significant allele frequency differences within and between hatchery broodstock and natural spawner collections. However, in recent years the allele frequency differences between the hatchery broodstock and natural spawner collections has declined. Furthermore, based on linkage disequilibrium, there is a genetic signal that is consistent with increasing homogenization of allele frequencies within hatchery broodstock collections, but a similar homogenization within the natural spawner collection is not apparent. These data suggest that there exists consistent year-to-year variation in allele frequencies among hatchery and natural spawning collections, but there is a trend toward homogenization of the allele frequencies of the natural- and hatchery-origin fish that compose the hatchery broodstock.

Four Treatment Groups

Analyses of genetic differences between hatchery (broodstock) and natural spawner collections is confounded by the fact that each these two groups are composed of fish of natural- and hatchery-origin. To understand the effects of hatchery supplementation on *natural-origin fish that spawn naturally*, we needed to divide the Chiwawa data set into four mutually exclusive groups: (1) hatchery-origin hatchery broodstock, (2) hatchery-origin natural spawner, (3) natural-origin hatchery broodstock, and (4) natural-origin natural spawner, with each group consisting of multiple collection years, for a total of 25 different groups.

Allele-sharing and Nonmetric Multidimensional Scaling –As with previous analyses discussed above, we constructed a pairwise allele-sharing distance matrix for all collections from each of these treatment groups and subjected this matrix to a nonmetric multidimensional scaling analysis, restricting the analysis to two dimensions. Figure 4 shows that five outlier groups dominate the allele-sharing distances within this data set. These outlier groups are also present in Figure 2, as discussed above, and Figure 2 and 4 resemble each other because the same fish are included in each analysis. The difference between Figures 2 and 4 is that in Figure 4 the fish are grouped into collection year and the four treatment groups, rather than collection year and two treatment groups (hatchery- versus natural-origin).

Figure 4 does not provide useful resolution of the groups within the polygon, because the outlier groups dominate the allele sharing distances. We removed the five outlier groups from Figure 4, recalculated the allele sharing distances and subjected this new matrix to a multidimensional scaling analysis (Figure 5). Figure 5 shows separation among the 2001, 2004-2006 collections, but this separation does not necessarily indicate that within-year collections are more similar to each other than any collection is to a collection from another year. For example, the 2006 natural-origin natural spawner and the 2005 natural-origin hatchery broodstock collections share 81% alleles, while the 2006 natural-origin natural spawner and 2006 hatchery-origin hatchery broodstock collections share 75% alleles. There does not appear to be any discernable pattern of change in allele-sharing distance among the collections relevant to pre- or post-supplementation. Although the 1989 pre-supplementation natural-origin collection appears distinct (Figure 5), the 1993 natural-origin hatchery broodstock collection appears quite similar to the 2005 and 2006 natural-origin collections (Figure 5). The 1993 natural-origin hatchery broodstock collection, although not technically pre-supplementation, is composed of fish whose ancestry cannot be traced to any Chiwawa hatchery fish. Therefore, there is no clear pattern of allele sharing change from pre-supplementation to recent collections.

There does appear to be some change in the average percentage of alleles shared within the 2001 to 2006 collections, with an increase from 74% in 2001 and 2004 to 78% and 79% in 2005 and 2006, respectively. The results provided by this analysis are consistent with the results presented in the origin and spawner data sets. That is, there are allele frequency and allele sharing differences among the collections, but analyses do not strongly suggest that these differences are a function of the supplementation program. Furthermore, there is also a weak signal that the hatchery and natural collections within the most recent years are more similar to each other than in the previous years.

Overall Genetic Variance – Although there are signals of allelic differentiation among Chiwawa River collections, there are no robust signs that these collections are substantially different from each other. We used two different analyses to measure the degree of genetic variation that exists among individuals and collections within the Chiwawa River. First, we conducted a principal component analysis using all Chiwawa samples with complete genotypes (i.e., no missing alleles from any locus). Although the first two principal component axes account for only 10.5% of the total molecular variance, a substantially greater portion of that variance is among individual fish, regardless of their identity, rather than among hatchery and natural collections (Figure 6). The variances in principal component scores among individuals are 11 and 13 times greater than the variance in scores among collections, along the first and second axes, respectively.

Second, we conducted a series of analyses of molecular variance (AMOVA) to ascertain the percentage of molecular variance that could be attributed to differences among collections. We organized these analyses to test also for differences in the hierarchical structure of the data. That is, we tested for differences among collections using the following framework:

- No organizational structure – all 25 origin-spawner collections considered separately
- Origin-spawner collections organized into 10 collection year groups
- Origin-spawner collections organized into 2 breeding location groups (hatchery versus natural)
- Origin-spawner collections organized into 2 origin groups (hatchery versus natural)
- Origin-spawner collections organized into the 4 origin-spawner groups

It is clear from this analysis that nearly all molecular variation, no matter how the data are organized, resides within a collection (Table 5). The percentage of total molecular variance occurring within collections ranged from 99.68% to 99.74%. The among group variance component was limited to less than 0.26% and in all organizational structures, except “no structure,” the among group percentage was not significantly greater than zero. Furthermore, none of the organizational structures provided better resolution than “no structure” in terms of accounting for molecular variance within the data set. *These results indicate that if there are significant differences among collections of Chiwawa fish, these differences account for less than one percent of the total molecular variance, and these differences cannot be attributed to fish origin or spawning location.*

Summary and Conclusions

We reject the null hypothesis that the allele frequencies of the hatchery collections equal the allele frequencies of the natural collections, which equals the allele frequency of the donor population. Furthermore, because the allele-sharing distances are not consistent within and among collections years, we also reject the second stated hypothesis discussed above. However, there is an extremely small amount of genetic variance that can be attributed to among collection differences. The allelic differentiation that does exist among collections does not appear to be a function of fish origin, spawning location, genetic drift, or collection year. Figure 5 and related statistics does suggest that hatchery and natural collections in 2005 and 2006 are more similar to each other than previous years’ collections, and this would be expected in a successful integrated hatchery supplementation program.

Since each of these collection years are generally composed of four-year-old fish, the differentiation among these collections for the most part is differentiation among specific cohorts. The slightly greater percentage of alleles shared among collections that are separated in time by multiples of four years, compared with collections that are not separated in time as such, suggests that cohort differences may be the most important factor accounting for differences in allele frequencies among collections.

<u>Task 4:</u> Develop a model of genetic drift.

See Task 3

<u>Task 5:</u> Analyze spring Chinook population samples from the Chiwawa River and Chiwawa Hatchery from multiple generations.

See Task 3

<u>Task 6:</u> Analyze among population differences for upper Wenatchee spring Chinook.

Supplementation of the Chiwawa River spring Chinook population may affect populations within the Wenatchee River watershed other than the Chiwawa River stock. If the stray rate for Chiwawa hatchery-origin fish is greater than that for natural-origin fish, an increase in gene flow from the Chiwawa population into other populations may result. If this gene flow is high enough, Chiwawa River fish may alter the genetic structure of these other populations. Records from field observations indicate that hatchery-origin fish are present in all major spawning aggregates (A.R Murdoch, unpublished data), and these fish are successfully reproducing (Blankenship et al 2006). The intent of this task is to investigate if there have been changes to the genetic structure of the spring Chinook stocks within upper Wenatchee tributaries during the past 15-20 years, and if changes have occurred, are they a function of the Chiwawa River Supplementation Program? Therefore, we ask the following two questions:

1. Are allele frequencies within populations in the upper Wenatchee stable through time? That is, is there significant allelic differentiation among collections within upper Wenatchee populations?
2. Are the recent collections from the upper Wenatchee populations more similar to the Chiwawa population than earlier collections from the same populations?

For this task we analyzed natural spawning collections from the White River (natural-origin), Little Wenatchee River (natural-origin), Nason Creek (natural-origin), and

Wenatchee mainstem (hatchery-origin), and hatchery collections from Leavenworth NFH and Entiat River NFH (Table 1). We also included in the analysis the natural- and hatchery-origin collections from the Chiwawa River. There are no repeated collections from Leavenworth, Entiat, Little Wenatchee, and Wenatchee mainstem (Table 1), so for many of the analyses we have limited our discussion to the Chiwawa River, White River, and Nason Creek collections. Furthermore, genetic structure of the Little Wenatchee collection, which consisted of only 19 samples, was unexpectedly quite different from the other collections. For example, the F_{ST} statistic measures the percent of total molecular variation that can be attributed to differences between populations. The median F_{ST} for all pairwise combinations of collections from all populations, except Little Wenatchee (33 populations, 528 individual F_{ST} statistics) equals 0.010 (1%), with a range of 0.000 to 0.037 (Table 6). The median F_{ST} for the Little Wenatchee paired with all other collections (33 individual F_{ST} statistics) equals 0.106 (10.6%), with a range of 0.074 to 0.121. The ten-fold increase in the F_{ST} statistic indicates that either the Little Wenatchee spring Chinook is unique among the upper Wenatchee River stocks, or this 1993 collection is somehow aberrant. Therefore, we exclude the Little Wenatchee collection from many other analyses.

Population Differentiation – Table 3 provides the levels of significance for all pairwise genic differentiation tests. Most between-collection comparisons are highly significant, with no pattern of increasing or decreasing differentiation with time, and no differences when comparisons are made with Chiwawa hatchery- versus Chiwawa natural-origin fish. For example, excluding the outlier 1996 and 1998 Chiwawa hatchery- and natural-origin collections, Nason Creek showed highly significant allele frequency differences between the Chiwawa hatchery- and natural-origin collections at 100% and 86% of the comparisons, respectively. The same comparisons with the White River produced 100% and 93% highly significant allele frequency comparisons, respectively. Allele frequencies between Nason Creek and White River were likewise differentiated from each other.

The collection allele frequencies within the upper Wenatchee system are significantly different, and these differences do not appear to change as a function of time (Table 3). Nason Creek shows greater within-population year-to-year variation in allele frequencies than does the White River, with 47% of the pairwise comparisons showing highly significant differences, compared with only 13% for the White River. However, the 2005 and 2006 collections from the White River appear to be somewhat more differentiated from not only each other, but from the earlier collections from the White River.

Despite the high degree of temporal and spatial structure suggested by the genic differentiation tests, as described above for within-Chiwawa analysis (Task 3), most of the genetic variation within this data set occurs within populations, rather than between populations (Table 6). The F_{ST} values for most population comparisons are between 0.01 and 0.02, indicating 1% to 2% among-population variance, with the remaining 98% to 99% variance occurring within populations. The White River shows the highest median F_{ST} among the natural-origin collections, equal to 0.014, compared with 0.009 for both the Nason Creek and Chiwawa natural-origin collections. The median F_{ST} for the Chiwawa hatchery-origin collections (0.012) was higher than that for the Chiwawa natural-origin collections.

Table 7 summarizes the information from the F_{ST} analyses, under five different temporal and spatial scenarios. Under all scenarios, over 99% of the molecular variance is within populations. There is significantly greater spatial structure among populations ("Origin") in 2005 and 2006 than from 1989 to 1996. That is, there appears to be more spatial structure among the Chiwawa hatchery-origin, Chiwawa natural-origin, White River, and Nason Creek now, than in 1989 to 1996, despite the potential homogenizing and cumulative effect of hatchery strays. However, we stress that the amount of molecular variance associated with the among population differences, despite being significantly greater than 0.00%, is limited to only 0.43%.

Allele-sharing and Nonmetric Multidimensional Scaling – As in the Chiwawa River data discussed above, we constructed an allele-sharing distance matrix and then subjected that matrix to a multidimensional scaling analysis (Figure 7). Consistent with all previously discussed multidimensional scaling analyses, the 1996 and 1998 adult, and the 1994 smolt collections are outliers. There is clear separation between the White River collections and all other natural-origin and Chiwawa hatchery-origin collections, indicating that there are more alleles shared among the Nason Creek and Chiwawa collections, than with the White River collections. Furthermore, there is a slight separation between the Chiwawa natural-origin natural spawner collections and Nason Creek collections, suggesting different groups of shared alleles between these populations. There is more variation in the allele-sharing distances among collections involved with the Chiwawa hatchery (origin or broodstock) than any of the natural-origin collections, even if we exclude the 1994, 1996, and 1998 collections. This suggests that there is more year-to-year variation in the composition of hatchery-origin and hatchery broodstock than within natural-origin populations throughout the upper Wenatchee. All Wenatchee mainstem fish are hatchery-origin, and if these fish are from the Chiwawa Supplementation Program (rather than from Leavenworth), it is not unexpected that this collection would be plotted within the Chiwawa polygon (Figure 7).

Assignment of Individual to Populations – Finally, we conducted individual assignment tests whereby we assigned each individual fish to a population, based on a procedure developed by Rannala and Mountain (1997) (Table 8 and 9). Individual fish may be correctly assigned to the population from which they were collected, or incorrectly assigned to a different population. Incorrect assignments may occur if the fish is an actual migrant (i.e., source population different from population where collected), or because the genotype for that fish matches more closely with a population different from its source. If there are many individuals from a population incorrectly assigned to populations other than its source population, that original population is either unreal (i.e., an admixture), or there is considerable gene flow between that population and other populations. Furthermore, in assigning individuals to populations, we can either accept the assignment with the highest probability, regardless of how low that probability may be, or we can establish a more stringent criterion, such as to not accept an assignment unless the posterior probability is equal to or greater than 0.90. This value is roughly equal to having the likelihood of the most-likely population equal to 10 times that of the second most-likely population.

We provide a summary of the assignments in Tables 8 and 9. On average, nearly 50% of the fish are assigned incorrectly if we accept all assignments (Table 8), but the incorrect assignment rate drops to roughly 10% when we accept only those assignments with probabilities greater than 0.90. However, with this more stringent criterion, nearly 64% of the fish go unassigned. These results indicate that the allele frequency distributions for these populations are very similar, and it would be very difficult to assign an individual fish of unknown origin to the correct population. If all fish are assigned, there is a 50% chance, overall, of a correct assignment. If you accept only those assignment with the 0.90 criterion, nearly two-thirds of the fish would be unassigned, but there is a 90% chance of correctly assigning those fish that are indeed assigned.

Of all the populations in the data set, there are fewer errors associated with assigning fish to the White River. If all fish are assigned (Table 8), 72% of those fish assigned to the White River, are actually from the White River (115 fish out of a total of 159 fish assigned to the White River). This compares to a rate of only 52% and 53% for Nason Creek and Chiwawa natural-origin, respectively, and 60% for the Chiwawa hatchery-origin collections. With the 0.90 criterion (Table 9), 89% of the fish assigned to the White River, are actually from the White River, compared with 70% and 65% for Nason Creek and Chiwawa natural origin, respectively, and 81% for the Chiwawa hatchery origin.

When all fish are assigned, most of the incorrectly assigned fish from Nason Creek and White River are assigned to Chiwawa River, at roughly equal frequencies to the hatchery- and natural-origin populations. Incorrectly assigned fish to other populations occur at a slightly higher rate in Nason Creek than in the White River. However, when only those fish meeting the 0.90 criterion are assigned (Table 9), incorrectly assigned fish from Nason Creek are distributed among White and Chiwawa Rivers, as well as Leavenworth NFH, and the Entiat NFH. Mis-assignment to the Chiwawa hatchery-origin was the highest among the Nason Creek collections, equal to nearly 14%. This contrasts with the White River where mis-assignments do not exceed 7% anywhere, and there is a roughly even distribution of mis-assignments among Nason Creek and Chiwawa River collections.

Summary and Conclusions – There is little geographic or temporal structure among populations within the upper Wenatchee systems. Among population molecular variance is limited to 1% or less. The little variance that can be attributed to among populations indicates that the White River is more differentiated from the Chiwawa and Nason populations than these populations are from each other. Furthermore, although we cannot rule out a hatchery effect on the Nason Creek and White River populations, there is no indication there has been any temporal changes in allele frequencies within these populations that can be attributed directly to the Chiwawa River Supplementation Program. In fact, Table 7 weakly suggests that there is more differentiation among these populations now, than there was before or at the early stages of Chiwawa supplementation.

Therefore, returning to our two original questions, there are significant differences in allele frequencies among collections within populations, and among populations within the upper Wenatchee spring Chinook stocks. However, these differences account for a very small portion of the overall molecular variance, and these populations overall are very similar to each other. There is no evidence that the Chiwawa River Supplementation Program has changed the allele frequencies in the Nason Creek and White River populations, despite the presence of hatchery-origin fish in both these systems. Finally, of all the populations within the Wenatchee River, the White River appears to be the most distinct. Yet, this distinction is more a matter of detail than of large significance, as the median F_{ST} between White River collections and all other collections (except the Little Wenatchee) is less than 1.5% among population variance.

Task 7: Calculate the inbreeding effective population size using demographic data for each sample year, and document the ratio of census to effective size.

This analysis was completed by Williamson et al. (submitted).

Task 8: Calculate LD N_b using genetic data for each sample year, and document the ratio of census to effective size.

We report N_e estimated for the Chiwawa River collections based on the bias correction method of Waples (2006) implemented in LDNe (Do and Waples unpublished). N_e estimates based on LD are best interpreted as the effective number of breeders (N_b) that produced the sample (Waples 2006).

For collections categorized by spawning location (i.e., hatchery broodstock or natural), estimates of N_b are shown in Table 10. Considering the hatchery broodstock, N_b estimates range from 30.4 (1996) to 274.3 (2005). To obtain N_e /N ratios, the N_b estimate is multiplied by four (i.e., mean generation length) and divided by the total in river (i.e., NOS [natural-origin spawners] plus HOS [hatchery-origin spawners]) census data from four years prior (i.e., major cohort; see Table 2). The observed N_e /N ratios for the broodstock collections range from 11% to 54% of the census estimate, excluding the 2000 collection which is 106%. A ratio greater than one is possible under special circumstances, and certain artificial mating schemes within hatcheries can inflate N_e above N; yet, it is unknown if this is the case for this collection. While no direct comparisons are possible, the N_b estimates reported by Williamson et al. (submitted) for Chiwawa broodstock collections from 2000 – 2003 are similar in magnitude to our estimates. For Chiwawa natural spawner collections, the N_b estimates range from 5.2 (1989) to 231.5 (2005), with observed N_e /N ratios of 22% - 48% of the census estimate.

Task 9: Calculate N_b using the temporal method for multiple samples from the same location.

Estimates of effective number of breeders (N_b) derived from Waples' (1990) temporal method are shown in Tables 11-13. Eight collection years were used for the Chiwawa broodstock collections (Table 11). The harmonic mean of all pairwise estimates of N_b ($\tilde{N}_b$) was 269.4. This estimate is the contemporary N_e for Chiwawa broodstock collections. For the five collection years of Chiwawa in-river spawners (Table 12), the estimated $\tilde{N}_b$ = 224.2. This estimate is the contemporary N_e for Chiwawa River natural spawner collections. Since the Chiwawa Supplementation Program is integrated by design, we also performed another estimation of N_e using composite hatchery and natural samples. There are paired samples from 2004-2006. We combined genetic data for hatchery (HOS) and natural (NOS) origin fish from 2004 – 2006 to create a single Chiwawa River natural spawner sample for each year. The three composite samples from 2004 – 2006 were then analyzed using the temporal method (Table 13), resulting in a $\tilde{N}_b$ = 386.8. This estimate is the contemporary N_e for Chiwawa River.

Williamson et al. (submitted) estimated N_e using Waples' (1990) temporal method for Chinook captured in 2004 and 2005, and used age data to decompose brood years into consecutive cohorts from 2000 – 2003. They report for Chiwawa broodstock a $\tilde{N}_b$ = 50.4. This estimate is not similar to our Chiwawa broodstock estimate. However, if we analyze the hatchery-origin Chinook only, our estimate is $\tilde{N}_b$ = 80.1 for collection years 1989 – 2006 (data not shown). Williamson et al. (submitted) report for Chiwawa naturally spawning Chinook a $\tilde{N}_b$ = 242.7, which is slightly higher than our estimate for in-river spawners from 1989 – 2006, but lower than our estimate from combined NOS and HOS Chinook from 2004 – 2006 collection years.

<u>Task 10:</u> Use available data and the Ryman-Laikre and Wang-Ryman models to determine the expected change of N_e for natural spring Chinook salmon in the Wenatchee River due to hatchery operation.

N_e is generally thought to be between 0.10 and 0.33 of the estimated census size (Bartley et al. 1992; RS Waples pers. comm.). We used this range to generate an estimate of N_e for Chiwawa natural spawners prior to hatchery operation. For brood years 1989 – 1992, the arithmetic mean census size was N=962.7 (Table 2), resulting in an estimated N_e ranging from 96.3 – 317.7. The contemporary estimate of N_e calculated using genetic data for the Chiwawa in-river spawners is N_e=224.2 (Table 12), falling in the middle of the pre-hatchery range. The N_e /N ratio calculated using 224.2 and the arithmetic census of NOS Chinook from 1989 – 2005 is 0.42. A more appropriate contemporary N_e to compare with the pre-hatchery estimate (i.e., 96.3 – 317.7) is the combined NOS and HOS estimate from natural spawners, since the supplementation program is integrated. As discussed above, the contemporary estimate of N_e calculated using genetic data for Chiwawa NOS and HOS Chinook is N_e=386.8 (Table 13), which is slightly larger than the pre-hatchery range, suggesting the N_e has not declined during the period of hatchery operation. The N_e /N ratio calculated using 386.8 and the arithmetic census of NOS and HOS Chinook from 1989 – 2005 is 0.40. These results suggest the Chiwawa Hatchery Supplementation Program has not resulted in a smaller N_e for the natural spawners from the Chiwawa River.

Williamson et al. (submitted) argued that since their combined (i.e., broodstock and natural) N_e estimate was lower than the naturally spawning estimate, the supplementation program likely had a negative impact on the Chiwawa River N_e. We disagree with this interpretation of these data. Since the natural spawning component is mixed hatchery and natural ancestry, the N_e estimates from natural spawning data are the results that bear on possible hatchery impacts. The census data show the population declined in the mid 1990's and rebounded by 2000 (Table 2). This trend is reflected in the N_e results, as shown above, and Williamson et al. (submitted) clearly show in their Table 4 the N_e was lower in 2000 (N_e = 989) than it was in 1992 (N_e = 2683). Yet, the important comparison they make in our view was the natural spawning N_e versus the natural only component N_e (i.e., hypothetically excluding hatchery program). Williamson et al. (submitted) report the 1989 – 1992 N_e estimated from naturally spawning Chinook (i.e., NOS and HOS integrated) was essentially the same as the natural only component estimate, 2683 and 2776, respectively. This result is not surprising since no HOS fish were present between 1989 – 1992. They also report that the 1997 – 2000 N_e estimated from naturally spawning Chinook (i.e., NOS and HOS integrated) was N_e =989, while the natural-origin estimate of N_e in 1997 – 2000 was N_e = 629. Since the natural-origin estimate of 629 is lower than 989, the N_e estimate from all in-river spawners, we argue that their analysis of demographic data show the N_e estimated from naturally spawning Chinook (i.e., NOS and HOS integrated) is larger only if the hatchery Chinook in the river are ignored.

Task 11: Use individual assignment methods to determine the power of self-assignment for upper Wenatchee River tributaries.

See "Assignment of Individual to Populations" in Task 6

Conclusions

Has the Chiwawa Hatchery Supplementation Program succeeded at increasing the census size of the target population while leaving genetic integrity intact? This is an important question, as hatcheries can impact natural populations by reducing overall genetic diversity (Ryman and Laikre 1991), reducing the fitness of the natural populations through relaxation of selection or inadvertent positive selection of traits advantageous in the hatchery (Ford 2002; Lynch and O'Hely 2001), and by reducing the reproductive success of natural populations (McLean et al. 2003). The census data presented here show that the current natural spawning census size is similar to the pre-supplementation census size. Despite large numbers of hatchery-origin fish on the Chiwawa River spawning grounds, the genetic diversity of the natural-origin collections appear unaffected by the supplementation program; heterozygosities are high, and contemporary N_e is similar (perhaps slightly higher) than pre-supplementation N_e. We did find significant year-to-year differences in allele frequencies in both the origin and spawner datasets, but these differences do not appear to be related to fish origin, spawning area, or genetic drift. However, we do suggest that cohort differences may be the most important factor accounting for differences in allele frequencies among collections.

The main objective of this study was to determine the potential impacts of the hatchery program on natural spring Chinook in the upper Wenatchee system. We did this by analyzing temporally replicated collections from the Chiwawa River, and by comparing genetic diversity prior to the presumed effect of the Chiwawa Hatchery Supplementation Program, with contemporary collections. We report that the genetic diversity present in the Chiwawa River is unchanged (allowing for differences among cohorts) from 1989 – 2006, and the contemporary estimate of the effective population size (N_e) using genetic data is approximately the same as the N_e estimate extrapolated from 1989 – 1992 census data (i.e., pre-hatchery collection years). We observed substantial genetic diversity, with heterozygosities ~80% over thirteen microsatellite markers. Yet, temporal variation in allele frequencies was the norm among temporal collections from the same populations (i.e., location). The genetic differentiation of replicated collections from the same population is likely the result of salmon life history in this area, as four-year-old Chinook comprise a majority of returns each year. The genetic tests are detecting the differences of contributing parents for each cohort. An important point related to the temporal variation, is that the hatchery broodstock is composed in part of the natural origin Chinook from the Chiwawa River. When we compared the genetic data (within a collection year) for Chinook brought into the hatchery as broodstock with the Chinook that remained in the river (years 2001, 2004 – 2006), there was a trend of decreasing statistical differences in allele frequencies from 2001 to 2004, and no differences were detected for 2005 and 2006. While the replicated collections may have detectable differences in allele frequencies, those differences reflect actual differences in cohorts, not the result of hatchery operations, and the hatchery broodstock collection method captures the differences in returning Chiwawa River spring adults each year. We conclude from these results that the genetic diversity of natural spring Chiwawa Chinook has been maintained during the Chiwawa Hatchery Supplementation Program.

We observe slight, but statistically significant population differentiation between Chiwawa River, White River, and Nason Creek collections. Murdoch et al (2006) and Williamson et al. (submitted) also observed population differentiation between Chiwawa River, White River, and Nason Creek collections. Yet, 99.3% of the genetic variation observed was within samples, very little variance could be attributed to population differences (i.e., population structure). The AMOVA analysis and poor individual assignment results suggest the occurrence of gene flow among Wenatchee River locations or a very recent divergence of these groups. While Murdoch et al. 2006 did not perform an AMOVA analysis, their F_{ST} results provide comparable data to our among-population results. Murdoch et al. 2006 report F_{ST} ranging from 2%-3% for pairwise comparisons between of Chiwawa, White, and Nason River collections. Since F_{ST} is an estimate of among-sample variance, these results also imply a majority of the genetic variance (i.e., 97%-98%) resides within collections. To provide further context for the magnitude of these variance estimates, we present the among-group data from Murdoch et al. 2006 comparing summer-run and spring-run Chinook from the Wenatchee River. They report that approximately 91% of observed genetic variance is within-collection for comparisons between collections of summer- and spring-run Chinook. Ultimately, the information provided by this and other reports will be incorporated into the management process for Wenatchee River Chinook. However, we would like to emphasize that the application of these genetic data to management is more about the goals related to the distribution of genetic diversity in the future than specific data values reported. If Chinook are collected at Tumwater Dam instead of within the upper Wenatchee River tributaries, a vast majority of the genetic variation present in the basin would be captured, although any differences among tributaries would be mixed. Alternatively, management policies could be crafted to promote and maintain the among-group genetic diversity that genetic studies consistently observe to be non-zero within the Wenatchee River.

We agree with Murdoch et al. (2006) that it appears hatchery Chinook are not contributing to reproduction in proportion to their abundance. Additionally, if the total census size (i.e., NOS and HOS combined) within the Chiwawa River does not continue to increase, genetic diversity may decline within this system, given the smaller N_e within the hatchery-origin collections compared with the natural-origin collections.

Acknowledgements

We would like to thank Denise Hawkins, Craig Busack, and Cheryl Dean for helpful comments regarding this project. This project was funded by Chelan County PUD and the Washington State General Fund.

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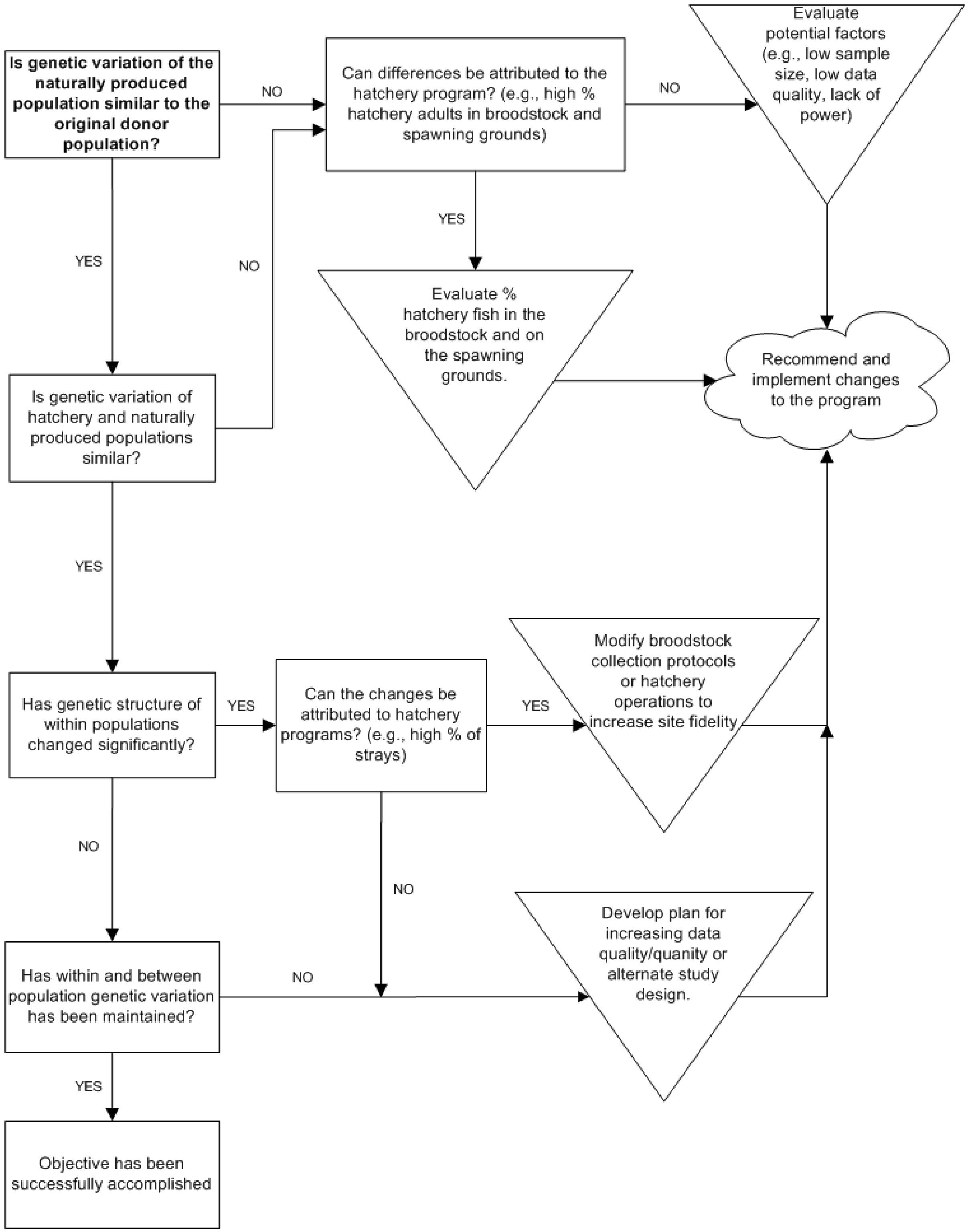

Figure 1. Conceptual process for evaluating potential changes in genetic variation in the Chiwawa naturally produced populations as a result of the supplementation hatchery programs (From Murdoch and Peven 2005).

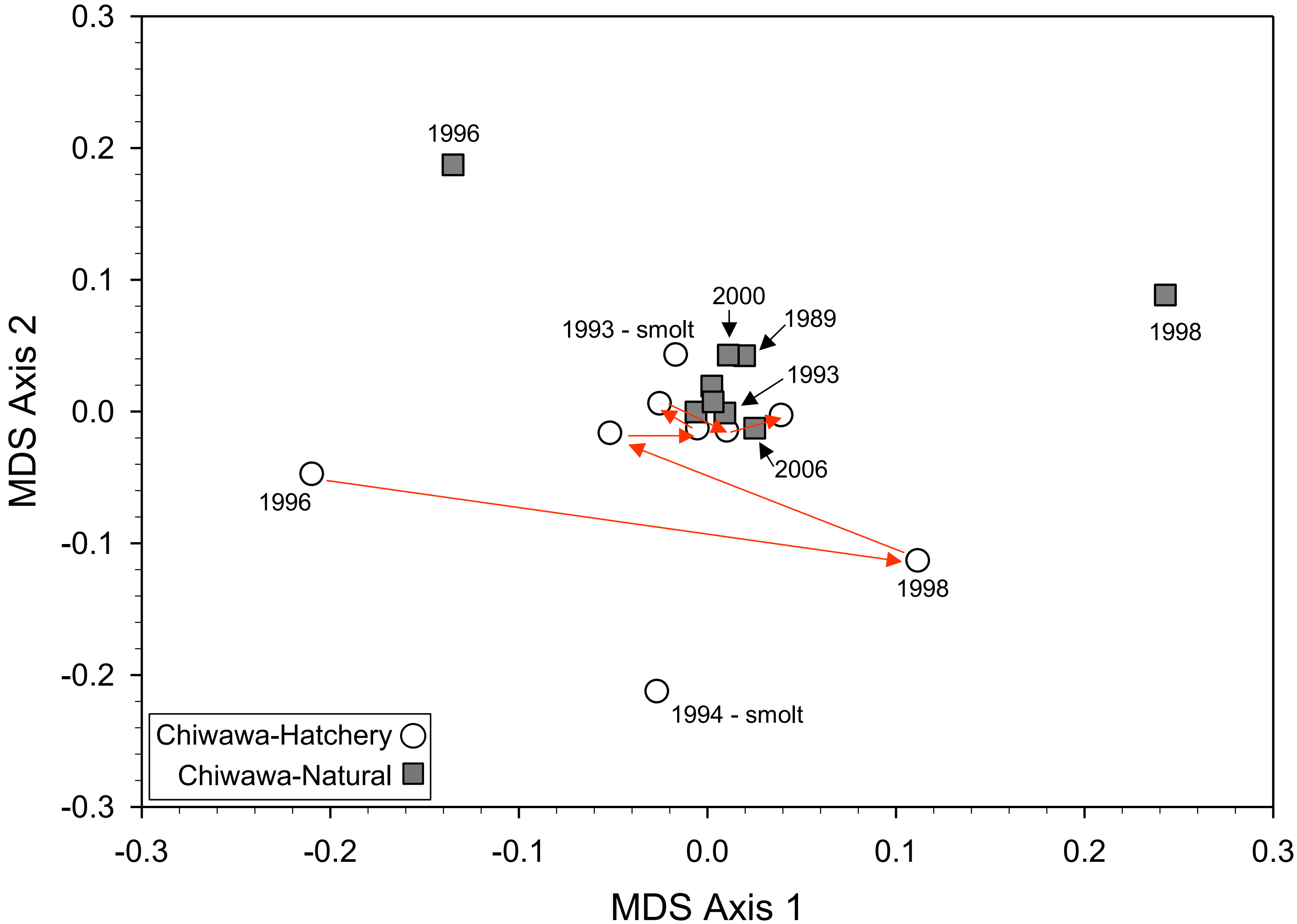

Figure 2. Multidimensional scaling plot from an allele-sharing distance matrix calculated from the Chiwawa data set organized by fish origin (i.e., hatchery versus natural). The red arrows connect consecutive hatchery-origin collections starting with the first adult collection (1996) and ending with the 2006 collection (see Table 1 for collection years).

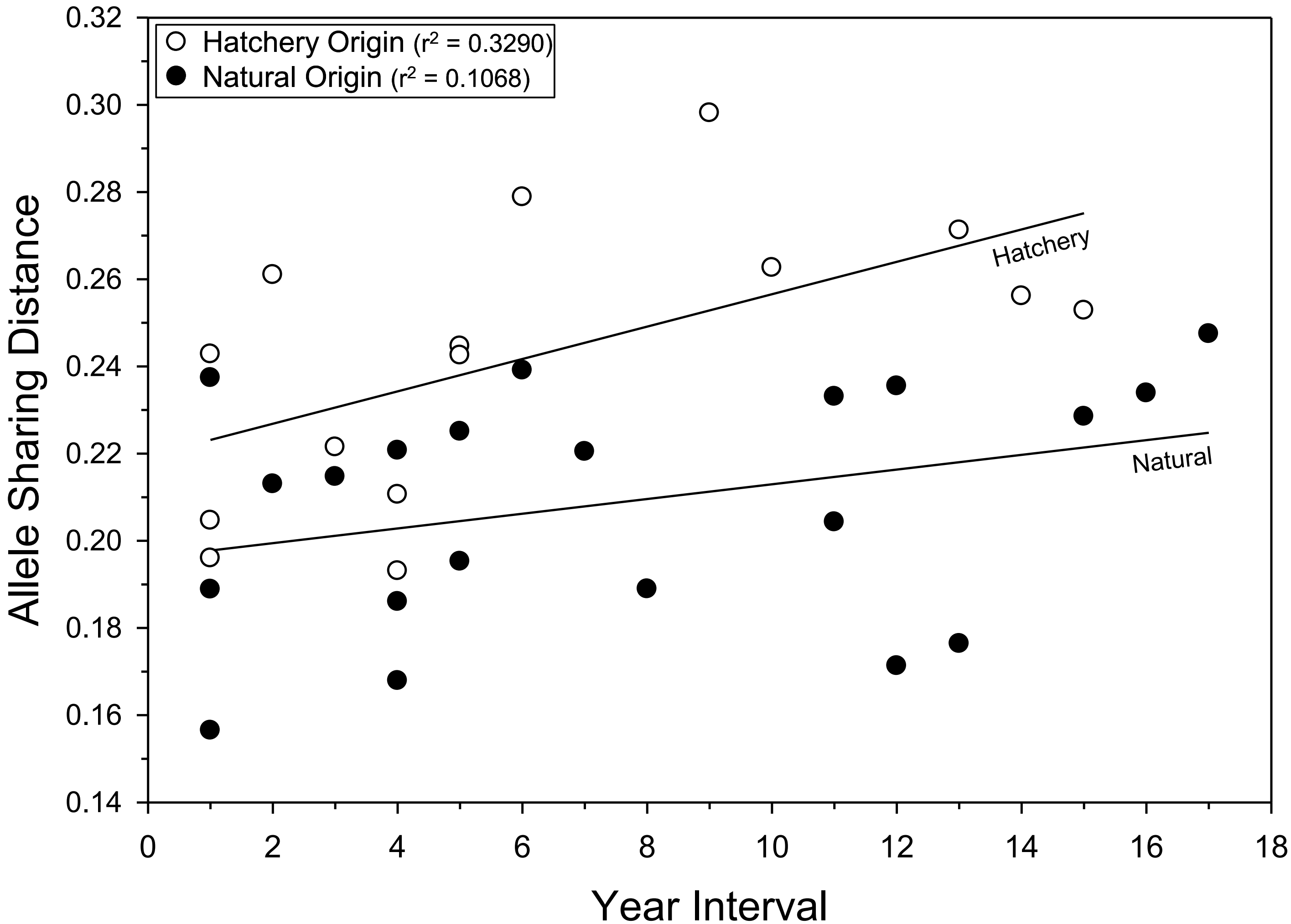

Figure 3. Relationships between the time interval in years and allele sharing distances, with each circle representing the pairwise relationship between two Chiwawa collections. Separate regression lines for the natural- and hatchery-origin collections. The slope for the natural-origin collection is not significantly different from zero (p=0.1483), while the slope for hatchery-origin collection is significantly greater than zero (p=0.0254) indicating a positive relationship between time interval and allele sharing distance.

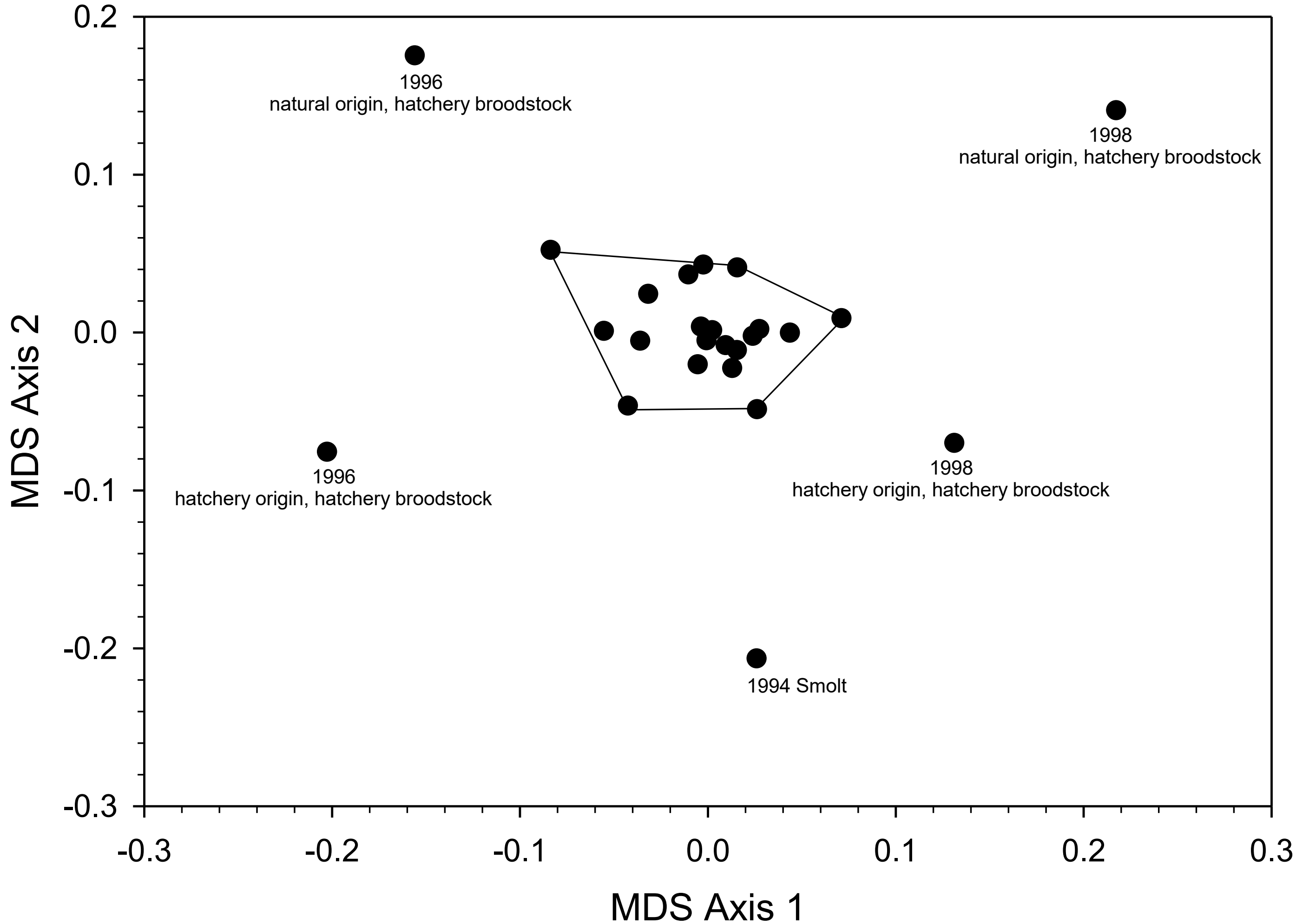

Figure 4. Multidimensional scaling plot from an allele-sharing distance matrix calculated from the Chiwawa data set organized by four treatment groups, as discussed in the text. Each circle represents a single collection within each of the four treatment groups, and the polygon encloses all groups that are not outliers. Each outlier group is specifically labeled.

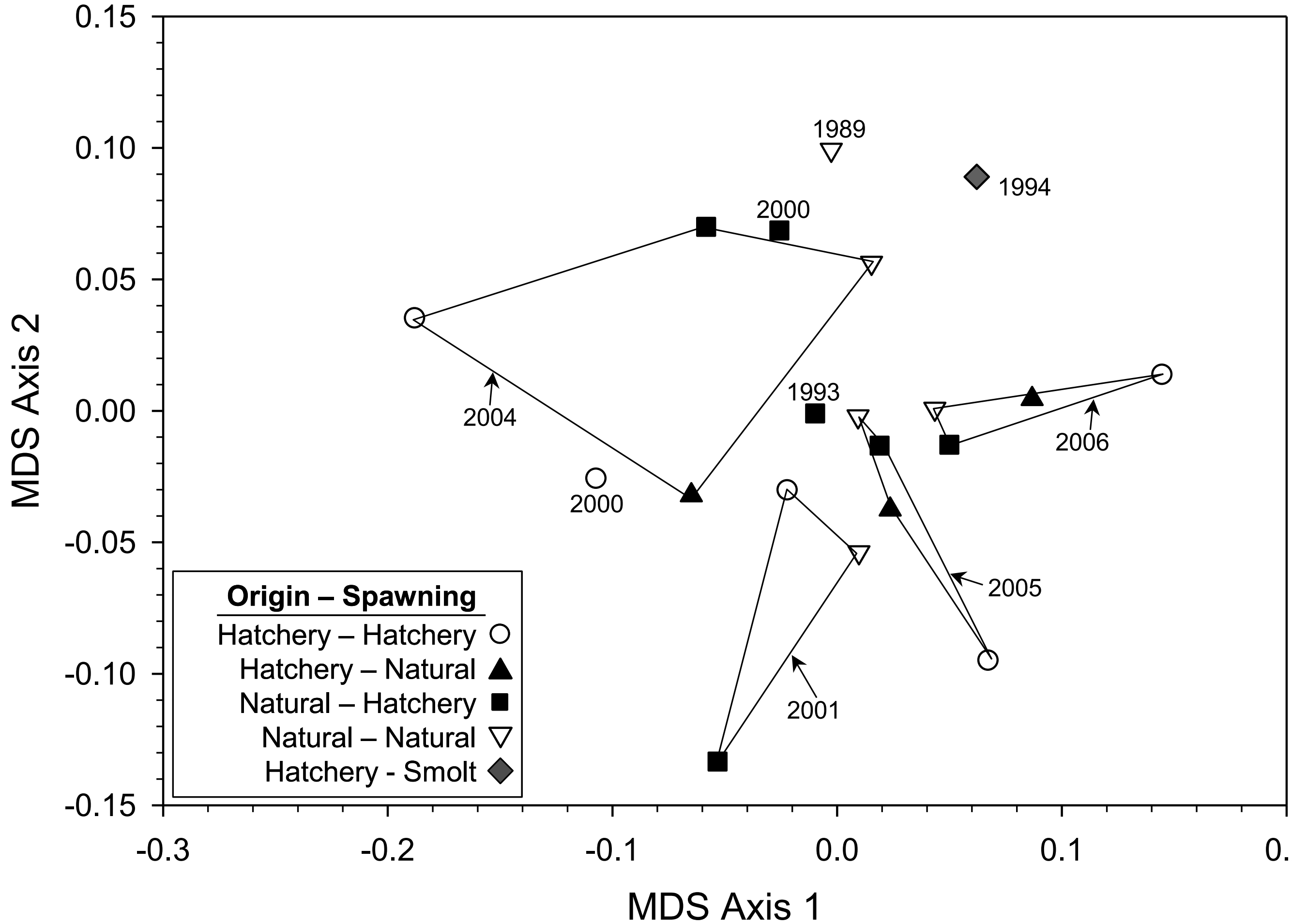

Figure 5. As in Figure 4, but allele-sharing distance matrix recalculated without the five outlier groups shown in Figure 4. Polygons group together treatment groups from the same collection year. Dates associated with symbols also refer to collection year. Collection years 2004-2006 included all four treatment groups, while collection year 2001 did not include a hatchery-origin natural spawner group. Legend is read as follows: Open circles refer to hatchery-origin hatchery spawner group, while filled box refers to natural-origin hatchery spawner group, and so on.

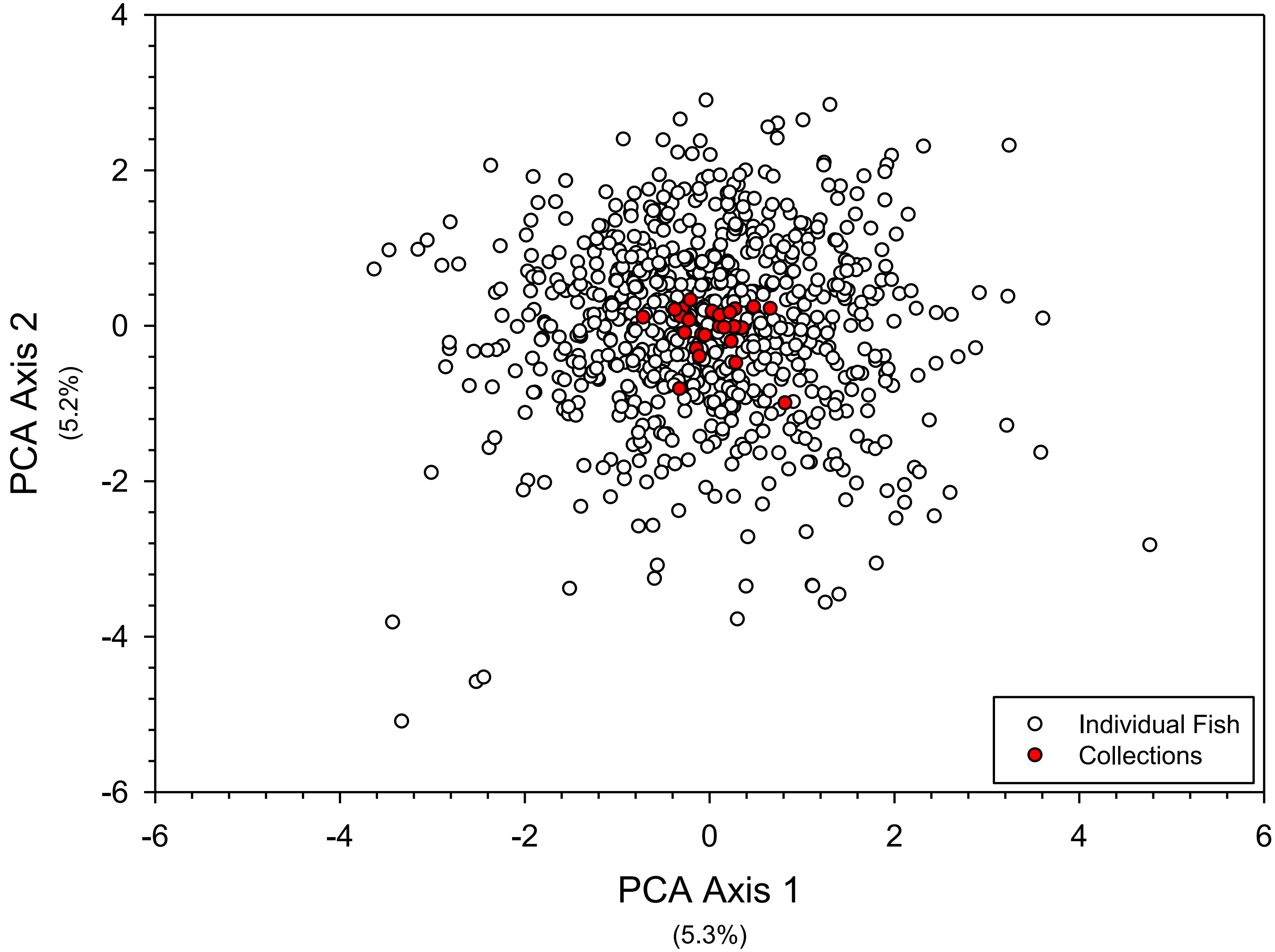

Figure 6. Principal component (PC) analysis of individual fish from the Chiwawa River. Only fish with complete microsatellite genotypes were included in the analysis (n = 757). Open circles are the PC scores for individual fish, and the filled circles are the centroids (bivariate means) for each of the 25 groups discussed in the text. PC axes 1 and 2 account for only 10.5% of the total molecular variance.

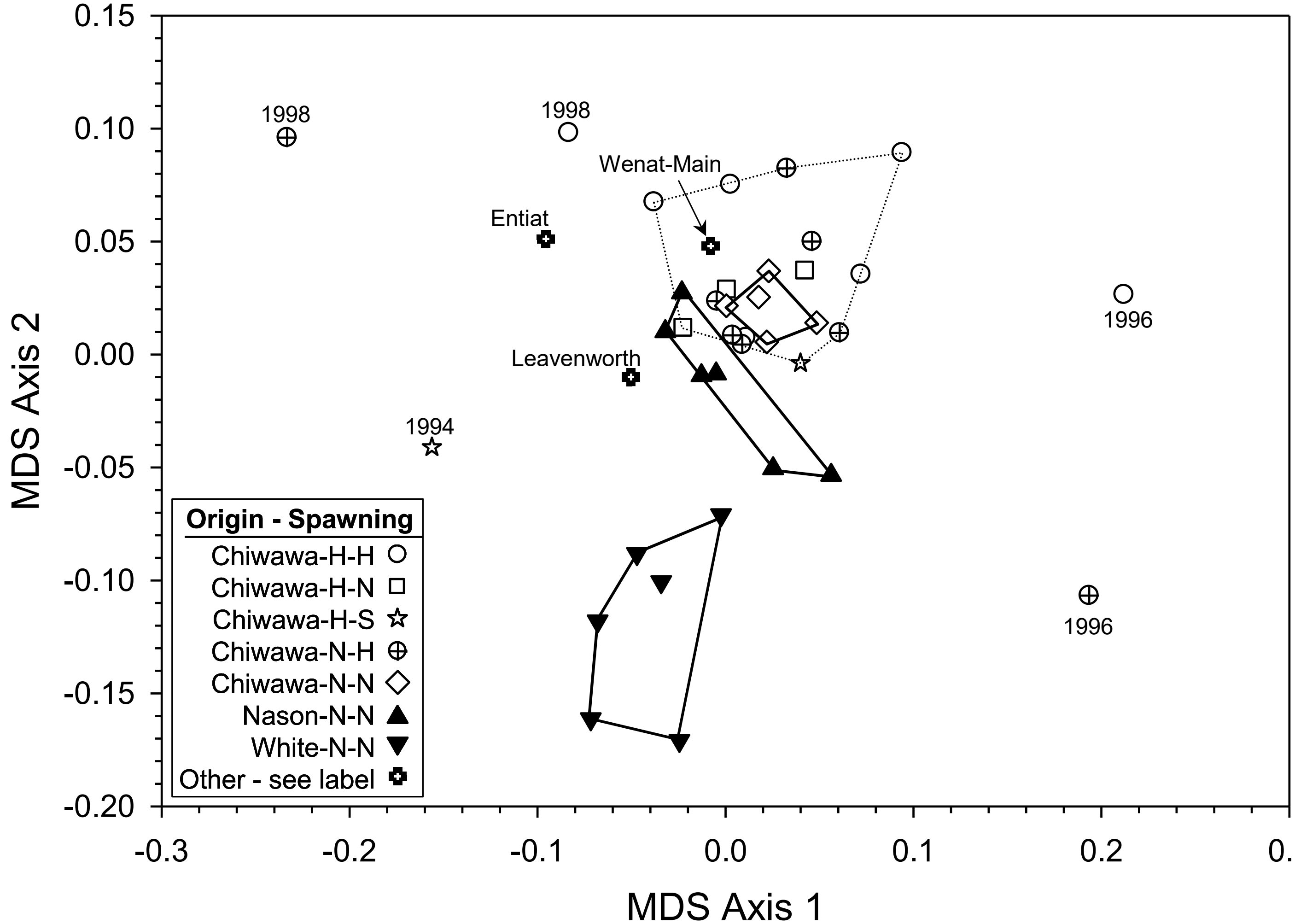

Figure 7. Multidimensional scaling plot from an allele-sharing distance matrix calculated from the Chiwawa origin data set and all other non-Chiwawa collections, except Little Wenatchee River. Legend is read with abbreviations beginning with origin and then spawning location. H=hatchery, N=natural, and S=smolts. Polygons with solid lines enclose the natural-origin natural spawner collections from each population (i.e., river). The polygon with the dotted lines enclose all Chiwawa collections, except for the five outlier collections, as discussed in text.

Table 1 Summary of within population genetic data. Chiwawa collection data are summarized in A) by origin of the sample (i.e., clipped vs. non-clipped). All collection data are summarized in B) by spawning location (i.e., hatchery broodstock or on spawning grounds). Hz is heterozygosity, HWE is the statistical significance of deviations from Hardy-Weinberg expectations (* = 0.05, ** = 0.01, and *** = 0.001), LD is the proportion of pairwise locus tests (across all populations) exhibiting linkage disequilibrium (bolded values are statistically significant), and the last column is mean number of alleles per locus.

Collection	Sample size	Gene Diversity	Observed Hz	HWE	F_{IS}	LD	Mean # Alleles
A) Origin							
1993 Chiwawa Hatchery	95	0.77	0.79	***	-0.02	**0.86**	14.00
1994 Chiwawa Hatchery	95	0.76	0.77	***	-0.01	**0.91**	11.38
1996 Chiwawa Hatchery	8	0.75	0.81	-	-0.01	0.00	8.23
1998 Chiwawa Hatchery	27	0.81	0.82	-	0.00	0.04	12.62
2000 Chiwawa Hatchery	43	0.75	0.78	***	-0.01	**0.19**	12.46
2001 Chiwawa Hatchery	69	0.77	0.80	***	-0.02	**0.14**	15.31
2004 Chiwawa Hatchery	72	0.77	0.77	***	0.01	**0.45**	15.92
2005 Chiwawa Hatchery	91	0.79	0.82	*	-0.03	**0.05**	16.15
2006 Chiwawa Hatchery	95	0.80	0.84	***	-0.05	**0.49**	15.85
1989 Chiwawa Natural	36	0.76	0.78	-	0.01	0.00	12.77
1993 Chiwawa Natural	62	0.78	0.81	-	-0.02	0.04	15.85
1996 Chiwawa Natural	8	0.72	0.78	-	-0.02	0.00	7.54
1998 Chiwawa Natural	10	0.78	0.84	-	0.00	0.00	8.23
2000 Chiwawa Natural	39	0.78	0.79	***	0.00	**0.10**	14.00
2001 Chiwawa Natural	75	0.78	0.80	-	-0.03	0.03	15.31
2004 Chiwawa Natural	85	0.78	0.77	-	0.02	0.01	15.77
2005 Chiwawa Natural	90	0.79	0.79	-	0.01	0.01	16.15
2006 Chiwawa Natural	96	0.80	0.81	-	-0.01	0.01	16.46

Table 1 Within population genetic data analysis summary continued.

Collection	Sample size	Gene Diversity	Observed Hz	HW	F_{IS}	LD	Mean # Alleles
B) Spawning Location							
1993 Chiwawa Broodstock	62	0.78	0.81	-	-0.02	0.00	15.85
1996 Chiwawa Broodstock	16	0.75	0.79	-	-0.02	0.00	10.92
1998 Chiwawa Broodstock	37	0.82	0.83	-	0.00	0.01	14.38
2000 Chiwawa Broodstock	82	0.78	0.78	***	0.00	**0.32**	15.62
2001 Chiwawa Broodstock	89	0.78	0.80	*	-0.02	**0.13**	15.77
2004 Chiwawa Broodstock	61	0.77	0.76	*	0.02	**0.13**	14.92
2005 Chiwawa Broodstock	75	0.79	0.78	*	0.02	0.01	15.85
2006 Chiwawa Broodstock	89	0.80	0.83	-	-0.03	**0.05**	16.46
1989 Chiwawa River	36	0.76	0.78	-	0.01	0.00	12.77
2001 Chiwawa River	55	0.78	0.80	-	-0.02	**0.09**	14.00
2004 Chiwawa River	96	0.78	0.78	*	0.01	**0.18**	17.23
2005 Chiwawa River	106	0.79	0.82	*	-0.02	**0.06**	16.69
2006 Chiwawa River	102	0.80	0.83	***	-0.03	**0.10**	16.77
1989 White River	48	0.75	0.75	-	0.01	0.01	12.85
1991 White River	19	0.76	0.76	-	0.03	0.00	10.92
1992 White River	22	0.75	0.79	-	-0.02	0.01	11.00
1993 White River	21	0.75	0.69	*	0.10	0.00	10.15
2005 White River	29	0.75	0.77	-	-0.01	0.03	12.23
2006 White River	40	0.76	0.76	-	0.01	0.04	13.38

Table 1 Within population genetic data analysis summary continued.

Collection	Sample size	Gene Diversity	Observed Hz	HW	F_{IS}	LD	Mean # Alleles
1993 Little Wenatchee R.	19	0.84	0.85	-	0.02	0.00	11.23
1993 Nason Creek	45	0.78	0.80	-	-0.01	0.01	13.77
2000 Nason Creek	51	0.76	0.78	-	-0.02	**0.13**	13.92
2001 Nason Creek	41	0.79	0.81	-	-0.01	**0.08**	14.23
2004 Nason Creek	38	0.76	0.76	-	0.02	0.03	13.23
2005 Nason Creek	45	0.78	0.82	-	-0.04	0.03	14.92
2006 Nason Creek	48	0.80	0.82	-	-0.01	0.00	15.77
2001 Wenatchee River	32	0.79	0.80	*	0.00	0.04	12.85
2000 Leavenworth NFH	73	0.80	0.82	*	-0.02	**0.15**	16.23
1997 Entiat NFH	37	0.81	0.83	-	-0.01	**0.06**	14.38

Table 2 Demographic data for Chiwawa Hatchery and Chiwawa natural spring Chinook salmon. BS is census size of hatchery broodstock, pNOB is the proportion of hatchery broodstock of natural origin, NOS is the census size of natural-origin spawners present in Chiwawa River, HOS is the census size of hatchery-origin spawners present in Chiwawa River, Total is NOS and HOS combined, and pNOS is the proportion of spawners present in Chiwawa River of natural origin.

	Hatchery		In River			
Brood Year	BS	pNOB	NOS	HOS	Total	pNOS
1989	28	1	1392	0	1392	1.00
1990	18	1	775	0	775	1.00
1991	32	1	585	0	585	1.00
1992	78	1	1099	0	1099	1.00
1993	94	1	677	491	1168	0.58
1994	11	0.64	190	90	280	0.68
1995	0	0	8	50	58	0.14
1996	18	0.44	131	51	182	0.72
1997	111	0.29	210	179	389	0.54
1998	47	0.28	134	45	178	0.75
1999	0	0	119	13	132	0.90
2000	30	0.3	378	310	688	0.55
2001	371	0.3	1280	2850	4130	0.31
2002	71	0.28	694	919	1613	0.43
2003	94	0.44	380	223	603	0.63
2004	215	0.39	820	788	1608	0.51
2005	270	0.33	250	1222	1472	0.17

Table 3 Levels of significance for pairwise tests of genic differentiation among all hatchery- and natural-origin collections used in this analysis. HS = highly significant ($P < 0.000095$; the Bonferroni corrected p-value for an alpha = 0.05); * = $P < 0.05$ (nominal critical value for most statistical test); - = $P > 0.05$ (not significant). A significant result between pairs of populations indicates that the allele frequencies between the pair are significantly different. Results are read by comparing the collections along the rows to collections along columns. The top block for each section is a symmetric matrix, as it compares collections within the same group.

		Chiwawa – Hatchery Origin								
		1993	**1994**	**1996**	**1998**	**2000**	**2001**	**2004**	**2005**	**2006**
Chiwawa – Hat. Origin	**1993**		HS	*	HS	HS	HS	HS	HS	HS
	1994	HS		HS	HS	HS	HS	HS	HS	HS
	1996	*	HS		*	-	*	-	-	*
	1998	HS	HS	*		HS	HS	HS	HS	HS
	2000	HS	HS	-	HS		HS	*	HS	HS
	2001	HS	HS	*	HS	HS		HS	*	HS
	2004	HS	HS	-	HS	*	HS		HS	HS
	2005	HS	HS	-	HS	HS	*	HS		HS
	2006	HS	HS	*	HS	HS	HS	HS	HS	
Chiwawa – Natural Origin	**1989**	HS	HS	-	HS	HS	*	HS	HS	HS
	1993	HS	HS	-	HS	HS	-	HS	*	HS
	1996	*	HS	-	*	-	-	-	-	-
	1998	HS	HS	-	-	HS	*	*	*	-
	2000	HS	HS	-	HS	HS	HS	*	HS	HS
	2001	HS	HS	-	HS	HS	HS	HS	*	HS
	2004	HS	HS	-	HS	HS	HS	HS	HS	HS
	2005	HS	HS	-	HS	HS	*	HS	*	HS
	2006	HS	HS	-	*	HS	HS	HS	HS	HS
Nason	**1996**	HS	HS	-	HS	HS	HS	HS	HS	HS
	2000	HS	HS	*	HS	HS	HS	HS	HS	HS
	2001	HS	HS	-	HS	HS	HS	HS	HS	HS
	2004	HS	HS	-	HS	HS	HS	HS	HS	HS
	2005	HS	HS	-	HS	HS	HS	HS	HS	HS
	2006	HS	HS	-	*	HS	HS	HS	HS	HS
White	**1989**	HS	HS	HS	HS	HS	HS	HS	HS	HS
	1991	HS	HS	-	HS	HS	HS	HS	HS	HS
	1992	HS	HS	*	HS	HS	HS	HS	HS	HS
	1993	HS	HS	*	HS	HS	HS	HS	HS	HS
	2005	HS	HS	-	HS	HS	HS	HS	HS	HS
	2006	HS	HS	HS	HS	HS	HS	HS	HS	HS
Other	**Wen-M**	HS	HS	*	HS	HS	*	*	-	HS
	Leaven	HS	HS	*	HS	HS	HS	HS	HS	HS
	Entiat	HS	HS	*	HS	HS	HS	HS	HS	HS

Table 3 (con't)

		Chiwawa – Natural Origin								
		1989	**1993**	**1996**	**1998**	**2000**	**2001**	**2004**	**2005**	**2006**
Chiwawa – Natural Origin	**1989**		-	-	-	-	*	*	*	*
	1993	-		-	*	*	*	HS	*	HS
	1996	-	-		-	-	-	-	-	-
	1998	-	*	-		*	*	HS	*	*
	2000	-	*	-	*		HS	-	HS	HS
	2001	*	*	-	*	HS		HS	*	HS
	2004	*	HS	-	HS	-	HS		HS	HS
	2005	*	*	-	*	HS	*	HS		*
	2006	*	HS	-	*	HS	HS	HS	*	
Nason	**1996**	*	*	-	*	*	HS	HS	HS	HS
	2000	HS	HS	HS	HS	HS	HS	HS	HS	HS
	2001	HS	*	-	*	HS	HS	HS	HS	HS
	2004	HS	HS	-	HS	HS	HS	HS	HS	HS
	2005	*	*	-	*	HS	HS	HS	HS	HS
	2006	HS	HS	-	-	HS	HS	HS	HS	HS
White	**1989**	HS	HS	*	HS	HS	HS	HS	HS	HS
	1991	HS	HS	*	-	HS	HS	HS	HS	HS
	1992	HS	HS	-	*	HS	HS	HS	HS	HS
	1993	HS	*	-	*	HS	HS	HS	HS	HS
	2005	HS	*	*	*	HS	HS	HS	*	HS
	2006	HS	HS	*	HS	HS	HS	HS	HS	HS
Other	**Wen-M**	*	-	-	-	*	*	HS	*	*
	Leaven	HS	HS	*	*	HS	HS	HS	HS	HS
	Entiat	HS	HS	*	HS	HS	HS	HS	HS	HS

Table 3 (con't)

		Nason					
		1996	2000	2001	2004	2005	2006
Nason	1996		HS	-	HS	-	*
	2000	HS		HS	HS	HS	HS
	2001	-	HS		*	-	*
	2004	HS	HS	*		*	HS
	2005	-	HS	-	*		-
	2006	*	HS	*	HS	-	
White	1989	HS	HS	HS	HS	HS	HS
	1991	*	HS	HS	HS	*	*
	1992	HS	HS	HS	HS	HS	HS
	1993	*	HS	HS	HS	HS	HS
	2005	*	HS	HS	HS	HS	HS
	2006	HS	HS	HS	HS	HS	HS
Other	Wen-M	HS	HS	HS	HS	*	HS
	Leaven	HS	HS	HS	HS	HS	HS
	Entiat	HS	HS	HS	HS	HS	HS

Table 3 (con't)

		White						Other		
		1989	1991	1992	1993	2005	2006	Wen-M 2001	Leaven 2000	Entiat 1997
White	1989		-	*	-	HS	HS	HS	HS	HS
	1991	-		-	-	*	*	*	HS	HS
	1992	*	-		-	*	*	HS	HS	HS
	1993	-	-	-		*	*	HS	HS	HS
	2005	HS	*	*	*		*	HS	HS	HS
	2006	HS	*	*	*	*		HS	HS	HS
Other	Wen-M	HS	*	HS	HS	HS	HS		HS	HS
	Leaven	HS	HS	HS	HS	HS	HS	HS		HS
	Entiat	HS	HS	HS	HS	HS	HS	HS	HS	

Table 4 Probabilities (above diagonal) and levels of significance (below diagonal) for pairwise tests of genic differentiation among all Chiwawa hatchery broodstock and Chiwawa natural spawner collections used in this analysis. HS = highly significant (P < 0.000476; the Bonferroni corrected p-value for an alpha = 0.05); * = P < 0.05 (nominal critical value for most statistical test); - = P > 0.05 (considered not significant). A significant result between pairs of populations indicates that the allele frequencies between the pair are significantly different. Pairwise comparisons between the hatchery broodstock and natural spawner collections from 2001, 2004, 2005, and 2006, respectively, are highlighted.

		Smolt		Hatchery Broodstock								Natural Spawners				
		1993	**1994**	**1993**	**1996**	**1998**	**2000**	**2001**	**2004**	**2005**	**2006**	**1989**	**2001**	**2004**	**2005**	**2006**
Smolt	**1993**		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	1994	HS		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Hatchery Broodstock	**1993**	HS	HS		0.9155	0.0000	0.0073	0.3647	0.0003	0.0694	0.0000	0.2220	0.0039	0.0008	0.0095	0.0000
	1996	HS	HS	-		0.0151	0.8388	0.0452	0.4916	0.3189	0.0716	0.5591	0.0759	0.8101	0.2364	0.0786
	1998	HS	HS	HS	*		0.0000	0.0000	0.0000	0.0000	0.0043	0.0000	0.0000	0.0000	0.0000	0.0005
	2000	HS	HS	*	-	HS		0.0000	0.4720	0.0000	0.0000	0.0036	0.0000	0.0712	0.0000	0.0000
	2001	HS	HS	-	*	HS	HS		0.0000	0.0059	0.0000	0.0003	0.0000	0.0000	0.0126	0.0000
	2004	HS	HS	*	-	HS	-	HS		0.0000	0.0000	0.0001	0.0000	0.0012	0.0000	0.0000
	2005	HS	HS	-	-	HS	HS	*	HS		0.0005	0.0024	0.0137	0.0025	0.7782	0.0018
	2006	HS	HS	HS	-	*	HS	HS	HS	*		0.0000	0.0000	0.0000	0.0000	0.5770
Natural Spawners	**1989**	HS	HS	-	-	HS	*	*	HS	*	HS		0.0023	0.0317	0.0000	0.0003
	2001	HS	HS	*	-	HS	HS	HS	HS	*	HS	*		0.0000	0.2641	0.0000
	2004	HS	HS	*	-	HS	-	HS	*	*	HS	*	HS		0.0000	0.0000
	2005	HS	HS	*	-	HS	HS	*	HS	-	HS	HS	-	HS		0.0000
	2006	HS	HS	HS	-	*	HS	HS	HS	*	-	*	HS	HS	HS	

Table 5 Analysis of molecular variance (AMOVA) for the Chiwawa collections, showing the partition of molecular variance into (1) within collections, (2) among collections but within group, and (3) among group components. Each column in the table represents a separate analysis testing for differences under a different spatial or temporal hypothesis. The different analyses are grouped together in a single table for comparisons. The values within the table are percentages and the parenthetical values are P-values, or probabilities, associated with that percentage. P-values greater than 0.05 indicate that the percentage is not significantly different from zero. For example, when collections are organized by hatchery- versus natural-origin ("Origin" – fourth column), 0.11% of the molecular variance is attributed to among group (i.e., hatchery- versus natural-origin), which is not significantly different from zero. No collections (first column) indicates no organization or grouping among all collections, and the among-group percentage is equal to the F_{ST} for the entire data set.

	No Structure	Collection Year	Spawning Location	Origin	Origin-Spawning Location
Among Groups	0.26 (0.00)	0.20 (0.43)	0.05 (0.48)	0.11 (0.15)	0.11 (0.06)
Among collections - Within groups	-	0.08 (0.003)	0.24 (0.00)	0.21 (0.00)	0.18 (0.06)
Within collections	99.74 (0.00)	99.72 (0.00)	99.71 (0.00)	99.68 (0.00)	99.71 (0.00)

Table 6 F_{ST} values for all pairwise combinations of populations. Each F_{ST} is the median value for all pairwise combinations of collections within each population (the number of collections within each population is shown parenthetically next to each population name on each row). For example, the F_{ST} for the Chiwawa hatchery versus the White River (0.019) is the median value of 54 pairwise comparisons. The bold values along the center diagonal are the median F_{ST} values within each collection. For those populations with only one collection, the diagonal value was set at 0.000.

	Chiwawa-Hatchery	Chiwawa-Natural	Entiat	Leaven-worth	Nason	Wenatchee-main	White	Little Wenatchee
Chiwawa-Hatchery (9)	**0.013**	0.008	0.016	0.012	0.011	0.005	0.019	0.111
Chiwawa-Natural (9)		**0.003**	0.012	0.011	0.007	0.003	0.014	0.105
Entiat (1)			**0.000**	0.005	0.010	0.008	0.019	0.078
Leavenworth (1)				**0.000**	0.007	0.008	0.014	0.092
Nason (6)					**0.006**	0.008	0.015	0.099
Wenatchee-main (1)						**0.000**	0.012	0.098
White (6)							**0.005**	0.113
Little Wenatchee (1)								**0.000**

Table 7 As in Table 5, except data includes Chiwawa hatchery- and natural-origin, Nason Creek, and White River collections

	All Years	All Years	1989-1996	2005-2006	2005-2006
	No Structure	Origin	Origin	Origin	Collection Year
Among Groups	0.28 (0.00)	0.33 (0.00)	-0.07 (0.67)	0.43 (0.01)	-0.06 (0.57)
Among Collections - Within groups	-	0.04 (0.00)	0.22 (0.00)	0.25 (0.00)	0.64 (0.00)
Within Collections	99.72	99.63	99.85	99.32	99.41

Table 8 Individual assignment results reported are the numbers of individuals assigned to each population using the partial Bayesian criteria of Rannala and Mountain (1997) and a "jack-knife" procedure (see Methods). The population with the highest posterior probability is considered the stock of origin (i.e., no unassigned individuals). Individuals from each population are assigned to specific populations (along rows). Bold values indicate correct assignment back to population of origin. Individuals assigned to a population are read down columns. For example, of the 595 individuals from Chiwawa hatchery origin, 134 individuals were assigned to Chiwawa natural origin (reading across). Of the 511 individuals assigned to Chiwawa natural origin (reading down), 60 were from Nason Creek.

Population	Total	Unassigned	1	2	3	4	5	6	7	8
1) Chiwawa Hatchery	595	0	**371**	134	2	16	0	45	15	12
2) Chiwawa Natural	501	0	156	**269**	4	5	0	42	9	16
3) Entiat	37	0	4	5	**13**	8	0	6	1	0
4) Leavenworth	73	0	9	8	3	**33**	0	17	0	3
5) Little Wenatchee	19	0	0	0	0	0	**19**	0	0	0
6) Nason	268	0	49	60	5	11	0	**131**	1	11
7) Wenatchee Mainstem	32	0	12	9	0	1	0	2	**6**	2
8) White	179	0	22	26	0	2	0	13	1	**115**
TOTAL	1704	0	623	511	27	76	19	256	33	159

Table 9 As in Table 8, except the posterior probability from the partial Bayesian criteria of Rannala and Mountain (1997) must be 0.90 or greater, to be assigned to a population. Those individuals with posterior probabilities less than 0.90 are unassigned.

Aggregate	**Total**	**Unassigned**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
1) Chiwawa Hatchery	595	332	**214**	31	1	4	0	10	3	0
2) Chiwawa Natural	501	375	30	**82**	0	1	0	5	2	6
3) Entiat	37	24	1	1	**5**	4	0	2	0	0
4) Leavenworth	73	51	0	1	1	**19**	0	1	0	0
5) Little Wenatchee	19	2	0	0	0	0	**17**	0	0	0
6) Nason	268	188	11	6	2	5	0	**53**	0	3
7) Wenatchee Mainstem	32	23	4	3	0	0	0	0	**2**	0
8) White	179	92	4	3	0	1	0	5	1	**73**
TOTAL	1704	1087	264	127	9	34	17	76	8	82

Table 10 Estimates of N_e based on bias correction method of Waples (2006) implemented in LDNe (Do and Waples unpublished). Collections are categorized by spawning location. Sample size is the harmonic mean of the sample size, 95% CI is the confidence interval calculated using Waples' (2006) equation 12, and Major Cohort assumes that each collection is 100% four-year-olds.

	Sample size	Estimated N_b	95% CI	Major Cohort	Census	N_e/N
1993 Chiwawa Broodstock	58.4	103.1	77.0 - 149.7	1989	1392	0.30
1996 Chiwawa Broodstock	15.5	30.4	19.6 - 58.1	1992	1099	0.11
1998 Chiwawa Broodstock	33.4	37.7	29.8 - 49.7	1994	280	0.54
2000 Chiwawa Broodstock	77.8	48.4	41.4 - 57.2	1996	182	1.06
2001 Chiwawa Broodstock	80.4	49.6	42.2 - 59.2	1997	389	0.51
2004 Chiwawa Broodstock	56.6	48.1	39.0 - 60.9	2000	688	0.28
2005 Chiwawa Broodstock	73	274.3	148.9 - 1131.8	2001	4130	0.27
2006 Chiwawa Broodstock	88.4	198.3	136.1 - 340.5	2002	1613	0.49
1989 Chiwawa River	26.6	5.2	3.9 - 6.3	1985		
2001 Chiwawa River	46.7	38.6	31.0 - 49.3	1997	389	0.40
2004 Chiwawa River	88.5	82.6	67.3 - 104.4	2000	688	0.48
2005 Chiwawa River	104.2	231.5	161.8 - 382.7	2001	4130	0.22
2006 Chiwawa River	101.1	107.3	87.2 - 136	2002	1613	0.27

Table 11 Summary of output from program SALMONNb and data for eight Chiwawa broodstock collections from Wenatchee River. For each pairwise comparison of samples *i* and *j*, $\tilde{S}$ is the harmonic mean sample size, *n* is the number of independent alleles used in the comparison, $\hat{N}_{b(i,j)}$ are the pairwise estimates of N_b, and Var [$\hat{N}_{b(i,j)}$] is the variance of $\hat{N}_{b(i,j)}$. $\tilde{N}_b$ is the harmonic mean of the $\hat{N}_{b(i,j)}$. Alleles with a frequency below 0.05 were excluded from the analysis to reduce potential bias.

Year	1993	1996	1998	2000	2001	2004	2005	2006
Pairwise $\tilde{S}$ (above diagonal) and *n* (below diagonal):								
1993	-	24.5	42.5	66.4	67.2	57.2	64.6	70.3
1996	82	-	21.2	25.8	26.0	24.4	25.6	26.4
1998	80	81	-	46.7	47.2	42.0	45.8	48.4
2000	80	82	84	-	78.6	65.2	75.1	82.7
2001	73	77	81	76	-	66.0	76.2	84.2
2004	77	81	75	76	78	-	63.5	69.0
2005	71	75	82	73	73	69	-	80.0
2006	81	80	84	75	74	75	72	-
Pairwise $\hat{N}_{b(i,j)}$ (above diagonal) and Var [$\hat{N}_{b(i,j)}$] (below diagonal):								
1993	-	-742.7	406.9	1240.8	-5432.0	829.8	808.9	729.0
1996	22491.2	-	110.4	-1786.5	765.9	162.8	824.7	382.7
1998	10910.4	67299.1	-	101.8	237.1	69.6	307.0	140.0
2000	6910.0	742895.8	19122.7	-	490.6	1498.2	706.9	201.6
2001	49318.3	21402.8	9754.2	6126.6	-	307.8	82.0	362.5
2004	8338.4	257267.7	24283.0	145043.4	7095.7	-	269.7	140.1
2005	31511.8	22242.5	10015.8	6596.6	114931.1	8240.4	-	599.6
2006	6223.8	43935.2	73518.7	10152.5	5885.3	12827.0	6370.8	-

$\tilde{N}_b = 269.4$

Table 12 Summary of output from program SALMONNb and data for five Chiwawa in-river spawner collections from Wenatchee River. For each pairwise comparison of samples *i* and *j*, $\tilde{S}$ is the harmonic mean sample size, *n* is the number of independent alleles used in the comparison, $\hat{N}_{b(i,j)}$ are the pairwise estimates of N_b, and Var [$\hat{N}_{b(i,j)}$] is the variance of $\hat{N}_{b(i,j)}$. $\tilde{N}_b$ is the harmonic mean of the $\hat{N}_{b(i,j)}$. Alleles with a frequency below 0.05 were excluded from the analysis to reduce potential bias.

Year	1989	2001	2004	2005	2006
Pairwise $\tilde{S}$ (above diagonal) and *n* (below diagonal):					
1989	-	33.3	40.2	41.7	42.2
2001	72	-	60.5	63.9	63.3
2004	72	77	-	95.3	94.0
2005	69	72	75	-	102.5
2006	76	76	77	78	-
Pairwise $\hat{N}_{b(i,j)}$ (above diagonal) and Var [$\hat{N}_{b(i,j)}$] (below diagonal):					
1989	-	118.4	299.0	143.3	165.3
2001	40378.8	-	181.7	-1537.3	153.5
2004	10455.2	7265.5	-	387.1	329.4
2005	20923.6	68660.6	5040.7	-	356.8
2006	16227.2	8886.9	3802.0	4522.8	-

$\tilde{N}_b = 224.2$

Table 13 Summary of output from program SALMONNb and data for three brood years that combined Chiwawa natural- and hatchery-origin samples from Wenatchee River. For each pairwise comparison of samples *i* and *j*, $\tilde{S}$ is the harmonic mean sample size, *n* is the number of independent alleles used in the comparison, $\hat{N}_{b(i,j)}$ are the pairwise estimates of N_b, and Var [$\hat{N}_{b(i,j)}$] is the variance of $\hat{N}_{b(i,j)}$. $\tilde{N}_b$ is the harmonic mean of the $\hat{N}_{b(i,j)}$. Alleles with a frequency below 0.05 were excluded from the analysis to reduce potential bias.

Year	2004	2005	2006
Pairwise $\tilde{S}$ (above diagonal) and *n* (below diagonal):			
2004	-	162	164.3
2005	77	-	188.2
2006	76	75	-
Pairwise $\hat{N}_{b(i,j)}$ (above diagonal) and Var [$\hat{N}_{b(i,j)}$] (below diagonal):			
2004	-	611.3	210.8
2005	9351.5	-	727.5
2006	14965.5	8673.9	-

$\tilde{N}_b = 386.8$

Appendix L

Fish Trapping at the Nason Creek Smolt Trap 2016

Population Estimates for Juvenile Salmonids in Nason Creek, WA

2016 Annual Report

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ABSTRACT

In 2016, Yakama Nation Fisheries Resource Management (YNFRM) monitored emigration of Endangered Species Act (ESA) listed Upper Columbia River (UCR) spring Chinook salmon and summer steelhead as well as naturally spawned juvenile coho salmon in Nason Creek. This report summarizes juvenile abundance and freshwater survival estimates for each of these species. Fish were captured using a 1.5m rotary smolt trap between March 1 and November 30, 2016. We collected 852 spring Chinook salmon, 672 summer steelhead, 1 bull trout, and 6 coho; all of natural origin and varying age classes. Daily fish abundances for spring Chinook, steelhead, and coho were expanded by stream discharge-to-trap efficiency regression or pooled estimates. All estimates were made with a 95% confidence interval (CI) with total emigration estimates for BY2014 spring Chinook juveniles and coho juveniles of 8,694 (± 5,207) and 223 (± 514), respectively. We estimated the total BY2013 summer steelhead emigration at the trap to be 13,417 (± 3,733). Egg-to-emigrant survival rates for BY2014 spring Chinook and BY2013 summer steelhead were both 1.7%. Productivity, as measured by emigrants-per-redd, for spring Chinook and summer steelhead, was 76 and 99, respectively.

CONTENTS

ABSTRACT i

CONTENTS ii

LIST OF FIGURES iv

LIST OF TABLES vi

ACKNOWLEDGEMENTS viii

1.0 INTRODUCTION 1

1.1 Watershed Description 1

2.1 Trapping Equipment and Operation 3

2.2 Biological Sampling 3

2.3 PIT Tagging 4

2.4 Mark-Recapture Trials 5

2.5 Data Analysis 6

2.5.1 Estimate of Abundance During Smolt Trapping 6

2.5.2 Estimate of Abundace During Trap Stoppages and Suspended Operations 8

2.5.3 Estimate of Abundance During The Winter Non-Trapping Period 9

2.5.4 Production and Survival 9

3.0 RESULTS 10

3.1 Dates of Operation 10

3.2 Daily Captures and Biological Sampling 10

3.2.1 Spring Chinook Yearlings (BY2014) 10

3.2.2 Spring Chinook Subyearlings (BY2015) 11

3.2.3 Hatchery Spring Chinook Smolts (BY2014) 12

3.2.4 Summer Steelhead 13

3.2.5 Hatchery Steelhead Smolts (BY2015) 15

3.2.6 Bull Trout 15

3.2.7 Coho Yearlings (BY2014) 16

3.2.8 Coho Subyearlings (BY2015) 16

3.2.9 Hatchery Coho Smolts (BY2014) 16

3.3 Remote Parr Tagging (BY2014 Spring Chinook) 17

3.4 Trap Efficiency Calibration and Population Estimates 18

3.4.1 Spring Chinook Yearlings (BY2014) 18
3.4.2 Spring Chinook Subyearlings (BY2015) 21
3.4.3 Summer Steelhead 22
3.4.4 Coho Yearlings (BY2014) 25
3.4.5 Coho Subyearlings (BY2015) 27
3.5 PIT Tagging 28
3.6 Incidental Species 28
3.7 ESA Compliance 29
4.0 DISCUSSION 30
5.0 LITERATURE CITED 35
APPENDIX A. Daily Stream Discharge 37
APPENDIX B. Daily Trap Operation 42
APPENDIX C. Regression Models 46
APPENDIX D. Historical Morphometric Data 52

LIST OF FIGURES

Figure 1. Map of Wenatchee River Subbasin with the Nason Creek rotary trap location............ 2

Figure 2. Mean daily stream discharge at the Nason Creek WDOE stream monitoring station in 2016.. 3

Figure 3. Daily catch of BY2014 spring Chinook yearlings with mean daily stream discharge at the Nason Creek rotary trap, March 1 to June 30, 2016. 11

Figure 4. Daily catch of BY2015 spring Chinook subyearlings with mean daily stream discharge at the Nason Creek rotary trap, July 1 to November 30, 2016.. 12

Figure 5. Daily catch of BY2014 hatchery spring Chinook smolts with mean daily stream discharge at the Nason Creek rotary trap, March 1 to June 30, 2016. 13

Figure 6. Daily catch of wild summer steelhead with mean daily stream discharge at the Nason Creek rotary trap, March 1 to July 31, 2016. Estimates of fish passage during trap interruptions are not depicted. 14

Figure 7. Daily catch of wild summer steelhead with mean daily stream discharge at the Nason Creek rotary trap, August 1 to November 30, 2016. Estimates of fish passage during trap interruptions are not depicted.. 14

Figure 8. Daily catch of BY2015 hatchery steelhead smolt with mean daily stream discharge at the Nason Creek rotary trap, March 1 to June 30, 2016. 15

Figure 9. Daily catch of BY2014 naturally-produced coho yearlings with mean daily stream discharge at the Nason Creek rotary trap, March 1 to June 30, 2016. 16

Figure 10. Daily catch of BY2014 hatchery coho smolt with mean daily stream discharge at the Nason Creek rotary trap, March 1 to June 30, 2016. 17

Figure 11. Daily detections of remote-tagged BY2014 spring Chinook at the lower Nason Creek PIT tag antenna array (NAL) between October 2015 and March 2016. 18

Figure 12. Relationships between estimated egg deposition and total emigrants produced, egg-to-emigrant survival, and emigrants per redd for Nason Creek spring Chinook, BY 2003 to 2014. *2014 brood (denoted by red border) does not include non-trapping estimate. 21

Figure 13. Relationships between estimated egg deposition and total emigrants produced, egg-to-emigrant survival, and emigrants per redd for Nason Creek summer Steelhead, BY 2003 to 2013. *2013 brood denoted by red border. 25

Figure 14. Relationships between estimated egg deposition and total emigrants produced, egg-to-emigrant survival, and emigrants per redd for Nason Creek natural-produced coho, BY 2003 to 2014. *2014 brood (denoted by red border). 27

Figure 15. Nason Creek daily discharge from September 2014 through December 2016, with corresponding 12-year mean Nason Creek discharge. 30

Figure 16. Comparison of wild spring Chinook abundance estimates (BY2007-2014) made at the White River, Nason Creek, and Chiwawa River smolt traps. *Non-trapping estimates not included. 31

Figure 17. Comparison of egg-to-emigrant survival (BY 2007-2014) and egg deposition for Nason Creek, Chiwawa River, and White River spring Chinook. *Non-trapping estimates not included. 32

LIST OF TABLES

Table 1. Summary of Nason Creek rotary trap operation. 10

Table 2. Summary of length and weight sampling of juvenile spring Chinook captured at the Nason Creek rotary trap in 2016. 11

Table 3. Summary of length, weight and condition factor by age class of wild summer steelhead emigrants and hatchery steelhead captured at the Nason Creek rotary trap. 15

Table 4. Summary of length and weight sampling of juvenile coho salmon captured at the Nason Creek rotary trap in 2016. 16

Table 5. Trap efficiency trials conducted with BY2014 wild spring Chinook yearlings and hatchery-origin coho yearling surrogates.. 19

Table 6. Estimated egg-to-emigrant survival and smolts-per-redd production for Nason Creek spring Chinook salmon. 19

Table 7. Trap efficiency trials conducted with BY2015 wild spring Chinook subyearlings........ 21

Table 8. Efficiency trials conducted with wild summer steelhead juveniles. 22

Table 9. Estimated egg-to-emigrant survival and emigrants-per-redd production for Nason Creek summer steelhead. 23

Table 10. Estimated egg-to-emigrant survival and smolts-per-redd production for Nason Creek coho salmon. 25

Table 11. Number of PIT tagged coho, Chinook, and steelhead with shed rates at the Nason Creek rotary trap in 2016. 28

Table 12. Summary of length and weight sampling of incidental species captured at the Nason Creek rotary trap in 2016. 28

Table 13. Summary of ESA species and coho salmon mortality at the Nason Creek rotary trap. 29

ACKNOWLEDGEMENTS

This project is part of a basin-wide monitoring program requiring close coordination between multiple agencies and contractors. We greatly appreciate the hard work of the Yakama Nation Fisheries Resource Management (YNFRM) crew members including Matthew Clubb, Jamie Hallman, Arlene Heemsah, Tim Jeffris, and Kevin Swager who maintained and operated the trap during all hours including nights/weekends and through challenging weather conditions. We would like to also thank the Wenatchee River Ranger District (U.S. Forest Service) and Mr. Duane Bolser for providing use of the trapping site and accommodating the needs of this project as well as to Peter Graf (Grant County PUD) for administering contracting and funding. Finally, thank you to Mike Hughes, Mclain Johnson, Andrew Murdoch, Ben Truscott, and Joshua Williams (Washington Department of Fish and Wildlife), and Tracy Hillman (Bio Analysts, Inc.) for shared data and smolt trap methodologies.

1.0 INTRODUCTION

Beginning in the fall of 2004, Yakama Nation Fisheries Resource Management (YNFRM) began operating a rotary smolt trap in Nason Creek for nine months per year. Prior to 2004, the smolt trap was operated on a limited basis solely for hatchery coho predation studies. This project is a cost share between the YNFRM's Mid-Columbia Coho Reintroduction Program (MCCRP) and Grant County PUD's Hatchery Monitoring Plan. Trap operations were conducted in compliance with ESA consultation specifically to address abundance and productivity of spring Chinook, steelhead trout, and coho salmon in Nason Creek.

Within this document we will report:

1) Juvenile abundance and productivity of spring Chinook salmon (tkwínat) *Oncorhynchus tshawytscha*, steelhead trout (shúshaynsh) *Oncorhynchus mykiss* and coho salmon (súnx) *Oncorhynchus kisutch* in Nason Creek.

2) Emigration timing of spring Chinook salmon, steelhead trout and coho salmon emigrating from Nason Creek.

The data presented will be directly used to address Objective 2 in the Monitoring and Evaluation Plan for PUD Hatchery Programs (Hillman et al. 2015) on a 5-year analytic cycle:

Objective 2: Determine if the proportion of hatchery fish on the spawning grounds affects the freshwater productivity of supplemented stocks (Hillman et al. 2013).

1.1 Watershed Description

The Nason Creek watershed drains 26,547 ha of alpine glaciated landscape where high precipitation and moderate rain on snow recurrence controls the hydrology and aquatic communities. Nason Creek originates near the Cascade crest at Stevens Pass and flows east for approximately 37 river kilometers (rkm) until joining the Wenatchee River at rkm 86.3 just below Lake Wenatchee. Both smolt trap locations employed in 2014 (see section 2.1 Trapping Equipment and Operations) were downstream from the majority of spring Chinook and steelhead spawning grounds (Figure 1). There are 26.4 rkm along the mainstem accessible to anadromous fish in Nason Creek. Private land ownership comprises 21,165 ha (79.7%) of the watershed while 5,180 ha (19.5%) are federal and 194 ha (0.1%) are state owned (USFS et al. 1996).

The channel morphology of the lower 25 rkm of Nason Creek has been impacted by development of highways, railroads, power lines, and residential development resulting in channel confinement and reduced side-channel habitat. The present condition is a low gradient (< 1.1%), low sinuosity (1:2 to 2:0 channel-to-valley length ratio) and depositional channel (USFS et al. 1996). Peak runoff typically occurs in May and June with occasional high water produced by rain on snow events in October and November.

In 2016, mean daily discharge for Nason Creek was 11.1 m^3/s (392 cfs; Figure 2). The onset of spring freshets was unseasonable early in 2016, with peak flows occurring approximately one month earlier than the 12-year mean. Accordingly, this resulted in a prolonged summer base-flow period, as snowpack was deminished at a much faster rate than normal. Fall freshets began in mid-October with a significant spike in flow, followed by normal levels of discharge. Water temperature data for 2016 was not available through Washington State Deportment of Ecology (WDOE).

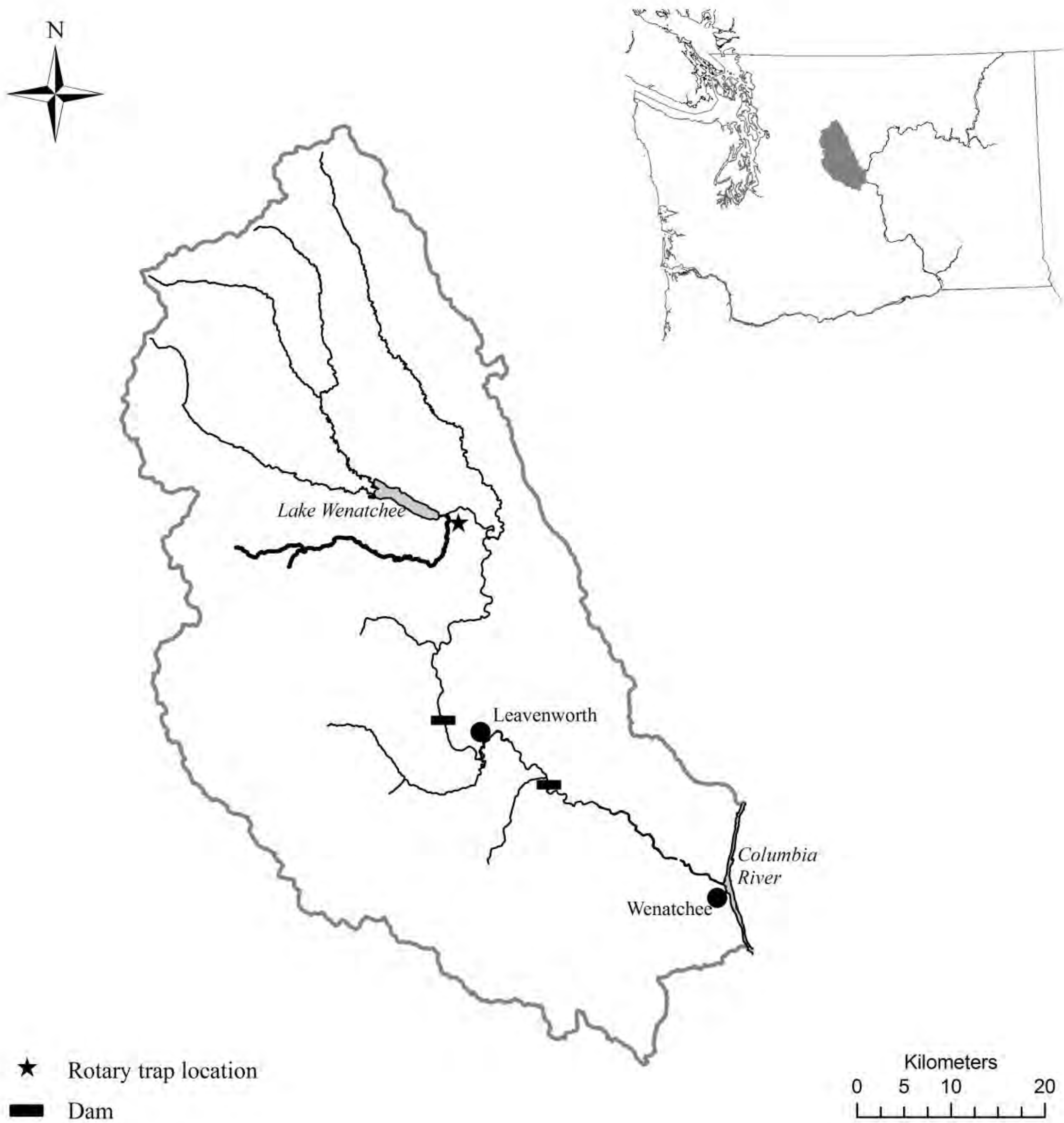


Figure 1. Map of Wenatchee River Subbasin with the Nason Creek rotary trap location.

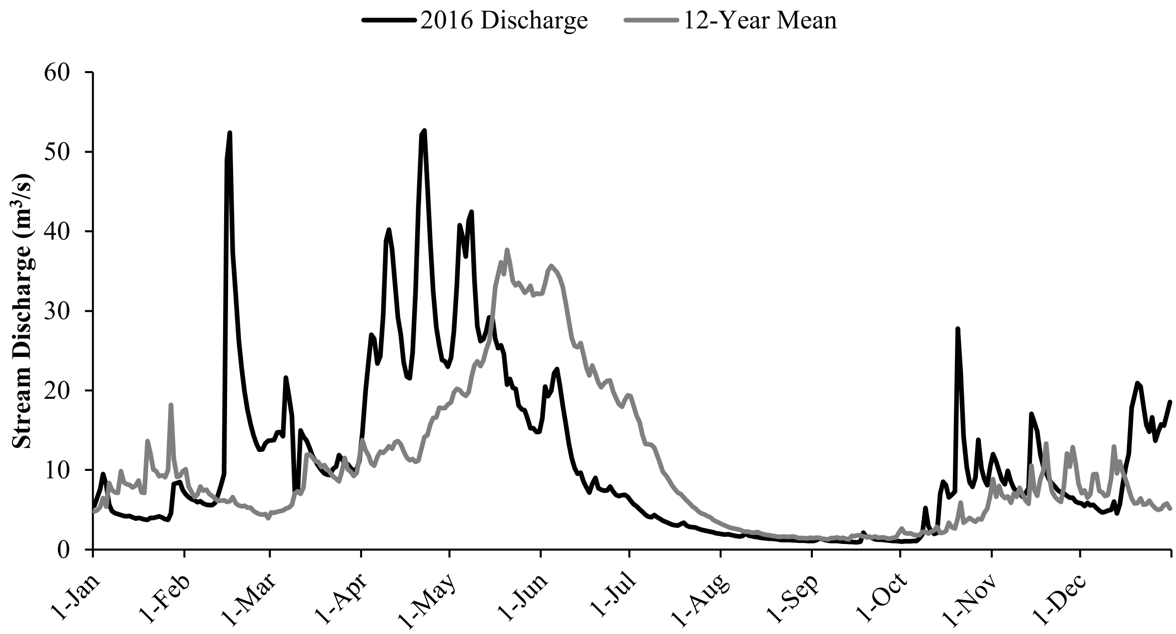


Figure 2. Mean daily stream discharge at the Nason Creek WDOE stream monitoring station in 2016.

2.0 METHODS

2.1 Trapping Equipment and Operation

The smolt trap was operated continually 24 hours per day, 7 days per week when conditions permitted. During spring snowmelt, operations occurred only during hours of darkness in order to minimize trap damage and capture mortality, while retaining the ability to sample during periods of peak fish movement. Without the threat of vandalism posed during periods of peak use at the previously-used campground location, summer operations at the Bolser location were not modified (daytime suspension).

On a daily basis, fish were removed from the primary collection box and retained in separate shore-anchored holding boxes until removed for efficiencies trials. A rotating drum-screen constantly removed small debris from the live box to avoid fish injury. All changes/modifications to the trap as well as periods of stoppage were noted.

2.2 Biological Sampling

Trap operating procedures and techniques followed a standardized basin-wide monitoring plan developed by the Upper Columbia Regional Technical Team (RTT) for the Upper Columbia

Salmon Recovery Board (UCSRB; Hillman 2004), which was adapted from Murdoch and Petersen (2000).

All fish were enumerated by species and size class. Fish to be sampled were anesthetized in a solution of MS-222, weighed with an electronic scale and measured in a wetted trough-type measuring board. Anesthetized fish received air through aquarium bubblers and were allowed to fully recover before being either released downstream of the trap or used in efficiency trials. Fork length (FL) and weight were recorded for all fish except when large numbers of fry or non-target species were collected; a sub-sample of 25 fish were measured and weighed while the remaining fish were tallied. Weight was measured to the nearest 0.1 gram and FL to the nearest millimeter. We used these data to calculate a Fulton-type condition factor (K-factor) using the formula:

$$K = (W/L^3) \text{ x } 100{,}000$$

where K = Fulton-type condition metric;
W = weight in grams;
L = fork length in millimeters;
And 100,000 is a scaling constant.

Scale samples were collected from steelhead measuring ≥ 60 mm FL so that age and brood year could be assigned. Samples were collected according to the needs and protocols set by Washington Department of Fish and Wildlife (WDFW), who conducted the analysis and provided YNFRM with results. Tissue samples were collected from spring Chinook and steelhead for DNA analysis. Samples from spring Chinook and steelhead were retained for reproductive success analyses conducted by WDFW and National Marine Fisheries Service (NMFS). All target salmonids were classified as either natural or hatchery origin by physical appearance, presence/absence of coded wire tags (CWTs), or post-orbital elastomer tags. Developmental stages were visually classified as fry, parr, transitional, or smolt. Fry were defined as newly emerged fish with or without a visible yolk sac and a FL measuring < 50 mm. Age-0 coho and spring Chinook salmon captured before July 1 were considered 'fry' and were excluded from subyearling population estimates because of the uncertainty that these fish were actively migrating (UCRTT, 2001).

2.3 PIT Tagging

All natural origin Chinook, steelhead and coho measuring ≥ 60 mm were PIT tagged. Once anesthetized, each fish was examined for external wounds or descaling, then scanned for the presence of a previously implanted PIT tag. If a tag was not detected, a pre-loaded 12mm Digital Angel 134.2 kHz type TX 1411ST PIT tag was inserted into the body cavity using a Biomark MK-25 Rapid Implant Gun. Each unique tag code was electronically recorded along with date of tag implantation, date of fish release, tagging personnel, FL, weight, and anesthetic bath temperature. Data were entered using P3 software and submitted to the PIT Tag Information System (PTAGIS). PIT tagging methods were consistent with methodologies described in the PIT Tag Marking Procedures Manual (CBFWA 1999) as well as in 2008 ISEMP protocols (Tussing 2008).

After marking and sampling, fish were held for a minimum of 24-hours in holding boxes at the trap to; a) ensure complete recovery, b) assess tagging mortality, and c) determine a PIT tag shed rate. Mark groups were released by hand 0.8 rkm above the trap at nautical twilight. At each release, fish were distributed evenly along river-left, and river-right banks in pools and other protected areas. Fish that were not used in mark-recapture trials were released downstream from the trap.

2.4 Mark-Recapture Trials

Groups of marked juveniles were released during a range of stream discharges in order to determine the trapping efficiency. PIT tags were the only method of marking used in 2016. These releases followed the protocols described in Hillman (2004), in which the author suggests a minimum sample size of 100 fish for each mark-recapture trial. Although 100 fish/trial represented the ideal mark group, low abundance of fish often required mark-recapture trials be completed with smaller sample sizes. To achieve the largest marked group possible, we combined catch over a maximum of 72 hours. Fish being held for mark-recapture trials were kept in auxiliary live boxes attached to the end of each pontoon or floating holding boxed anchored to the stream bank. A pre-season, minimum mark group size for each species/life stage was initially determined based on past regression models. In light of high abundance, minimum trial sizes could be raised to a more robust mark group with the intention of strengthening existing regression models.

Each mark-recapture trial was conducted over a three-day (72 hour) period to allow time for passage or capture. Completed trials were only considered invalid if an interruption to trapping occurred or proper pre-release procedures were not followed. Trials resulting in zero recaptures were included in the efficiency regression (if determined valid once vetted through release/recapture protocols) as allowed by the new method of observed trap efficiency calculation. The model used (Bailey) employs use of recaptures +1 in the calculation of efficiency as a mode of bias correction. As a result, even trials yeilding no recaptures can be included in regression modeling (See equation 3 in **2.5.1 Estimate of Abundance**).

In the event that low juvenile abundaces could not provide any opportunities for efficiency trials, releases were performed to allow for a pooled estimate. These releases did not have a minimum size and were released at equal intervals across the migratory period. Pooled estimates at the Nason Creek trap were utilized as an alternative method of estimation prior to the development of a viable regression model.

2.5 Data Analysis

2.5.1 Estimate of Abundance During Smolt Trapping

Seasonal juvenile migration, N, was estimated as the sum of daily migrations, N_i, i.e., $N = \sum_i N_i$, and daily migration was calculated from catch and efficiency:

$$\hat{N}_i = \frac{C_i}{\hat{e}_i}, \qquad \textbf{(1)}$$

where C_i = number of fish caught in period *I*;

$\hat{e}_i$ = trap efficiency estimated from the flow-efficiency relationship, $\sin^2(b_0 + b_1 flow_i)$,

where b_0 is estimated intercept and b_1 is the estimated slope of the regression.

The regression parameters b_0 and b_1 are estimated using linear regression for the model:

$$\arcsin\left(\sqrt{e_k^{obs}}\right) = \beta_0 + \beta_1 flow_k + \varepsilon, \qquad \textbf{(2)}$$

where e_k^{obs} = observed trap efficiency of Eq. 2 for trapping period *k*;

β_0 = intercept of the regression model;

β_1 = slope parameter;

ε = error with mean 0 and variance σ^2.

In Equation 2, the observed trap efficiency, e_k^{obs}, is calculated as follows,

$$e_k^{obs} = \frac{r_k + 1}{m}. \qquad \textbf{(3)}$$

The estimated variance of seasonal migration is calculated from daily estimates as:

$$Var\left(\sum_{i=1}^{n} \hat{N}_i\right) = \underbrace{\sum_i Var(N_i)}_{Part\ A} + \underbrace{\sum_i \sum_j Cov(N_i, N_j)}_{Part\ B},$$

or,

$$Var\left(\sum_{i=1}^{n} \hat{N}_i\right) = \underbrace{\sum_i Var\left(\frac{(C_i + 1)}{\hat{e}_i}\right)}_{Part\ A} + \underbrace{\sum_i \sum_j Cov\left(\frac{(C_i + 1)}{\hat{e}_i}, \frac{(C_j + 1)}{\hat{e}_j}\right)}_{Part\ B}. \qquad \textbf{(4)}$$

Part A of equation 4 is the variance of daily estimates. Part B is the between-day covariance. Note that the between-day covariance exists only for days that use the same trap efficiency model. If, for example, day 1 is estimated with one trap efficiency model, and day 2 estimated from a different model, then there is no covariance between day 1 and day 2. The full expression for the estimated variance:

$$\hat{Var}\left(\sum_{i=1}^{n}\hat{N}_i\right)=\underbrace{\sum_i \hat{N}_i^2\left(\frac{N_i\hat{e}_i(1-\hat{e}_i)}{(C_i+1)^2}+\frac{4(1-\hat{e}_i)}{\hat{e}_i}\hat{Var}(b_0+b_1 flow_i)\right)}_{PartA}+$$
$$\underbrace{\sum_i\sum_j 4\left(\hat{N}_i(1-\hat{e}_i)\right)\left(\hat{N}_j(1-\hat{e}_j)\right)\cdot\left[\hat{V}ar(b_0)+flow_i flow_j \hat{V}ar(b_1)\right]}_{PartB}$$

where $\hat{Var}(b_0+b_1 flow_i)=M\hat{S}E\left(1+\frac{1}{n}+\frac{(flow_i-\overline{flow})^2}{(n-1)s_{flow}^2}\right)$, and $\hat{V}ar(b_0)$ and $\hat{V}ar(b_1)$ are obtained from regression results. In Excel, the standard error (SE) of the coefficients is provided. The variance is calculated as the square of the standard error, SE^2.

In cases when there was no significant flow-efficiency relationship (i.e., low correlation), then a pooled, or average trap efficiency will suffice for the stratum. The estimator is calculated as follows:

$$\hat{\hat{e}}=\frac{\sum_{j=1}^{k} r_j}{\sum_{j=1}^{k} m_j}$$

where $\hat{\hat{e}}$ = the average or pooled trap efficiency for the stratum;
m_j = the number of smolts marked and released in efficiency trial j for the stratum;
r_j = the number of smolts recaptured out of m_j marked fish in efficiency trial j.

Abundance for a trapping period is estimated as:

$$\hat{N}_i^{pooled}=\frac{C_i}{\hat{\hat{e}}},$$

,and total stratum abundance is:

$$N^{pooled}=\sum_i \hat{N}_i^{pooled}.$$

The variance of seasonal abundance takes into account the variability in catch numbers that are a result of binomial sampling (Part A), the pooled variance of trap efficiency, $\hat{\hat{e}}$ (Part B), and the covariance in daily estimates that arises from using a common estimate of efficiency across all trapping days (Part C):

$$\hat{Var}\left(\sum_{i=1}^{n}\hat{N}_i^{pooled}\right)=\underbrace{\left(\sum_i \frac{\hat{N}_i\left(1-\hat{\bar{e}}\right)}{\hat{\bar{e}}}\right)}_{PartA}+\underbrace{\frac{Var\left(\hat{\bar{e}}\right)}{\hat{\bar{e}}^2}\sum_i \hat{N}_i^2}_{PartB}+\underbrace{\frac{Var\left(\hat{\bar{e}}\right)}{\hat{\bar{e}}^2}\sum_i\sum_j \hat{N}_i\hat{N}_j}_{PartC}.$$

The Part B and Part C terms are combined in the calculation as a new Part B:

$$\hat{Var}\left(\sum_{i=1}^{n}\hat{N}_i^{pooled}\right)=\underbrace{\left(\sum_i \frac{\hat{N}_i\left(1-\hat{\bar{e}}\right)}{\hat{\bar{e}}}\right)}_{PartA}+\underbrace{\frac{Var\left(\hat{\bar{e}}\right)}{\hat{\bar{e}}^2}\left[\sum_i \hat{N}_i^2+\sum_i\sum_j \hat{N}_i\hat{N}_j\right]}_{PartB}.$$

The variance of $\hat{\bar{e}}$ is calculated as:

$$\hat{Var}\left(\hat{\bar{e}}\right)=\hat{Var}\left(\frac{\sum_{k=1}^{n} r_k}{\sum_{k=1}^{n} m_k}\right)=\frac{\sum_{k=1}^{n}\left(r_k-\hat{\bar{e}}_k m_k\right)^2}{\overline{m}^2 n(n-1)}$$

where $\overline{m}$ is the average release size across all efficiency trial, $\frac{\sum_{k=1}^{n} m_k}{n}$.

Confidence intervals were calculated using the following formulas:

95% confidence interval = $1.96\times\sqrt{\sum \mathrm{var}\left[\hat{N}_i\right]}$

The single M-R estimator of abundance carries a set of well documented assumptions (Everhart and Youngs 1981; Seber 1982),

1. The population is closed to mortality.
2. The probability of capturing a marked or unmarked fish is equal.
3. Marked fish were randomly dispersed in the population prior to recapture.
4. Marking does not affect probabilities of capture.
5. Marks were not lost between the time of release and recapture.
6. All marks are reported upon recapture.
7. The number of fish in the trap, C, is fully enumerated and known without error.

2.5.2 Estimate of Abundace During Trap Stoppages and Suspended Operations

Daily catch during stoppages of seven days or less was estimated by averaging catch three days prior to, and after the discreet non-trapping event and then applying that value to the consecutive days without operation. This method had been used consistently in the past given the duration of the stoppage is limited, and is applied to all target species.

For periods of suspended trapping longer than seven days, a methodology developed and currently employed by local WDFW smolt trap operators was used (J. Williams, personal communication, March 8, 2017). This method uses historic run-timing to determine the proportion of the entire emigrant estimate missed during the period of suspended trapping. Once determined, the estimated percentage can be used with in-year data to extrapolate how many fish were missed. This method is used exclusively during the fall migratory period, when low summer flows commonly result in extended stoppages. Because steelhead are considered non-migratory during this period, this type of estimate was only applied to spring Chinook subyearlings.

2.5.3 Estimate of Abundance During The Winter Non-Trapping Period

An estimate of spring Chinook emmigration during the non-trapping period (December 1 through February 28) was calculated using remote-tagged spring chinook parr and the lower Nason Creek PIT tag array (NAL). A flow-detection efficiency regression was developed using mark-groups previously released to test the efficiency of the smolt trap. Daily spring Chinook detections at the NAL array and the developed regression were then applied to the Bailey estimator, as was peformed with daily trap abundance data (See equation **2.5.1 Estimate of Abundance**). Tag rate determined at the Nason Creek smolt trap was used to account for unmarked emmigrants passing the NAL array.

Tag rate, t_i, was calculated as:

$$t_i = \frac{t}{p}$$

where t = total smolt trap recaptures subsequent to the tagging effort;
p = total catch at the smolt trap.

Daily abundace during the non-trapping period is calculated as:

$$\hat{N}_i = \left(\frac{C_i}{\hat{e}_i}\right) \Big/ t_i ,$$

where C_i = number of fish caught in period I;
$\hat{e}_i$ = trap efficiency estimated from the flow-efficiency relationship, $\sin^2(b_0 + b_1 flow_i)$;
t_i = tag rate.

2.5.4 Production and Survival

Production estimates by age class were summed to produce a total emigration estimate. For spring Chinook and coho, estimates of fall migrant parr were added to subsequent spring smolt estimates to generate a single brood year estimate. For steelhead, a single brood year may require up to three years for emigration from Nason Creek to occur. Pending scale analysis, steelhead captured in 2016 were aged via an age-length histogram built upon previously analyzed scale samples. For all three species, egg-to-emigrant estimates were calculated by dividing estimated emigrants by approximated egg deposition during a spawning brood (average fecundity used to determine egg deposition derived from WDFW Chiwawa broodstock spawning). The number of emigrants-per-redd for each brood year was calculated by dividing the total emigrant estimate by the number of redds counted during spawning ground surveys.

3.0 RESULTS

3.1 Dates of Operation

The Nason Creek smolt trap was installed on February 25, and operated in its fixed position for the entirety of the trapping season (March 1 to November 30). Removal of the trap occurred on December 5. We attempted to run the trap continuously 24 hours a day, 7 days per week. Intentional suspension of trapping activities occurred for two periods in the summer-early fall due to base flows (July 31 – August 8 and August 10 - October 9; Table 1). Pulling of the trap also occurred on October 21 as a precautionary measure during a high-water event.

Table 1. Summary of Nason Creek rotary trap operation.

Date of Trap Operations	Trap Status	Description	Days
March 1 to June 30	Operating	Continuous data collection	120
	Interrupted	Interrupted by debris	2
	Pulled	Intentionally pulled due to high flow, low flow, or heavy debris load	0
July 1 to November 30	Operating	Continuous data collection	76
	Interrupted	Interrupted by debris	6
	Pulled	Intentionally pulled due to high flow, low flow, or heavy debris load	71

3.2 Daily Captures and Biological Sampling

3.2.1 Spring Chinook Yearlings (BY2014)

Between March 1 and June 30, a total of 61 wild Chinook yearlings were captured at the trap (Figure 3). A peak catch of 12 yearling smolts coincided with a secondary spike in discharge occurring in early April. Following this peak, catch dropped substantially with the last emigrating Chinook yearling captured on April 8. Mean FL and weight for Chinook yearlings was 96 mm (n = 61; SD = 5.5) and 9.0 g (n = 61; SD = 1.7; Table 2), respectively. Tissue samples were collected from 61 fish for an ongoing, parental-based DNA analysis by WDFW. There were no wild spring Chinook mortalities.

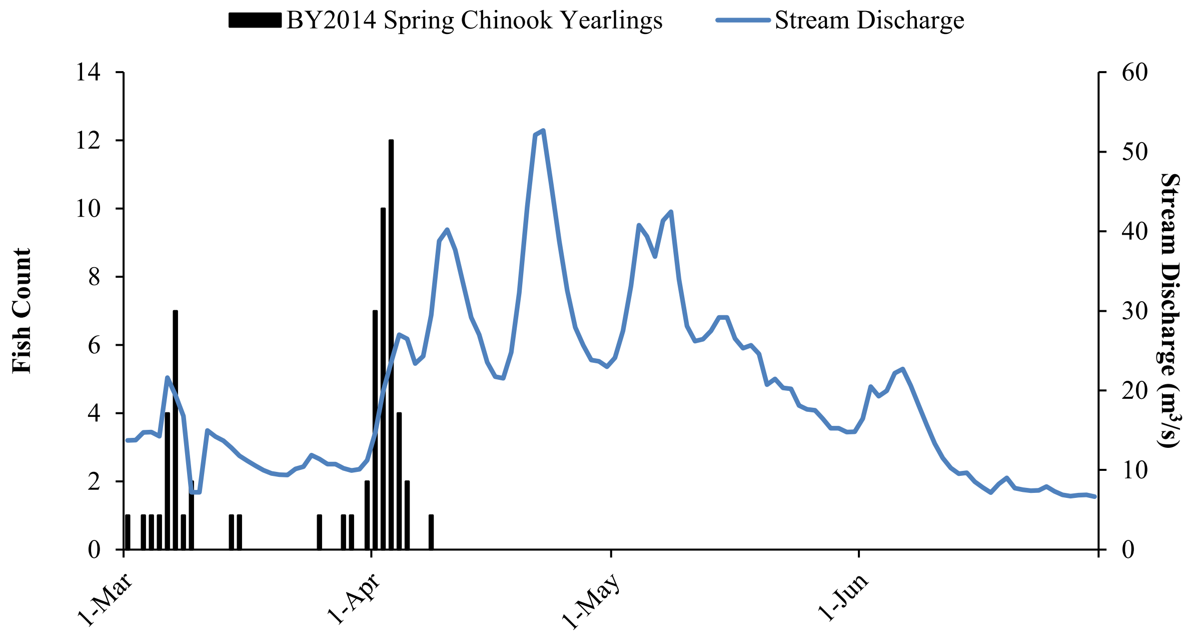


Figure 3. Daily catch of BY2014 spring Chinook yearlings with mean daily stream discharge at the Nason Creek rotary trap, March 1 to June 30, 2016.

Table 2. Summary of length and weight sampling of juvenile spring Chinook captured at the Nason Creek rotary trap in 2016.

Brood Year	Origin/Species/Stage	Fork Length (mm)			Weight (g)			K-Factor
		Mean	*n*	SD	Mean	*n*	SD	
2014	Wild Spring Chinook Yearling Smolt	96	61	5.5	9.0	61	1.7	1.01
2015	Wild Spring Chinook Subyearling Fry	38	285	3.0	0.5	285	0.2	0.78
2015	Wild Spring Chinook Subyearling Parr	85	491	12.7	6.9	490	2.5	1.07
2014	Hatchery Spring Chinook Yearling Smolt	119	87	13.5	19.6	87	7.6	1.09

3.2.2 Spring Chinook Subyearlings (BY2015)

A total of 491 wild spring Chinook subyearling parr (FL ≥ 50 mm) and 300 subyearling fry (FL < 50 mm) were captured in 2016 (Figure 4). The majority of parr movement was documented in late October following the first fall freshets. Mean FL and weight among subyearling parr was 85 mm (n = 491; SD = 12.7) and 6.9 g (n = 490; SD = 2.5), respectively. We estimate that an additional 20 Chinook subyearling parr would have been captured during short stoppages (≤7 days) had the trap run without interruption. Daily catch estimates were not made during the two periods of suspended trapping; total emmigrant estimates for these two periods will be included in section 3.4.2. Tissue samples were collected from 431 fish for an ongoing, parental-based DNA analysis by WDFW. Six subyearling Chinook (four fry and two parr) mortalities occurred in 2016. All deaths were attributed to trapping.

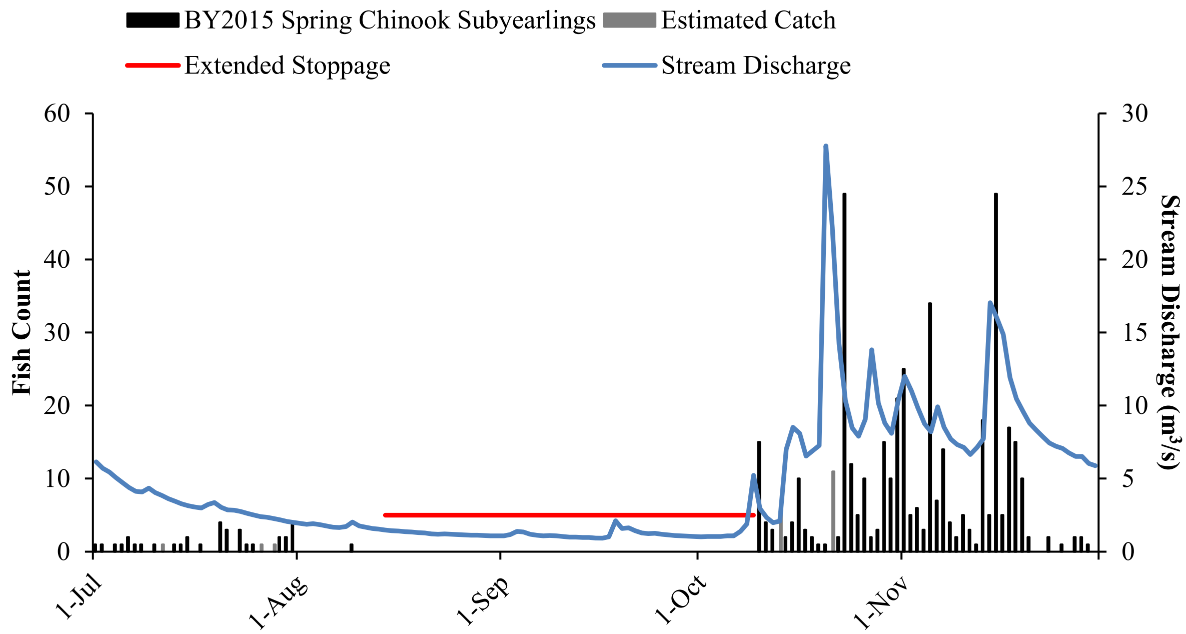


Figure 4. Daily catch of BY2015 spring Chinook subyearlings with mean daily stream discharge at the Nason Creek rotary trap, July 1 to November 30, 2016.

3.2.3 Hatchery Spring Chinook Smolts (BY2014)

In the spring of 2016, 31,651 hatchery spring Chinook smolts were released into Nason Creek. All hatchery spring Chinook were released directly from the Grant County Public Utility District (GCPUD) Nason Creek Acclimation Facility located at rkm17.3. Subsequently, a total of 124 smolts were captured with a mean FL and weight of 119 mm (n =87; SD = 13.5) and 19.6 g (n = 87; SD = 7.6), respectively (Figure 5). Hatchery spring Chinook were not captured at the smolt trap beyond June 3. There were no mortalities incurred.

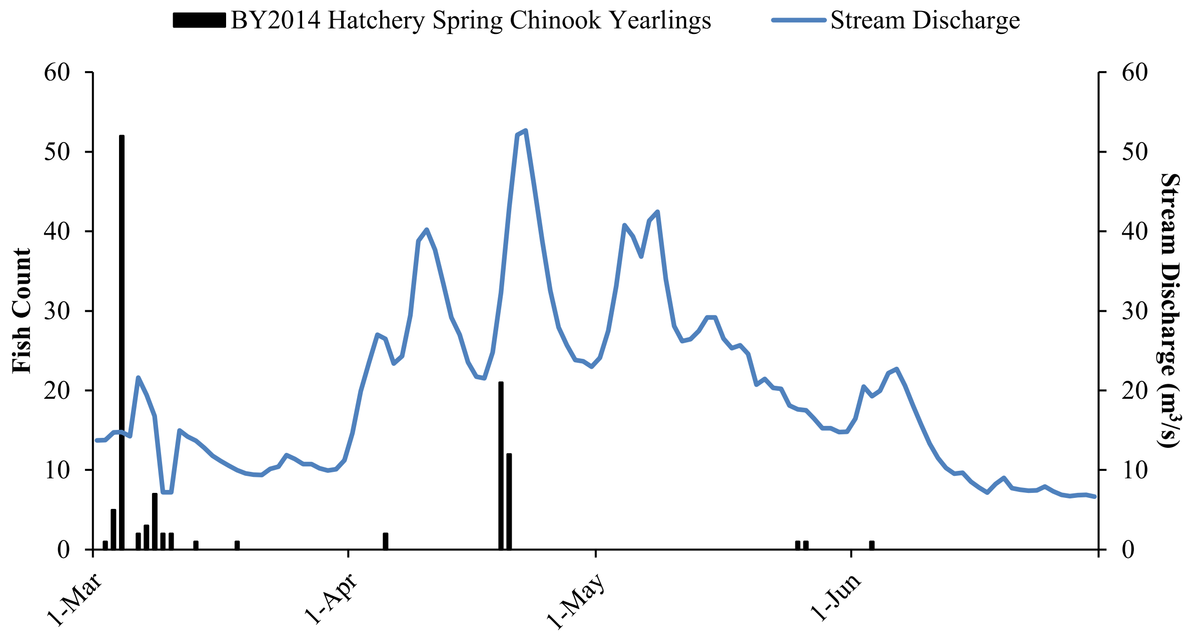


Figure 5. Daily catch of BY2014 hatchery spring Chinook smolts with mean daily stream discharge at the Nason Creek rotary trap, March 1 to June 30, 2016.

3.2.4 Summer Steelhead

A total of 1,007 wild summer steelhead juveniles were captured throughout the season from March 1 to November 30, with a peak catch of 79 juveniles on August 9 (Figs. 6&7). We estimated that an additional 6 age-1 juveniles would have been captured had there been no interruptions to trapping during the migratory period (Mar 1 to July 31). Histogram analysis of known steelhead ages sampled from 2005 to 2014 allowed us to estimate ages of fish captured in 2016 using FL. We estimate that of the total steelhead captured, 702 were young-of-the-year, 285 were age-1, 19 were age-2, and 1 was age-3. Subyearling steelhead had a mean FL of 56mm (n = 674; SD = 16.4), and a mean weight of 2.4 (n = 617; SD = 1.8). The majority of steelhead juveniles captured were age-1 parr emigrating past the trap in spring. Mean FL and weight of age-1 fish was 87 mm (n = 278; SD = 21.5; Table 3) and 8.3 g (n = 278; SD = 5.9), respectively. Age-2 steelhead were caught primarily in the spring, with only two fish being captured after July 31. Mean FL and weight of age-2 fish was 143 mm (n = 19; SD = 17.4) and 31.1 g (n = 19; SD = 9.6), respectively. A single age-3 fish with a FL of 202 mm and weight of 90.1 g was also captured. Scales were taken from a sub-sample (n = 141) to be used for future age analyses. One mortality was incurred (See **3.6 ESA Compliance**).

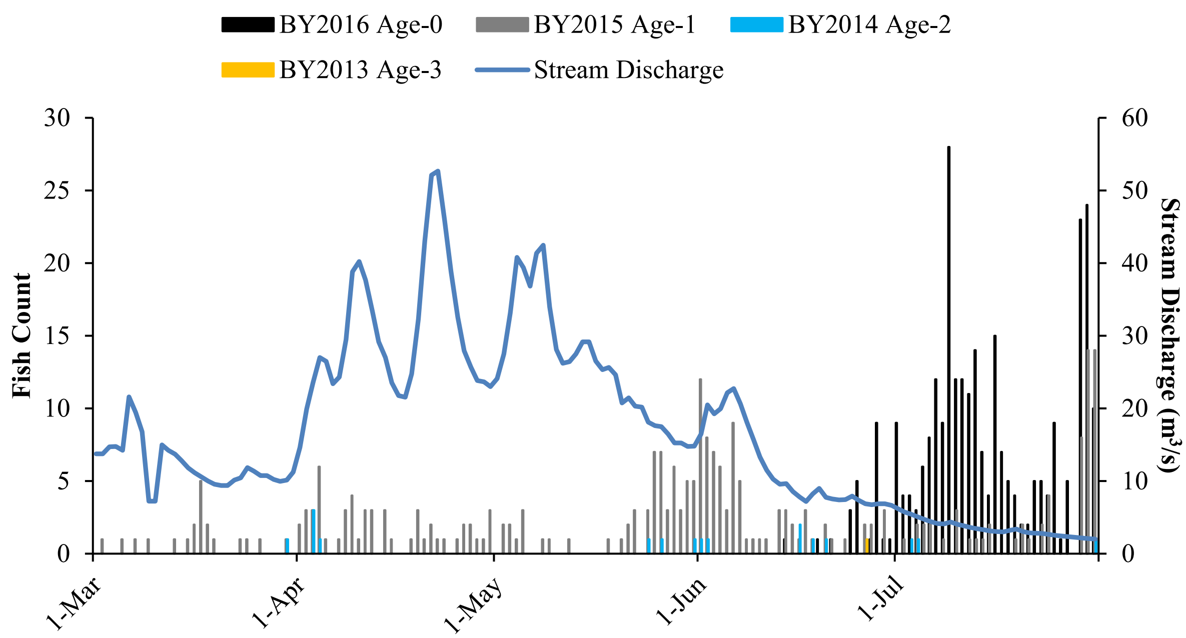


Figure 6. Daily catch of wild summer steelhead with mean daily stream discharge at the Nason Creek rotary trap, March 1 to July 31, 2016. Estimates of fish passage during trap interruptions are not depicted.

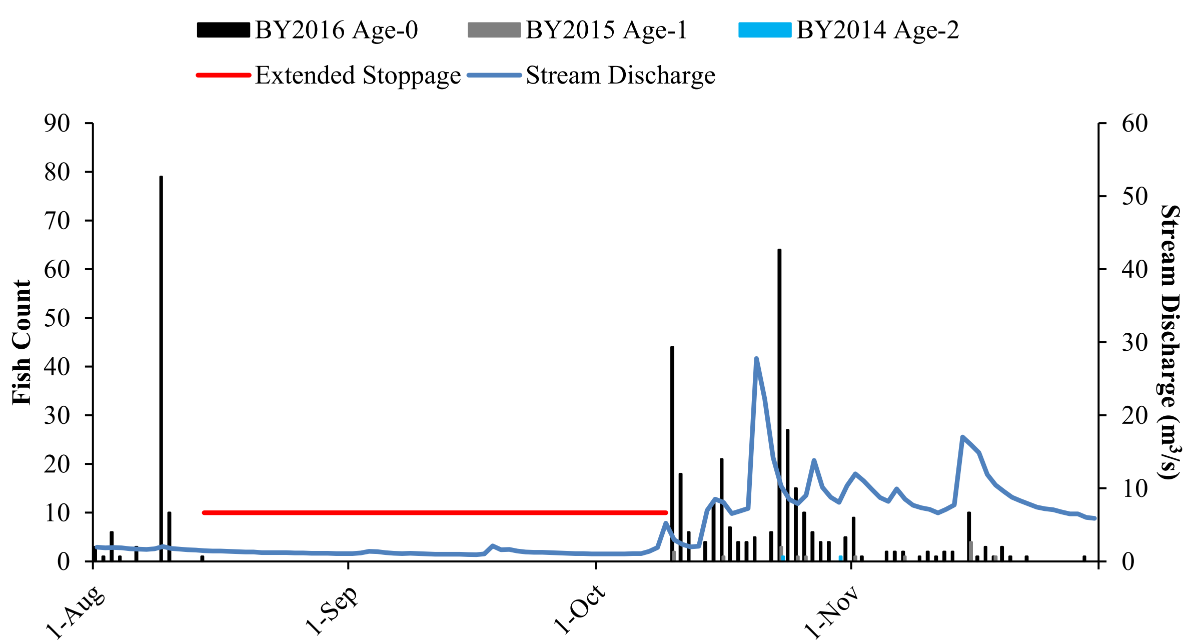


Figure 7. Daily catch of wild summer steelhead with mean daily stream discharge at the Nason Creek rotary trap, August 1 to November 30, 2016. Estimates of fish passage during trap interruptions are not depicted.

Table 3. Summary of length, weight and condition factor by age class of wild summer steelhead emigrants and hatchery steelhead captured at the Nason Creek rotary trap.

Brood Year	Origin/Species/Stage	Fork Length (mm)			Weight (g)			K-Factor
		Mean	*n*	SD	Mean	*n*	SD	
2016	Wild Summer Steelhead (Age-0)	56	674	16.4	2.4	617	1.8	1.02
2015	Wild Summer Steelhead (Age-1)	87	278	21.5	8.3	278	5.9	1.05
2014	Wild Summer Steelhead (Age-2)	143	19	17.4	31.1	19	9.6	1.04
2013	Wild Summer Steelhead (Age-3)	202	1	—	90.1	1	—	1.09
2015	Hatch. Summer Steelhead Smolt	175	95	15.5	55.1	95	16.2	0.99

3.2.5 Hatchery Steelhead Smolts (BY2015)

During April and May, WDFW directly planted a total of 55,105 hatchery summer steelhead smolts into Nason Creek above the smolt trap (M. Babiar, personal communication, February 8, 2017). Subsequently, a total of 98 hatchery steelhead were captured at the smolt trap with a mean FL and weight of 175 mm (n =95; SD = 15.5) and 55.1 g (n = 95; SD = 16.2), respectively (Figure 8). The last hatchery smolt was caught on June 14. Hatchery origin was determined by the presence of coded wire tags (CWT). There were no hatchery-origin steelhead smolt mortalities.

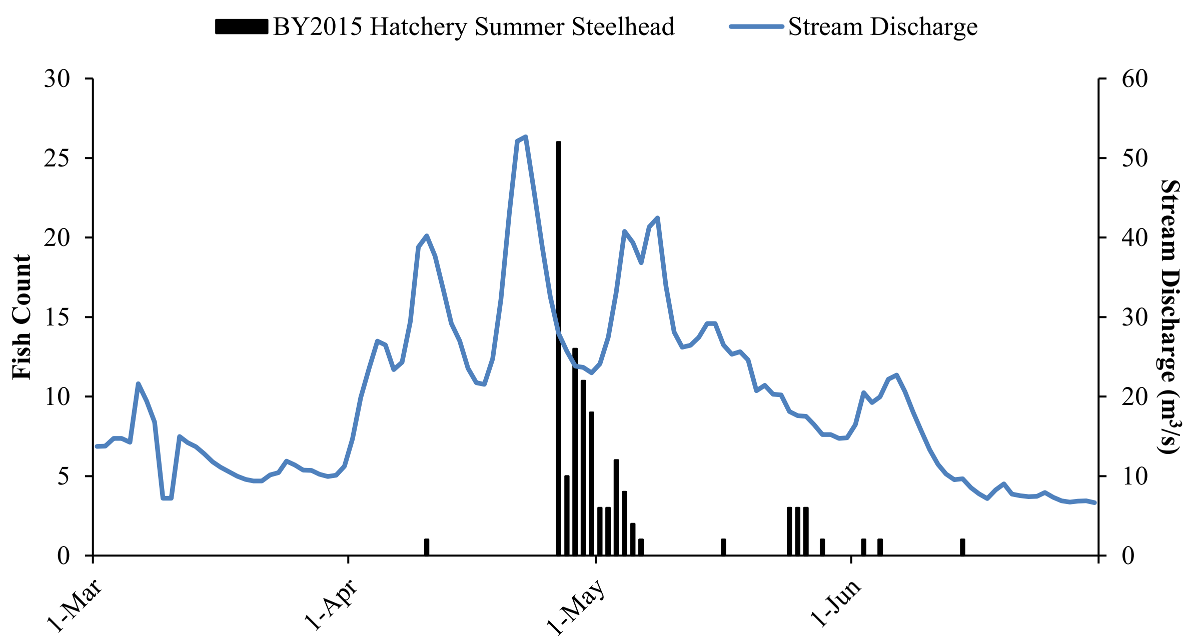


Figure 8. Daily catch of BY2015 hatchery steelhead smolt with mean daily stream discharge at the Nason Creek rotary trap, March 1 to June 30, 2016.

3.2.6 Bull Trout

Bull trout presence at the trap in 2016 was limited to a single fish with a FL of 199 mm and weight of 70.0 g. The bull trout was released immediately after morphometric measurements were taken. No other sampling/tagging activities were performed.

3.2.7 Coho Yearlings (BY2014)

Six naturally-produced coho yearlings were captured during spring emigration between March 1 and June 30 (Figure 9). Their mean FL and weight was 100 mm (*n* = 6; *SD* = 15.8) and 11.1 g (*n* = 6; *SD* = 5.5), respectively (Table 4). Scale and tissue samples were not taken from naturally-produced coho smolts in 2016. There were no coho yearling mortalities.

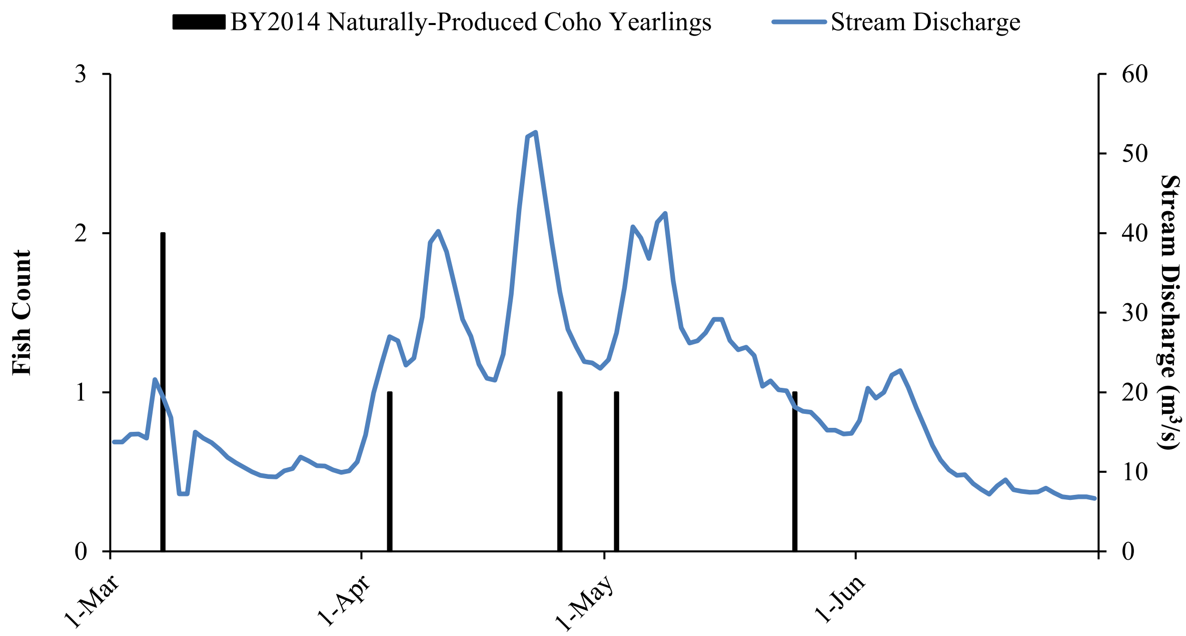


Figure 9. Daily catch of BY2014 naturally-produced coho yearlings with mean daily stream discharge at the Nason Creek rotary trap, March 1 to June 30, 2016.

Table 4. Summary of length and weight sampling of juvenile coho salmon captured at the Nason Creek rotary trap in 2016.

Brood Year	Origin/Species/Stage	Fork Length (mm)			Weight (g)			K-Factor
		Mean	*n*	SD	Mean	*n*	SD	
2013	Naturally Produced Coho Yearling Smolt	100	6	15.8	11.1	6	5.5	1.03
2013	Hatchery Coho Yearling Smolt	134	302	8.4	24.8	301	5.0	1.02

3.2.8 Coho Subyearlings (BY2015)

There were no BY2015 naturally-produced coho fry or parr captured at the Nason Creek smolt trap in 2016.

3.2.9 Hatchery Coho Smolts (BY2014)

A total of 276,063 hatchery coho were released into Nason Creek above the trap in spring of 2016. All hatchery coho released were acclimated in natural ponds adjacent to Nason Creek and reared to smolt stage prior to volitional release. Between March 1 and June 30, a total of 343 hatchery coho were captured at the trap (Figure 10). Mean FL was 134 mm (n = 302; SD = 8.4) and mean weight was 24.8 g (n = 301; SD = 5.0; Table 2). A peak daily catch of 45 hatchery coho smolts occurred on April 29 following volitional release into Nason Creek. Two trapping mortalities were incurred. Hatchery coho emigration data at the Nason Creek trap assists the MCCRP by providing size-at-emigration, emigration timing and duration of residence in Nason Creek.

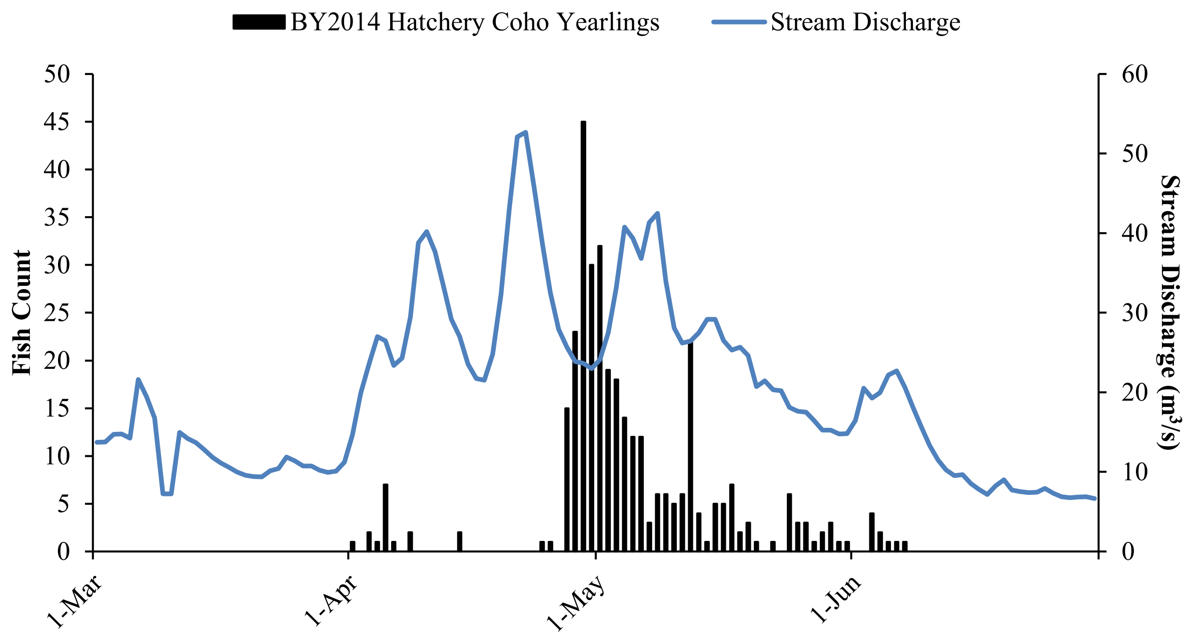


Figure 10. Daily catch of BY2014 hatchery coho smolt with mean daily stream discharge at the Nason Creek rotary trap, March 1 to June 30, 2016.

3.3 Remote Parr Tagging (BY2014 Spring Chinook)

YNFRM and WDFW personnel PIT tagged and released a total of 1,214 BY2014 spring Chinook parr between September 23 and October 15, 2015. The total surveyed area included Nason Creek from rkm 0.8 to 26.1. All collections were performed via backpack electrofisher. Equal capture effort (measured in electrofisher seconds used) was applied across all reaches.

Between October 1 and March 30, a total of 100 re-sights of the remote tagged spring Chinook were documented at the NAL array (Figure 11). Of these detections, only two were during the winter non-trapping period. High flows in November caused significant damages to the NAL array, resulting in antennas 1, 5, and 6 being inoperable throughout the non-trapping period (J. Deason Personal Communication, February 10, 2016).

Subsequent to the remote tagging effort, five remote-tagged BY2014 spring Chinook were recaptured at the Nason Creek smolt trap. Total spring Chinook catch at the smolt trap was 255 emigrants during the same period. The pooled tag rate for remote-tagged spring Chinook captured at the Nason smolt trap was 2.0%.

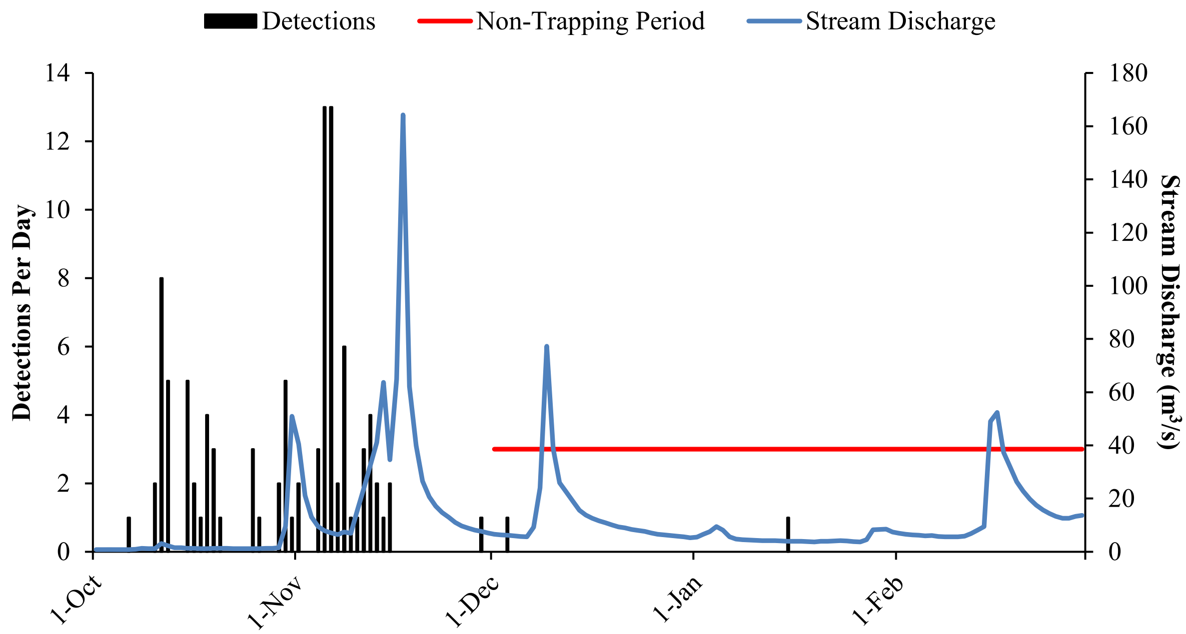


Figure 11. Daily detections of remote-tagged BY2014 spring Chinook at the lower Nason Creek PIT tag antenna array (NAL) between October 2015 and March 2016.

3.4 Trap Efficiency Calibration and Population Estimates

3.4.1 Spring Chinook Yearlings (BY2014)

Infrequent releases, low abundance, and a lack of recaptures did not allow a flow-efficiency model to be used on BY2014 yearling emigrants. In order to produce an estimate, a pooled efficiency (6.6%) composed of spring Chinook yearling releases in 2016 was used (Table 5). We recognize the sub-optimal nature of this estimation methodology, and will recalculate the estimates using linear regression analysis as soon as feasible. We estimated a total of 930 (± 5,083; 95% CI) BY2014 spring Chinook yearlings emigrated in spring of 2016 (Table 6). Parr emmigration during the non-trapping period was estimated using a flow-efficiency regression (r^2 = 0.38; p = 0.007) based on detections at the NAL pit tag array. This antenna efficiency is solely based on detections made on the three antennas that were functional during winter of 2016. We estimated that 1,442 (± 1,297; 95% CI) BY2013 spring Chinook emigrated out of Nason Creek during the non-trapping period. Combined with a recalculated BY2014 subyearling estimate of 8,694 (± 5,207; 95% CI), we estimated that a total of 7,280 (± 5,197; 95% CI) BY2014 spring Chinook juveniles emigrated from Nason Creek.

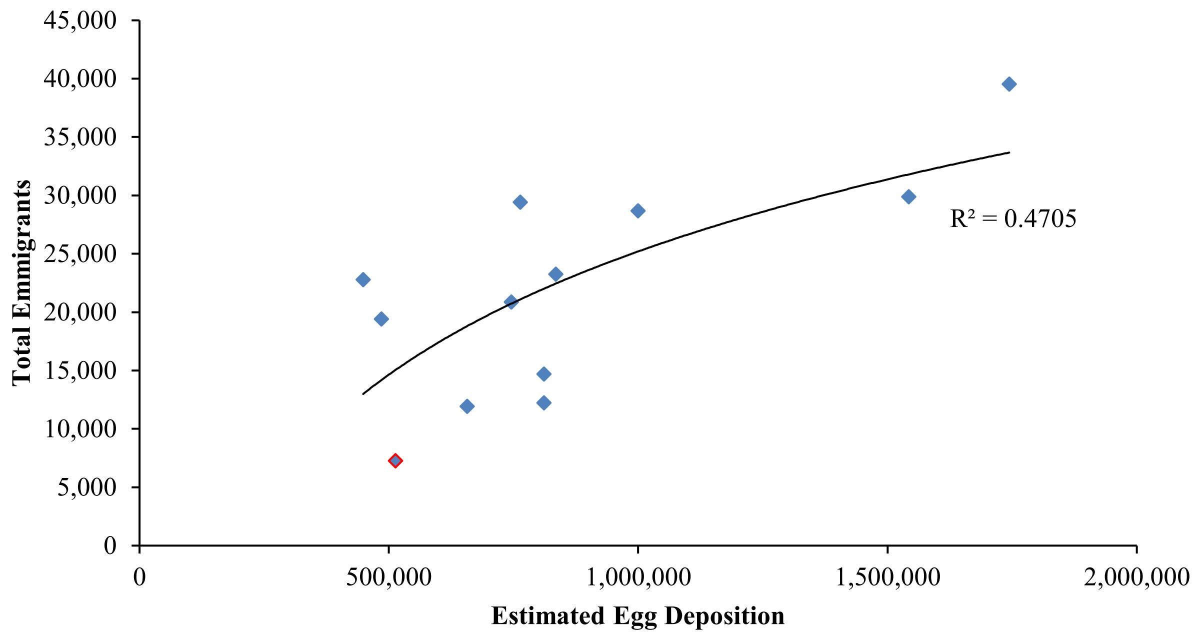
Table 5. Trap efficiency trials conducted with BY2014 wild spring Chinook yearlings and hatchery-origin coho yearling surrogates.

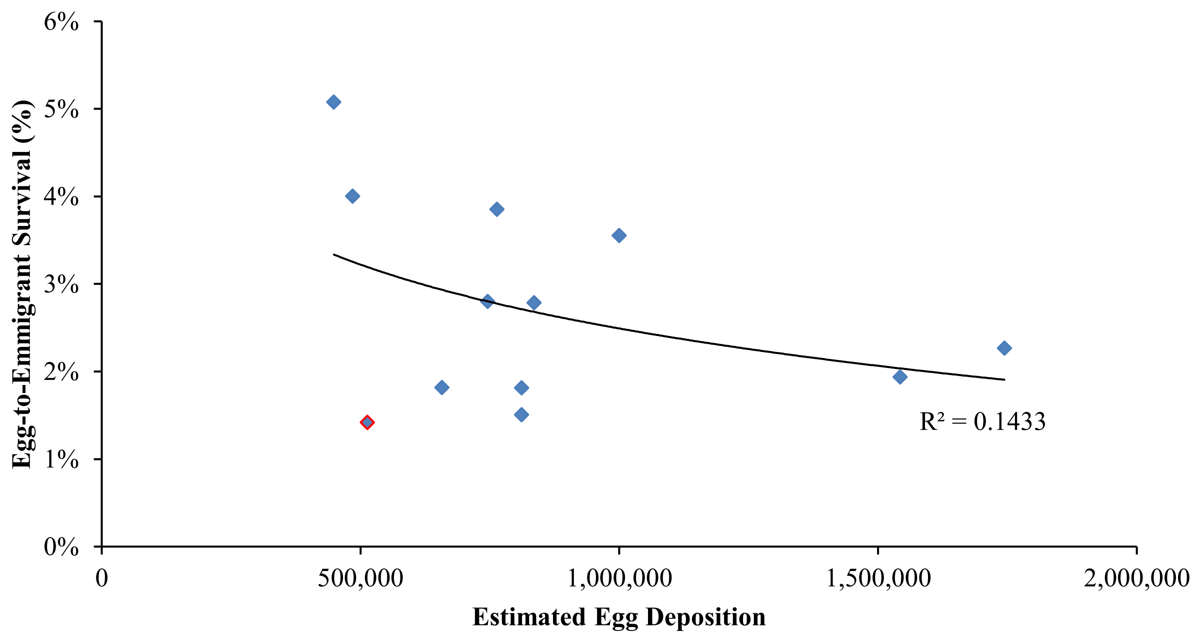
Origin/Species/Stage	Age	Date	Marked	Recaptured	Discharge (m^3/s)
Wild Chinook Yearlings	1+	3/4/2016	3	0	14.0
Wild Chinook Yearlings	1+	3/8/2016	12	4	15.9
Wild Chinook Yearlings	1+	3/12/2016	3	0	13.5
Wild Chinook Yearlings	1+	3/16/2016	2	0	10.5
Wild Chinook Yearlings	1+	3/28/2016	2	0	9.7
Wild Chinook Yearlings	1+	4/1/2016	10	0	13.9
Wild Chinook Yearlings	1+	4/5/2016	28	0	25.3
Wild Chinook Yearlings	1+	4/9/2016	1	0	37.7
Total			**61**	**4**	

Table 6. Estimated egg-to-emigrant survival and smolts-per-redd production for Nason Creek spring Chinook salmon.

Brood Year	No. Redds	Fecundity[a]	Est. Egg Deposition	No. of Emigrants				Egg-to-Emigrant	Emigrants per Redd
				Age-0[b]	Non Trap[d]	Age-1	Total ± 95% CI		
2002	294	4,654	1,368,276	—	—	4,683	—	—	—
2003	83	5,844	485,052	13,067	—	6,358	19,425 ± 1,993	4.0%	234
2004	169	4,799	811,031	12,111	—	2,597	14,708 ± 2,938	1.8%	87
2005	193	4,327	835,111	14,565	—	8,696	23,261 ± 5,440	2.8%	121
2006	152	4,324	657,248	4,144	—	7,798	11,942 ± 1,744	1.8%	79
2007	101	4,441	448,541	17,097	—	5,679	22,776 ± 2,983	5.1%	226
2008	336	4,592	1,542,912	26,284	—	3,611	29,895 ± 7,244	1.9%	89
2009	167	4,573	763,691	27,720	—	1,705	29,425 ± 12,777	3.9%	176
2010	188	4,314	811,032	8,685	—	3,535	12,220 ± 1,972	1.5%	65
2011	170	4,385	745,450	18,457	—	2,422	20,879 ± 3,887	2.8%	123
2012	413	4,223	1,744,099	34,961	—	4,561	39,522 ± 6,395	2.3%	96
2013	212	4,716	999,792	21,697	6,822	6,992[e]	35,511 ± 34,195	3.6%	168
2014	115	4,467	513,705	6,321	1,442	930[e]	8,694 ± 5,207	1.7%	76
2015	85	5,132	436,220	6,813	—	—	—	—	—
Avg.[c]	192	4,584	863,139	17,092	—	4,574	21,799	2.76%	128

[a] Data provided by Hillman et al. 2015.
[b] Does not include subyearling fry prior to July 1.
[c] 12-year average of complete brood data, BY2003-2014.
[d] Estimated emigration during the winter non-trapping period (December 1 – February 28).
[e] Pooled estimate


45,000
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
Total Emmigrants
R² = 0.4705
0
500,000
1,000,000
1,500,000
2,000,000
Estimated Egg Deposition


6%
5%
4%
3%
2%
1%
0%
Egg-to-Emmigrant Survival (%)
R² = 0.1433
0
500,000
1,000,000
1,500,000
2,000,000
Estimated Egg Deposition

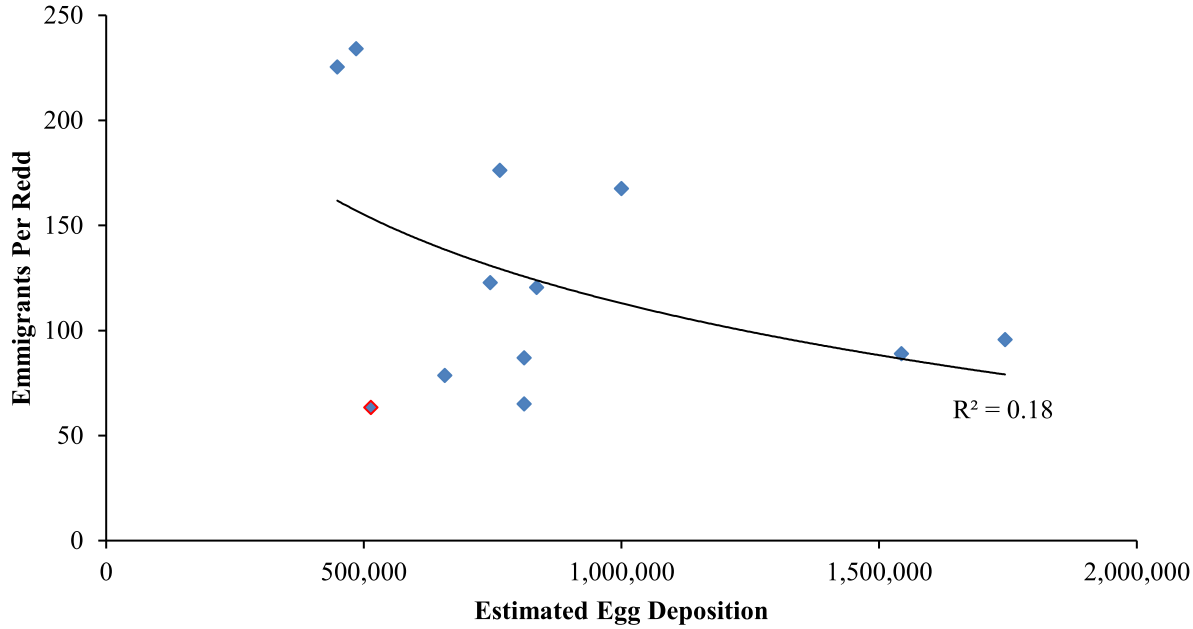


Figure 12. Relationships between estimated egg deposition and total emigrants produced, egg-to-emigrant survival, and emigrants per redd for Nason Creek spring Chinook, BY 2003 to 2014. *2014 brood (denoted by red border) does not include non-trapping estimate.

3.4.2 Spring Chinook Subyearlings (BY2015)

A linear regression model was developed using subyearling mark groups released in the fall of 2014 and 2016. The resulting regression ($r^2 = 0.60$; $p = 0.005$) was based on individual mark groups of ≥ 50 Chinook subyearlings only. Using this model we estimated that a total of 3,813 (± 1,116; 95% CI) BY2015 spring Chinook emigrated past the trap in the fall of 2016 (Table 6).

Table 7. Trap efficiency trials conducted with BY2015 wild spring Chinook subyearlings.

Origin/Species/Stage	Age	Date	Marked	Recaptured	Discharge (m^3/s)
Wild Chinook Subyearlings	0	7/2/2016	2	0	5.2
Wild Chinook Subyearlings	0	7/6/2016	4	0	3.9
Wild Chinook Subyearlings	0	7/14/2016	1	0	2.9
Wild Chinook Subyearlings	0	7/18/2016	2	0	2.9
Wild Chinook Subyearlings	0	7/22/2016	3	0	2.5
Wild Chinook Subyearlings	0	8/3/2016	1	0	1.7
Wild Chinook Subyearlings	0	10/24/2016	59	6	8.0
Wild Chinook Subyearlings	0	11/1/2016	68	8	10.6
Wild Chinook Subyearlings	0	11/6/2016	49	6	9.6
Wild Chinook Subyearlings	0	11/15/2016	69	11	15.3
Wild Chinook Subyearlings	0	11/20/2016	32	3	8.2
Total			**290**	**34**	

3.4.3 Summer Steelhead

Low abundance of summer steelhead emigrants in the spring of 2016 required a pooled estimate be used in light of the inability to meet minimum mark-group sizes (n = 50) for regression analysis. Releases of PIT-tagged steelhead were subsequently released every four days upstream at the established release location (Table 8). In a total of 31 separate trials, 216 wild summer steelhead were released upstream with 3 recaptures (1.4%). Estimates of age-0 fry and parr were not made due to insufficient evidence that active migration is occurring at this young age. Previous attempts at the old location to build a model based on young-of-the-year steelhead parr in the fall have yielded weak flow-efficiency relationships; further suggesting that age-0 parr catch is the result of displacement rather than active migration. We estimated that 19,872 (± 69,909; 95% CI) BY2015 age-1, 1,124 (± 4,437; 95% CI) BY2014 age-2, and 72 (± 294; 95% CI) BY2013 age-3 steelhead emigrated past the trap in 2016 (Table 9). We estimate that total (age 1-3) BY2013 emigration to be 13,417(± 9,133; 95% CI). All pooled estimates will be recalculated upon development of a species-specific flow-efficiency model.

Table 8. Efficiency trials conducted with wild summer steelhead juveniles.

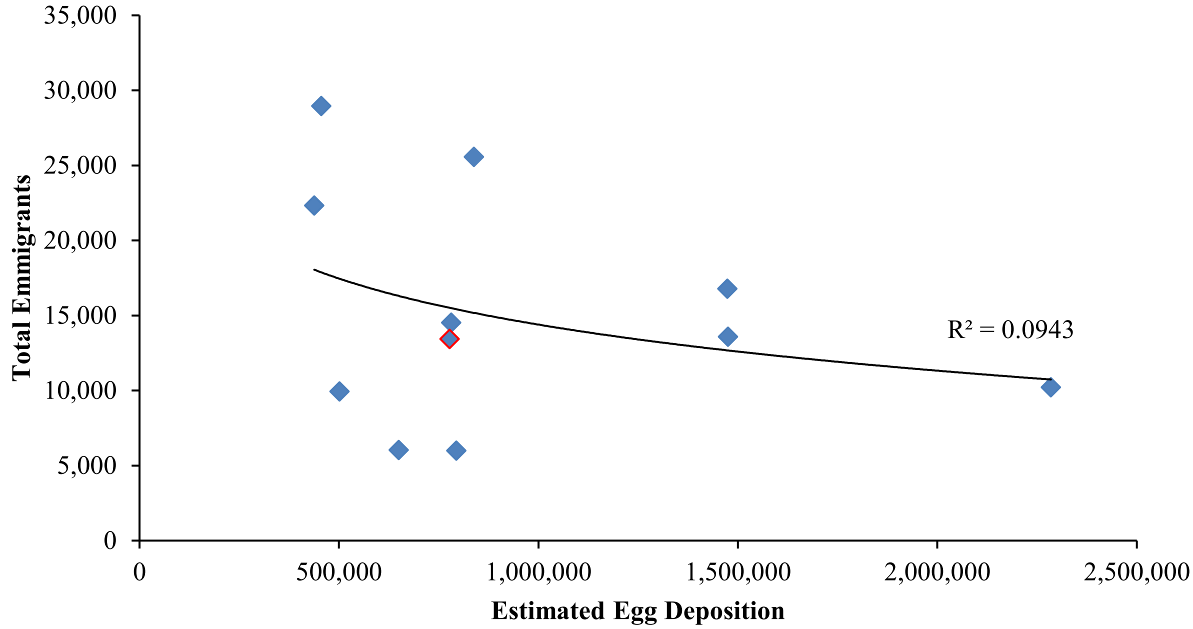
Origin/Species/Stage	Date	Marked	Recaptured	Discharge (m^3/s)
Wild Steelhead Parr/Smolt	3/4/2016	1	0	14.8
Wild Steelhead Parr/Smolt	3/8/2016	2	0	15.9
Wild Steelhead Parr/Smolt	3/12/2016	1	0	13.5
Wild Steelhead Parr/Smolt	3/16/2016	4	0	10.5
Wild Steelhead Parr/Smolt	3/20/2016	8	0	8.9
Wild Steelhead Parr/Smolt	3/24/2016	2	0	11.2
Wild Steelhead Parr/Smolt	4/1/2016	4	0	13.9
Wild Steelhead Parr/Smolt	4/5/2016	16	0	25.3
Wild Steelhead Parr/Smolt	4/9/2016	4	0	37.7
Wild Steelhead Parr/Smolt	4/13/2016	7	0	28.2
Wild Steelhead Parr/Smolt	4/17/2016	3	0	20.7
Wild Steelhead Parr/Smolt	4/21/2016	7	0	52.4
Wild Steelhead Parr/Smolt	4/25/2016	3	0	32.0
Wild Steelhead Parr/Smolt	4/29/2016	6	0	23.0
Wild Steelhead Parr/Smolt	5/3/2016	7	0	32.6
Wild Steelhead Parr/Smolt	5/7/2016	3	0	41.3
Wild Steelhead Parr/Smolt	5/11/2016	2	0	25.6
Wild Steelhead Parr/Smolt	5/23/2016	6	0	19.6
Wild Steelhead Parr/Smolt	5/27/2016	20	2	16.3
Wild Steelhead Parr/Smolt	5/31/2016	16	0	13.9
Wild Steelhead Parr/Smolt	6/4/2016	35	0	17.4
Wild Steelhead Parr/Smolt	6/8/2016	17	0	17.0
Wild Steelhead Parr/Smolt	6/12/2016	3	0	9.5
Wild Steelhead Parr/Smolt	6/16/2016	10	1	7.2
Wild Steelhead Parr/Smolt	6/20/2016	7	0	7.0

Origin/Species/Stage	Date	Marked	Recaptured	Discharge (m^3/s)
Wild Steelhead Parr/Smolt	6/24/2016	2	0	7.2
Wild Steelhead Parr/Smolt	6/28/2016	5	0	6.2
Wild Steelhead Parr/Smolt	7/2/2016	4	0	5.2
Wild Steelhead Parr/Smolt	7/6/2016	8	0	3.9
Wild Steelhead Parr/Smolt	7/10/2016	2	0	3.6
Wild Steelhead Parr/Smolt	7/14/2016	1	0	2.9
Total		**216**	**3**	

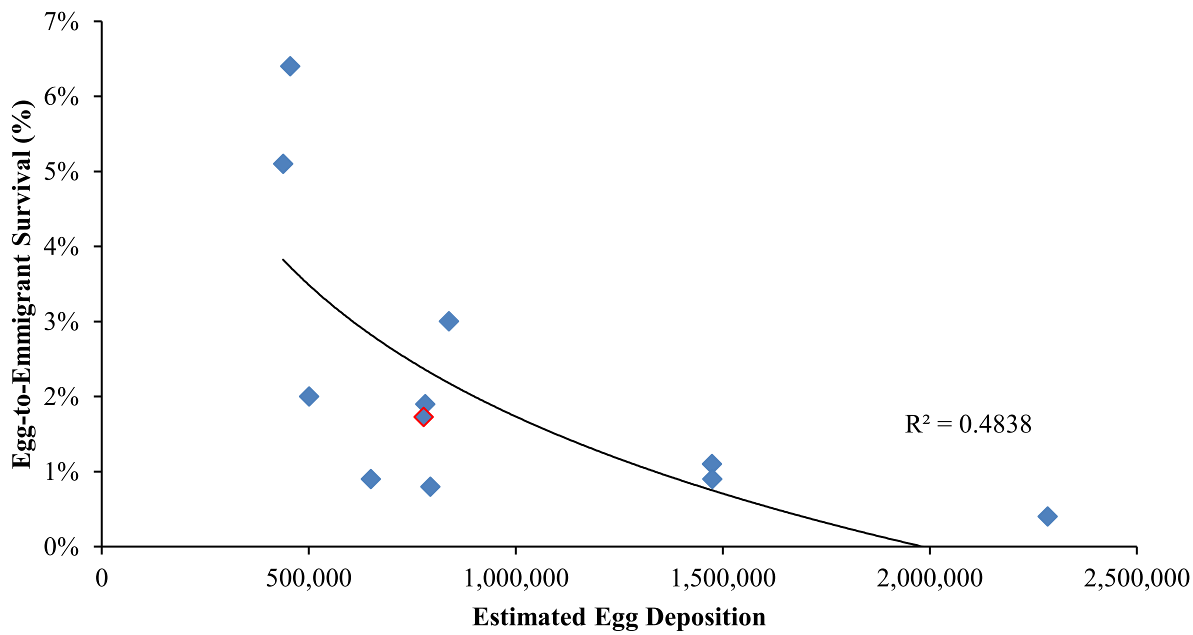
Table 9. Estimated egg-to-emigrant survival and emigrants-per-redd production for Nason Creek summer steelhead.

Brood Year	No. of Redds	Fecundity[a]	Est. Egg Deposition	No. of Emigrants				Egg-to-Emigrant	Emigrants per Redd
				1+	2+	3+	Total ± 95%CI		
2001	27	5,951	160,677	DNOT	DNOT	846	—	—	—
2002	80	5,776	462,080	DNOT	2,475	0	—	—	—
2003	121	6,561	793,881	4,906	1,054	27	5,987 ± 1,193	0.80%	49
2004	127	5,118	649,986	5,107	906	22	6,035 ± 885	0.90%	48
2005	412	5,545	2,284,540	7,416	2,502	298	10,216 ± 2,147	0.40%	25
2006	77	5,688	437,976	19,609	2,673	37	22,319 ± 5,722	5.10%	290
2007	78	5,840	455,520	26,518	2,325	117	28,960 ± 7,739	6.40%	371
2008	88	5,693	500,984	8,782	1,164	0	9,946 ± 2,382	2.00%	113
2009	126	6,199	781,074	13,606	608	312	14,526 ± 2,868	1.90%	115
2010	270	5,458	1,473,660	12,767	3,999	0	16,776 ± 3,885	1.10%	62
2011	235	6,276	1,474,860	13,109	482	0	13,591 ± 3,525	0.90%	58
2012	158	5,309	838,822	24,637	813	116[c]	25,566 ± 6,020	3.00%	162
2013	135	5,749	777,735	11,837	1,508[c]	72[c]	13,417 ± 9,133	1.73%	99
2014	198	5,831	1,154,538	22,504[c]	1,224[c]	—	—	—	—
2015	171	6,220	1,063,620	19,872[c]	—	—	—	—	—
Avg[b]	166	5,767	951,731	13,481	1,639	91	15,213	2.20%	127

[a] Data provided by Hillman et al. 2015
[b] 11-year average of complete brood estimates, BY2003-2013
[c] Pooled estimate



35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
Total Emmigrants
R² = 0.0943
0
500,000
1,000,000
1,500,000
2,000,000
2,500,000
Estimated Egg Deposition



7%
6%
5%
4%
3%
2%
1%
0%
Egg-to-Emmigrant Survival (%)
R² = 0.4838
0
500,000
1,000,000
1,500,000
2,000,000
2,500,000
Estimated Egg Deposition

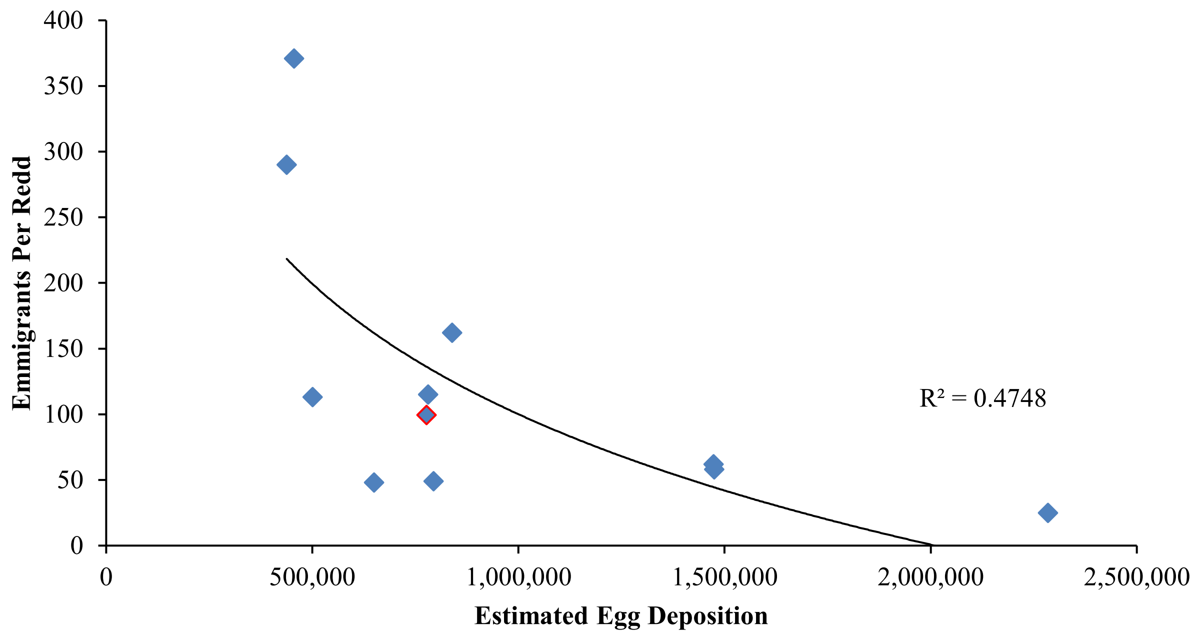


Figure 13. Relationships between estimated egg deposition and total emigrants produced, egg-to-emigrant survival, and emigrants per redd for Nason Creek summer Steelhead, BY 2003 to 2013. *2013 brood denoted by red border.

3.4.4 Coho Yearlings (BY2014)

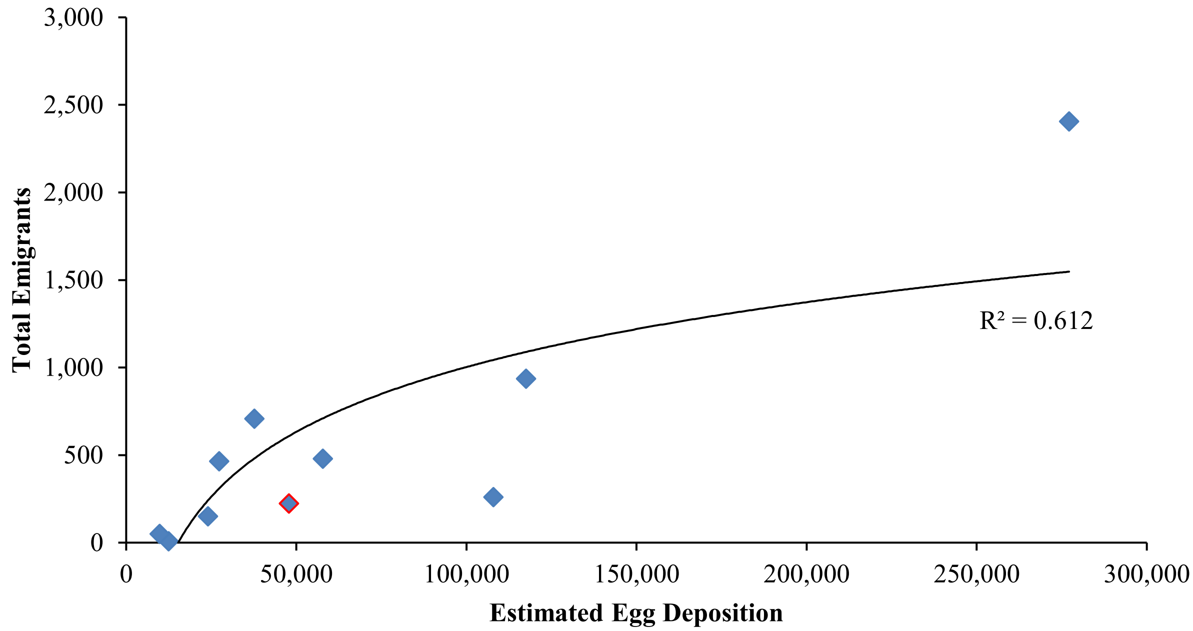
Limited abundance of BY2014 coho yearlings did not provide any opportunities to perform any efficiency trials in the spring of 2016. In lieu of a species-specific model, a pooled efficiency based on yearling spring Chinook releases was applied to wild coho smolts. In the spring of 2016, we estimated that 92 (± 504; 95% CI) emigrated past the trap (Table 10). Combined with a subyearling estimate of 131 (± 96; 95% CI),this gave us a total BY2014 emigrant estimate of 223 (± 514; 95% CI).

Table 10. Estimated egg-to-emigrant survival and smolts-per-redd production for Nason Creek coho salmon.

Brood Year	No. of Redds	Fecundity	Est. Egg Deposition	No. of Emigrants			Egg-to-Emigrant	Emigrants per Redd
				Age-0[a]	Age-1	Total ± 95% CI		
2003	6	2,458	14,748	DNOT	394	—	—	—
2004	35	3,084	107,940	204	56	260 ± 155	0.20%	7
2005	41	2,866	117,506	27	910	937 ± 347	0.80%	23
2006	4	3,126	12,504	7	0	7 ± 10	0.10%	2
2007	10	2,406	24,060	14	136	150 ± 104	0.60%	15
2008	3	3,275	9,825	50	0	50 ± 57	0.50%	17
2009	14	2,691	37,674	471	237	708 ± 478	1.90%	51
2010	8	3,411	27,288	27	437	464 ± 231	1.70%	58
2011	89	3,114	277,146	1,018	1,387	2,405 ± 612	0.90%	27
2012	21	2,752	57,792	46	434	480 ± 237	0.80%	23

Brood Year	No. of Redds	Fecundity	Est. Egg Deposition	No. of Emigrants			Egg-to-Emigrant	Emigrants per Redd
				Age-0[a]	Age-1	Total ± 95% CI		
2013	0	—	—	91	91[c]	182 ± 714	—	—
2014	16	2,992	47,872	131[c]	92[c]	223 ± 514	0.47%	14
2015	0	—	—	0	—	—	—	—
Avg.[b]	24	2,972	71,961	190	344	533	0.80%	24

[a] Does not include subyearling fry prior to July 1.
[b] 10-year average of complete brood data, BY2004-2014.
[c] Pooled estimate



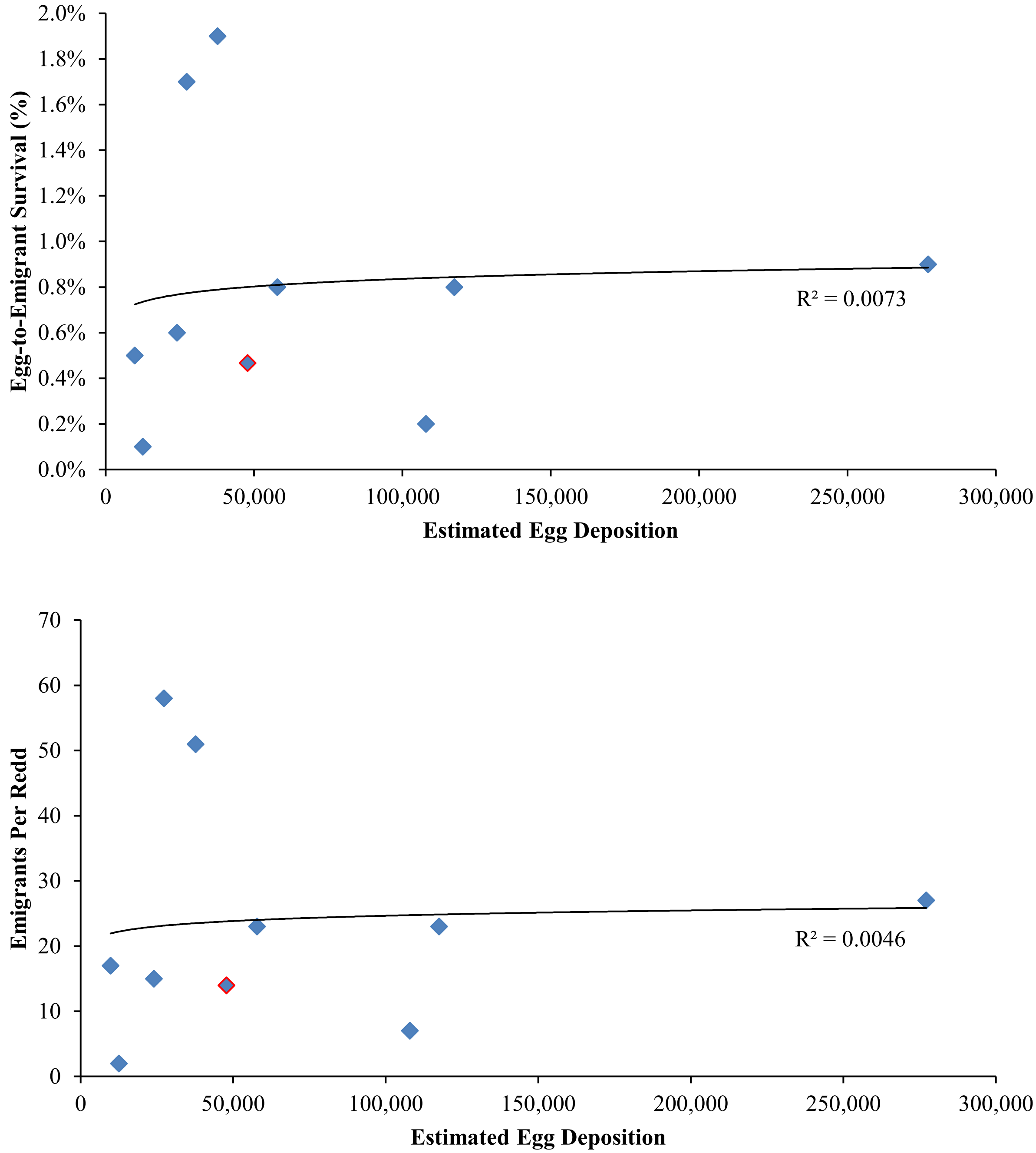


Figure 14. Relationships between estimated egg deposition and total emigrants produced, egg-to-emigrant survival, and emigrants per redd for Nason Creek natural-produced coho, BY 2003 to 2014. *2014 brood (denoted by red border).

3.4.5 Coho Subyearlings (BY2015)

Due to lack of BY2015 naturally-produced coho catch, we concluded that there were no emigrants from Nason in 2016.

3.5 PIT Tagging

During the 2016 trapping season, we PIT tagged 495 wild spring Chinook, 531 steelhead, and 6 naturally produced coho (Table 11). All tagging files were submitted to the PTAGIS database. One shed PIT tag (implanted in steelhead parr) was recovered in a holding box where fish had been held for 24-72 hours after tagging. During remote tagging efforts in the fall of 2015, 1,214 spring Chinook were PIT tagged by YNFRM and WDFW personnel.

Table 11. Number of PIT tagged coho, Chinook, and steelhead with shed rates at the Nason Creek rotary trap in 2016.

Species/Stage	Year-to-date Catch	Year-to-date PIT Tagged	No. of Shed Tags	Percent Shed Tags
Chinook Yearling Smolt	61	61	0	0.0%
Chinook Subyearling Parr (Mar 1 to June 30)	44	21	0	0.0%
Chinook Subyearling Parr (July 1 to Nov 30)	447	413	0	0.0%
Steelhead Parr	663	522	1	0.2%
Steelhead Smolt	9	9	0	0.0%
Coho Yearling Smolt	6	6	0	0.0%
Coho Subyearling Parr	0	0	—	—

* Counts do not include fish with FL<50mm (fry).

3.6 Incidental Species

Along with wild spring Chinook, wild steelhead/rainbow trout, and naturally produced coho, other resident fish species captured at the Nason Creek rotary trap and included in Table 12 are: bull trout *Salvelinus* confluentus, cutthroat trout *Oncorhynchus clarki*, flathead minnow *Pimephales promelas*, longnose dace *Rhinichthys cataractae*, northern pikeminnow *Ptychocheilus oregonensis*, redside shiner *Richardsonius balteatus,* sculpin *Cottus sp.,* sucker *Catostomus sp.,* and mountain whitefish *Prosopium williamsoni*.

Table 12. Summary of length and weight sampling of incidental species captured at the Nason Creek rotary trap in 2016.

Species	Total Count	Length (mm)			Weight (g)		
		Mean	N	SD	Mean	N	SD
Bull Trout	1	199	1	—	70.0	1	—
Cutthroat Trout	1	140	1	—	25.2	1	—
Fathead Minnow	4	52	4	3.7	1.7	4	0.3
Longnose Dace	230	52	230	19.2	2.5	228	4.1
Northern Pikeminnow	18	91	18	23.1	9.6	18	6.1
Redside Shiner	99	41	99	17.6	1.5	84	2.2
Sculpin	84	64	83	35.5	7.9	76	11.7
Sucker	319	58	319	23.4	3.8	317	18.7
Whitefish	81	58	81	39.8	4.8	79	25.8

3.7 ESA Compliance

The Nason Creek smolt trap was operated under consultation with NMFS and USFWS. Total numbers of UCR spring Chinook and UCR summer steelhead that were captured or handled (indirect take) at the trap were less than the maximum permitted (20%) for each species. Lethal take was well below the allowable level of 2% for all ESA-listed species (Table 13). Stream temperatures did not exceed 18˚C at any time in which fish were being handled.

Table 13. Summary of ESA species and coho salmon mortality at the Nason Creek rotary trap.

Species/Stage/Brood Year	Total Collected	Total Mortality	% Mortality
Spring Chinook Yearling (BY2014)	61	0	0.0%
Spring Chinook Subyearling (BY 2015)	791	6	0.8%
Total Wild Spring Chinook	**852**	**6**	**0.7%**
Total Hatchery Spring Chinook	**124**	**0**	**0.0%**
Steelhead Age-0 (BY2016)	702	1	0.1%
Steelhead Age-1 (BY2015)	285	0	0.0%
Steelhead Age-2 (BY2014)	19	0	0.0%
Steelhead Age-3 (BY2013)	1	0	0.0%
Total Wild Summer Steelhead	**1,007**	**1**	**0.1%**
Total Hatchery Summer Steelhead	**98**	**0**	**0.0%**
Total Bull Trout	**1**	**0**	**0.0%**
Coho Yearling (BY2014)	6	0	0.0%
Coho Subyearling (BY2015)	0	0	—
Total Naturally-Produced Coho	**6**	**0**	**0.0%**

4.0 DISCUSSION

Operation of the Nason Creek smolt trap in 2016 was, as in 2015, affected by an unseasonably early and warm spring that caused a quickly diminished snowpack. The resulting prolonged base-flow period meant that the trap could not be operated for much (70 d) of the mid to late summer due to insufficient water velocity. Aside from issues associated with the summer low flow period, inactivity due to other environmental conditions and mechanical issues was minimized. The critical assumptions noted in section 2.5.1, upon which the mark-recapture methodology was predicated, were not violated insofar as we could determine from measuring tag retention/tagging mortality, examining the health of all fish in mark groups prior to release, and ensuring that all fish encountered were thoroughly scanned for PIT tags post-release. All prudent measures were taken to ensure that fish used in mark groups avoided predation between point of release and the trap e.g., release into shallow water refugia.

Since establishment in the summer of 2014, smolt trap operations at the Bolser site have occurred largely under a prolonged period of El Niño spanning from approximately October 2014 through June 2016 (NOAA 2016). Oceanic Niño Index (ONI) levels for this period were especially high (≥ 2.0), with similar conditions not experienced since warming events in 1982/1983 and 1997/1998. Inland manifestations of this most recent El Niño included variable flow and temperature regimes, often deviating greatly from normal trends in both timing and magnitude (Figure 15). Comparison to the 12-year mean discharge and observed flows shows that high water events occurred early, and in periods in which cold temperature normally limit discharge. Quickly diminished snowpack caused by the high, early winter flows subsequently lead to early spring runoff and prolonged base-flow periods in the summer months.

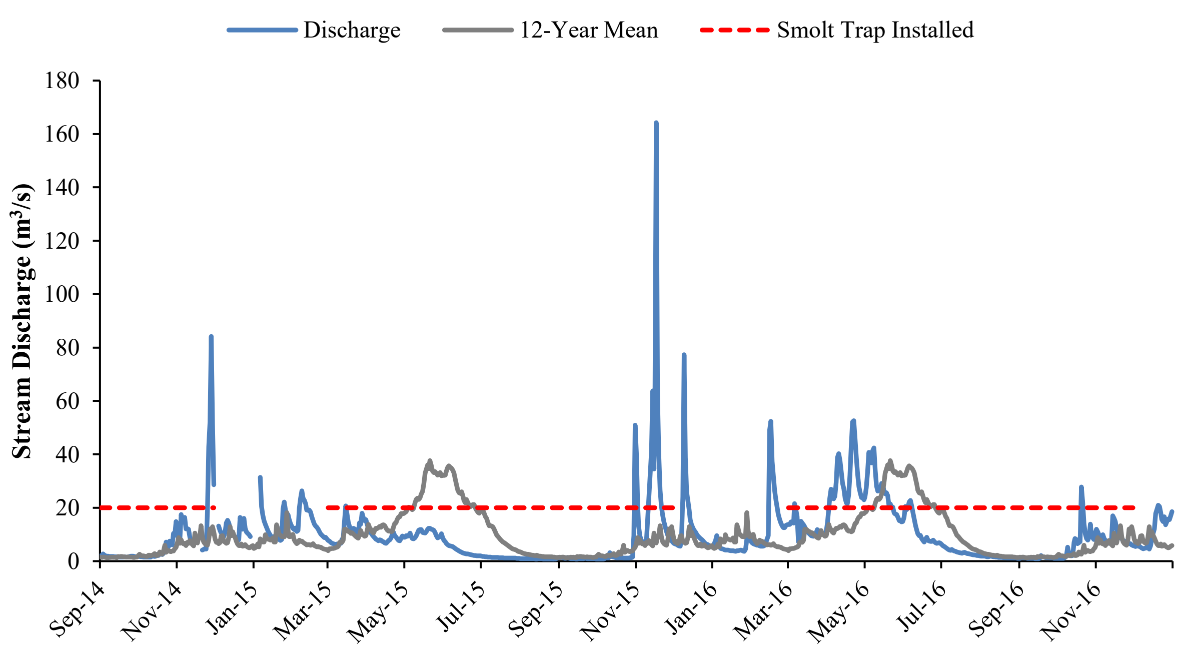


Figure 15. Nason Creek daily discharge from September 2014 through December 2016, with corresponding 12-year mean Nason Creek discharge.

Spring Chinook

The 2014 wild spring Chinook brood at Nason Creek yielded the smallest total emigrant estimate on record at the trap. Egg-to-emigrant survival in comparison to the nearby White River and Chiwawa River showed that Nason Creek was the only monitored tributary in the Wenatchee basin to demonstrate a decrease in in-stream survival between the 2013 and 2014 broods despite similar trends in redd deposition (Figure 17). Comparison of egg-to-emigrant survival and estimated egg deposition suggested that between the three tributaries, Nason Creek produced the most marked outlier (Figure 18). The degree to which Nason Creek deviated from the trends seen in the other tributaries may be due to the comparative effect that the El Niño event had on the individual watershed. The smallest, lowest elevation, and warmest of the three tributaries compared, Nason Creek saw the greatest physical impact of the warming phenomenon.

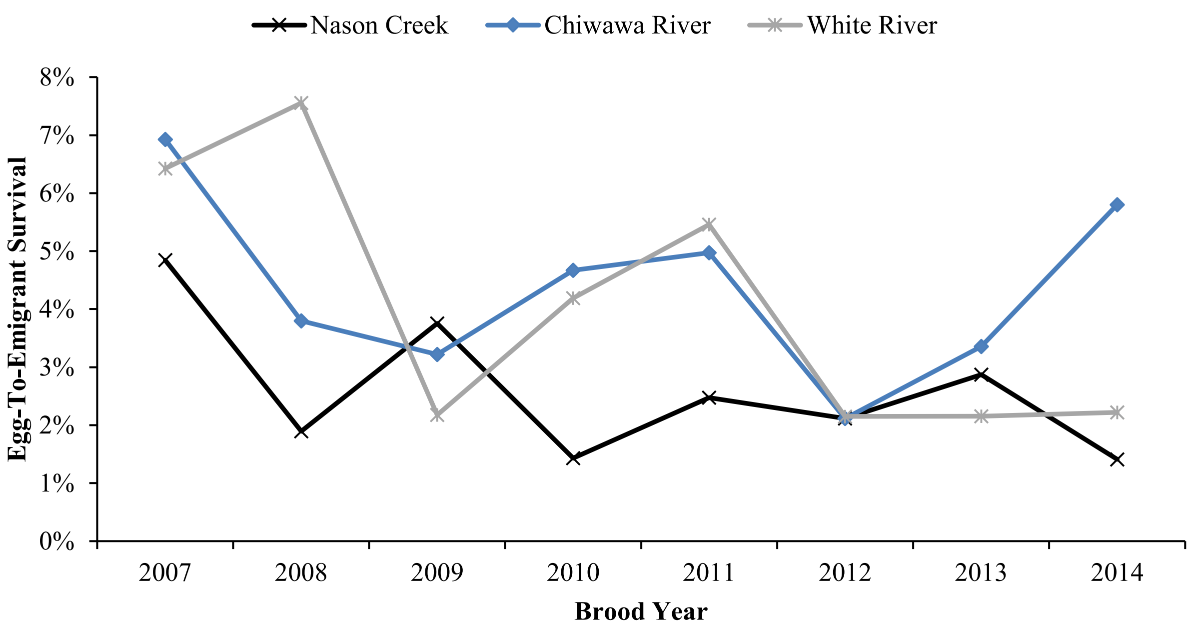


Figure 16. Comparison of wild spring Chinook abundance estimates (BY2007-2014) made at the White River, Nason Creek, and Chiwawa River smolt traps. *Non-trapping estimates not included.

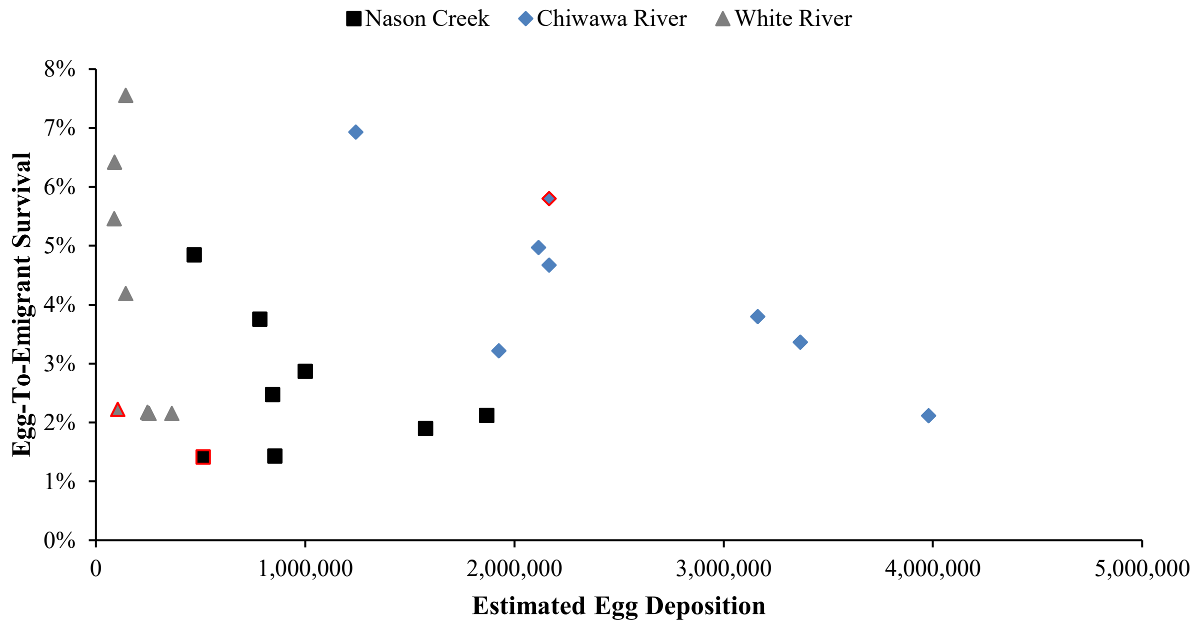


Figure 17. Comparison of egg-to-emigrant survival (BY 2007-2014) and egg deposition for Nason Creek, Chiwawa River, and White River spring Chinook. *Non-trapping estimates not included.

The low comparative survival of BY2014 Chinook was likely due in-apart to decreased survival associated with the anomalous flow and temperature regimes caused by El Niño. Redd scour and sedimentation brought on by irregularly high flows has been shown to increase in-gravel mortality (Montgomery et al. 1996 & Lotspeich and Everest 1981). Although difficult to quantify the exact influence of scour and sedimentation on our estimates, we assume that the strong negative correlation between juvenile survival and peak flow during incubation demonstrated in other tributaries had some negative influence in Nason Creek (Seiler et al. 2002). Some elevated level of increased mortality was also likely incurred as a result of warm water temperatures, decreased habitat available, and elevated competition for resources during the prolonged base flow period in the summer of 2015. Identified in normal years as an impaired watershed due to regular exceedance of 303(d) criteria, Nason Creek saw three consecutive months in 2015 (June-August) in which maximum temperatures exceeded 22ºC (Cristea and Pelletier 2005). Marine and Cech (2004) showed that between three laboratory-based rearing temperature regimes (13-16ºC, 17-20ºC, and 21-24ºC), higher water temperatures significantly decreased growth rates, smoltification indices, and predator avoidance capability. Though Marine and Cech did not see any increased mortality associated with higher rearing temperatures, we assume that effects noted in the study would have an impact on survival in-situ.

BY2014 spring Chinook parr that survived the summer months in Nason Creek were then met with extremely high discharges in the month of November 2015. Flows during this high-water event were large enough to cause a major reconfiguration of log jams and channel morphology in sections. During this period in which we presume a large proportion of the remaining Chinook in Nason Creek were involuntarily pushed out of the system, the trap was unable to run due to water high velocity and debris load. During this event, remote-tagged Chinook were also pushed from the system when the PIT tag arrays were the least effective. We suspect that along with a higher incidence of in-stream mortality, much of the BY2014 brood left Nason Creek when estimation methodologies were unavailable or ineffective.

A total of only 85 redds in Nason Creek in 2015 was the lowest on record since 2003. The extent to which high winter flows of 2015/2016 affected the BY2015 emigration estimate will potentially be determined upon completion of the outmigration in the summer of 2017. Impact on this brood may be great in that much of the winter flooding occurred pre-emergence; a period of high vulnerability to both scour and sedimentation. The estimated survival of this brood will hopefully indicate the ability of Nason Creek spring Chinook to endure such in-gravel conditions.

Summer Steelhead

The 2013 Nason summer steelhead brood estimate did not reflect the low survival seen in BY2014 Chinook concluding their outmigration at the same time. Although BY2013 steelhead abundance and survival both fell below their 11-year averages, they were not outliers. This is presumably due to the fact that the overwhelming majority (88%) of BY2013 steelhead emigrants left during the spring of 2014; a period not characterized by irregularly high flows or preceded by adverse rearing conditions. The BY2013 age-2 and age-3 emigrant estimates are based on pooled efficiencies, and will be recalculated upon establishment of a viable multi-year regression. Recalculation of these estimates based on a flow-efficiency regression will most likely result in a slightly lower total estimate due to the pooled estimates use of low fixed efficiencies (0.86% and 1.34%). However, because age-2 & 3 steelhead emigrants comprise a relatively small proportion of the total outmigration, recalculation may not change in-stream survival to a great extent.

Potential effects of the El Niño period on developing (BY2014 and BY2015) estimates are still unclear due to the use of pooled estimates employing the aforementioned low fixed efficiencies. BY2014 and BY2015 estimates thus far have produced age-1 estimates that are markedly higher than the 11-year mean. Completion of both emigrant estimates as well as recalculation with a viable flow-efficiency regression will determine if this high abundance is accurate, and in stark contrast to the poor survival calculated in cohabitating spring Chinook.

Coho

Despite a relatively large Wenatchee basin spawner escapement in 2014, only 16 redds were documented in Nason Creek; below the 11-year mean of 24 redds. The resulting total emigrant estimate was also below the 11-year mean, and in the absence of a flow-efficiency regression, calculated with a pooled estimate. As with similar methodologies used to calculate other species abundances in the absence of a flow-efficiency relationship, we suspect that these pooled estimated are likely overestimated due to low efficiencies used. BY2014 coho were likely affected by the El Niño weather trend similarly to BY2014 spring Chinook, given similar in-stream residence times.

A poor adult coho return in 2015 required exhaustive broodstock retention at Tumwater dam to meet hatchery production goals. As a result, no coho were documented in Nason Creek. This is reflected in the complete lack of BY2015 subyearlings at the trap during the 2016 trap year. Given little coho passage above Tumwater dam, and a very small likelihood that any spawning activity occurred in Nason Creek in 2015, we suspect that yearling emigrants will be absent completely for this brood as well.

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APPENDIX A. Daily Stream Discharge

Date	Stream Discharge (m^3/s)
1/1/2016	5.5
1/2/2016	6.6
1/3/2016	7.6
1/4/2016	9.5
1/5/2016	8.1
1/6/2016	5.7
1/7/2016	4.8
1/8/2016	4.6
1/9/2016	4.5
1/10/2016	4.3
1/11/2016	4.2
1/12/2016	4.2
1/13/2016	4.2
1/14/2016	4.0
1/15/2016	3.9
1/16/2016	4.0
1/17/2016	3.9
1/18/2016	3.8
1/19/2016	3.7
1/20/2016	
1/21/2016	
1/22/2016	4.1
1/23/2016	4.2
1/24/2016	4.0
1/25/2016	3.8
1/26/2016	3.7
1/27/2016	4.5
1/28/2016	8.2
1/29/2016	
1/30/2016	8.5
1/31/2016	7.5
2/1/2016	7.0
2/2/2016	6.6
2/3/2016	6.3
2/4/2016	6.2
2/5/2016	6.0
2/6/2016	6.1
2/7/2016	5.8
2/8/2016	5.6
2/9/2016	5.6
2/10/2016	5.6
2/11/2016	5.9
2/12/2016	6.9
2/13/2016	
2/14/2016	9.5
2/15/2016	49.0
2/16/2016	52.4
2/17/2016	37.4
2/18/2016	31.7
2/19/2016	26.3
2/20/2016	22.8
2/21/2016	19.9
2/22/2016	17.6
2/23/2016	15.7
2/24/2016	14.4
2/25/2016	13.3
2/26/2016	12.6
2/27/2016	12.6
2/28/2016	13.4
2/29/2016	13.7
3/1/2016	
3/2/2016	13.8
3/3/2016	14.7
3/4/2016	14.8
3/5/2016	14.2
3/6/2016	21.6
3/7/2016	19.4
3/8/2016	16.8
3/9/2016	7.2
3/10/2016	7.2
3/11/2016	15.0
3/12/2016	14.2
3/13/2016	13.7
3/14/2016	12.8
3/15/2016	11.8
3/16/2016	11.1
3/17/2016	10.6
3/18/2016	10.0
3/19/2016	9.6
3/20/2016	9.4
3/21/2016	9.4
3/22/2016	10.1
3/23/2016	10.4
3/24/2016	11.9

3/25/2016	11.4	5/9/2016	34.0
3/26/2016	10.8	5/10/2016	28.1
3/27/2016	10.7	5/11/2016	26.2
3/28/2016	10.2	5/12/2016	26.4
3/29/2016	9.9	5/13/2016	27.5
3/30/2016	10.1	5/14/2016	29.2
3/31/2016	11.2	5/15/2016	29.2
4/1/2016	14.6	5/16/2016	26.5
4/2/2016	19.9	5/17/2016	25.3
4/3/2016	23.6	5/18/2016	25.7
4/4/2016	27.0	5/19/2016	24.6
4/5/2016	26.5	5/20/2016	20.7
4/6/2016	23.4	5/21/2016	21.4
4/7/2016	24.3	5/22/2016	20.3
4/8/2016	29.4	5/23/2016	20.2
4/9/2016	38.8	5/24/2016	18.1
4/10/2016	40.2	5/25/2016	17.6
4/11/2016	37.7	5/26/2016	17.5
4/12/2016	33.4	5/27/2016	16.5
4/13/2016	29.2	5/28/2016	15.2
4/14/2016	27.0	5/29/2016	15.2
4/15/2016	23.5	5/30/2016	14.8
4/16/2016	21.7	5/31/2016	14.8
4/17/2016	21.5	6/1/2016	16.5
4/18/2016	24.8	6/2/2016	20.5
4/19/2016	32.3	6/3/2016	19.3
4/20/2016	43.0	6/4/2016	20.0
4/21/2016	52.1	6/5/2016	22.2
4/22/2016	52.7	6/6/2016	22.7
4/23/2016	45.9	6/7/2016	20.6
4/24/2016	38.8	6/8/2016	18.1
4/25/2016	32.6	6/9/2016	15.7
4/26/2016	27.9	6/10/2016	13.3
4/27/2016	25.7	6/11/2016	11.5
4/28/2016	23.8	6/12/2016	10.3
4/29/2016	23.7	6/13/2016	9.5
4/30/2016	23.0	6/14/2016	9.7
5/1/2016	24.1	6/15/2016	8.5
5/2/2016	27.5	6/16/2016	7.8
5/3/2016	33.1	6/17/2016	7.2
5/4/2016	40.8	6/18/2016	8.2
5/5/2016	39.4	6/19/2016	9.0
5/6/2016	36.8	6/20/2016	7.7
5/7/2016	41.3	6/21/2016	7.5
5/8/2016	42.5	6/22/2016	7.4

6/23/2016	7.4	8/7/2016	1.6
6/24/2016	7.9	8/8/2016	1.7
6/25/2016	7.3	8/9/2016	2.0
6/26/2016	6.9	8/10/2016	1.8
6/27/2016	6.7	8/11/2016	1.7
6/28/2016	6.9	8/12/2016	1.6
6/29/2016	6.9	8/13/2016	1.5
6/30/2016	6.7	8/14/2016	1.5
7/1/2016	6.1	8/15/2016	1.4
7/2/2016	5.7	8/16/2016	1.4
7/3/2016	5.4	8/17/2016	1.4
7/4/2016	5.1	8/18/2016	1.3
7/5/2016	4.7	8/19/2016	1.3
7/6/2016	4.4	8/20/2016	1.3
7/7/2016	4.1	8/21/2016	1.2
7/8/2016	4.1	8/22/2016	1.2
7/9/2016	4.4	8/23/2016	1.2
7/10/2016	4.0	8/24/2016	1.2
7/11/2016	3.9	8/25/2016	1.2
7/12/2016	3.6	8/26/2016	1.2
7/13/2016	3.5	8/27/2016	1.1
7/14/2016	3.3	8/28/2016	1.1
7/15/2016	3.1	8/29/2016	1.1
7/16/2016	3.1	8/30/2016	1.1
7/17/2016	3.0	8/31/2016	1.1
7/18/2016	3.2	9/1/2016	1.1
7/19/2016	3.4	9/2/2016	1.2
7/20/2016	3.0	9/3/2016	1.4
7/21/2016	2.9	9/4/2016	1.3
7/22/2016	2.8	9/5/2016	1.2
7/23/2016	2.8	9/6/2016	1.1
7/24/2016	2.6	9/7/2016	1.1
7/25/2016	2.5	9/8/2016	1.1
7/26/2016	2.4	9/9/2016	1.1
7/27/2016	2.4	9/10/2016	1.0
7/28/2016	2.3	9/11/2016	1.0
7/29/2016	2.2	9/12/2016	1.0
7/30/2016	2.1	9/13/2016	1.0
7/31/2016	2.0	9/14/2016	1.0
8/1/2016	1.9	9/15/2016	0.9
8/2/2016	1.9	9/16/2016	0.9
8/3/2016	1.9	9/17/2016	1.0
8/4/2016	1.8	9/18/2016	2.1
8/5/2016	1.8	9/19/2016	1.6
8/6/2016	1.7	9/20/2016	1.6

9/21/2016	1.4
9/22/2016	1.3
9/23/2016	1.2
9/24/2016	1.3
9/25/2016	1.2
9/26/2016	1.2
9/27/2016	1.1
9/28/2016	1.1
9/29/2016	1.1
9/30/2016	1.0
10/1/2016	1.0
10/2/2016	1.0
10/3/2016	1.0
10/4/2016	1.0
10/5/2016	1.1
10/6/2016	1.1
10/7/2016	1.4
10/8/2016	1.9
10/9/2016	5.2
10/10/2016	2.9
10/11/2016	2.3
10/12/2016	2.0
10/13/2016	2.1
10/14/2016	7.0
10/15/2016	8.5
10/16/2016	8.1
10/17/2016	6.5
10/18/2016	
10/19/2016	7.3
10/20/2016	27.8
10/21/2016	22.2
10/22/2016	14.2
10/23/2016	10.3
10/24/2016	8.5
10/25/2016	7.9
10/26/2016	9.1
10/27/2016	13.8
10/28/2016	10.2
10/29/2016	8.8
10/30/2016	8.1
10/31/2016	10.4
11/1/2016	12.0
11/2/2016	11.0
11/3/2016	9.9
11/4/2016	8.7
11/5/2016	8.2
11/6/2016	9.9
11/7/2016	8.5
11/8/2016	7.7
11/9/2016	7.3
11/10/2016	7.1
11/11/2016	6.7
11/12/2016	7.1
11/13/2016	7.7
11/14/2016	17.0
11/15/2016	16.0
11/16/2016	14.9
11/17/2016	11.9
11/18/2016	10.5
11/19/2016	9.6
11/20/2016	8.8
11/21/2016	8.3
11/22/2016	7.9
11/23/2016	7.4
11/24/2016	7.2
11/25/2016	7.1
11/26/2016	6.8
11/27/2016	6.5
11/28/2016	6.5
11/29/2016	6.0
11/30/2016	5.9
12/1/2016	5.8
12/2/2016	5.5
12/3/2016	5.9
12/4/2016	
12/5/2016	5.6
12/6/2016	5.2
12/7/2016	4.9
12/8/2016	4.7
12/9/2016	4.7
12/10/2016	4.9
12/11/2016	5.0
12/12/2016	6.0
12/13/2016	4.6
12/14/2016	5.7
12/15/2016	8.2
12/16/2016	10.4

12/17/2016	12.0
12/18/2016	17.8
12/19/2016	19.4
12/20/2016	20.9
12/21/2016	20.5
12/22/2016	18.0
12/23/2016	15.7
12/24/2016	14.8
12/25/2016	16.6
12/26/2016	13.7
12/27/2016	14.8
12/28/2016	15.7
12/29/2016	15.6
12/30/2016	17.0
12/31/2016	18.5

APPENDIX B. Daily Trap Operation

Date	Trap Status	Comments
3/1/2016	Op.	
3/2/2016	Op.	
3/3/2016	Op.	
3/4/2016	Op.	
3/5/2016	Op.	
3/6/2016	Op.	
3/7/2016	Op.	
3/8/2016	Op.	
3/9/2016	Op.	
3/10/2016	Op.	
3/11/2016	Op.	
3/12/2016	Op.	
3/13/2016	Op.	
3/14/2016	Op.	
3/15/2016	Op.	
3/16/2016	Op.	
3/17/2016	Op.	
3/18/2016	Op.	
3/19/2016	Op.	
3/20/2016	Op.	
3/21/2016	Op.	
3/22/2016	Op.	
3/23/2016	Op.	
3/24/2016	Op.	
3/25/2016	Op.	
3/26/2016	Op.	
3/27/2016	Op.	
3/28/2016	Op.	
3/29/2016	Op.	
3/30/2016	Op.	
3/31/2016	Op.	
4/1/2016	Op.	
4/2/2016	Op.	
4/3/2016	Op.	
4/4/2016	Op.	
4/5/2016	Op.	
4/6/2016	Op.	
4/7/2016	Op.	
4/8/2016	Op.	
4/9/2016	Op.	
4/10/2016	Op.	
4/11/2016	Op.	
4/12/2016	Op.	
4/13/2016	Op.	
4/14/2016	Op.	
4/15/2016	Op.	
4/16/2016	Op.	
4/17/2016	Op.	
4/18/2016	Op.	
4/19/2016	Op.	
4/20/2016	Op.	
4/21/2016	Op.	
4/22/2016	Op.	
4/23/2016	Op.	
4/24/2016	Op.	
4/25/2016	Op.	
4/26/2016	Op.	
4/27/2016	Op.	
4/28/2016	Op.	
4/29/2016	Op.	
4/30/2016	Op.	
5/1/2016	Op.	
5/2/2016	Op.	
5/3/2016	Op.	
5/4/2016	Op.	
5/5/2016	Op.	
5/6/2016	Op.	
5/7/2016	Op.	
5/8/2016	Op.	
5/9/2016	Op.	
5/10/2016	Op.	
5/11/2016	Op.	
5/12/2016	Op.	
5/13/2016	Op.	
5/14/2016	Op.	
5/15/2016	Op.	
5/16/2016	Op.	
5/17/2016	Op.	
5/18/2016	Op.	

5/19/2016	Op.		7/1/2016	Op.	
5/20/2016	Op.		7/2/2016	Op.	
5/21/2016	Op.		7/3/2016	Op.	
5/22/2016	Op.		7/4/2016	Op.	
5/23/2016	Op.		7/5/2016	Op.	
5/24/2016	Op.		7/6/2016	Op.	
5/25/2016	Op.		7/7/2016	Op.	
5/26/2016	Op.		7/8/2016	Op.	
5/27/2016	Op.		7/9/2016	Op.	
5/28/2016	Op.		7/10/2016	Op.	
5/29/2016	Op.		7/11/2016	No Op.	Stopped - low flow
5/30/2016	Op.		7/12/2016	Op.	
5/31/2016	Op.		7/13/2016	Op.	
6/1/2016	Op.		7/14/2016	Op.	
6/2/2016	Op.		7/15/2016	Op.	
6/3/2016	Op.		7/16/2016	Op.	
6/4/2016	Op.		7/17/2016	Op.	
6/5/2016	No Op.	Stopped by debris	7/18/2016	Op.	
6/6/2016	Op.		7/19/2016	Op.	
6/7/2016	Op.		7/20/2016	Op.	
6/8/2016	Op.		7/21/2016	Op.	
6/9/2016	Op.		7/22/2016	Op.	
6/10/2016	Op.		7/23/2016	Op.	
6/11/2016	Op.		7/24/2016	Op.	
6/12/2016	Op.		7/25/2016	Op.	
6/13/2016	Op.		7/26/2016	No Op.	Stopped - low flow
6/14/2016	Op.		7/27/2016	Op.	
6/15/2016	Op.		7/28/2016	No Op.	Stopped - low flow
6/16/2016	Op.		7/29/2016	Op.	
6/17/2016	Op.		7/30/2016	Op.	
6/18/2016	Op.		7/31/2016	No Op.	Stopped - low flow
6/19/2016	Op.		8/1/2016	No Op.	Stopped - low flow
6/20/2016	Op.		8/2/2016	Op.	
6/21/2016	Op.		8/3/2016	No Op.	Stopped - low flow
6/22/2016	Op.		8/4/2016	No Op.	Stopped - low flow
6/23/2016	Op.		8/5/2016	No Op.	Stopped - low flow
6/24/2016	Op.		8/6/2016	No Op.	Stopped - low flow
6/25/2016	Op.		8/7/2016	No Op.	Stopped - low flow
6/26/2016	Op.		8/8/2016	No Op.	Pulled - low flow
6/27/2016	Op.		8/9/2016	Op.	
6/28/2016	Op.		8/10/2016	No Op.	Pulled - low flow
6/29/2016	Op.		8/11/2016	No Op.	Pulled - low flow
6/30/2016	No Op.	Stopped - debris	8/12/2016	No Op.	Pulled - low flow

8/13/2016	No Op.	Pulled - low flow
8/14/2016	No Op.	Pulled - low flow
8/15/2016	No Op.	Pulled - low flow
8/16/2016	No Op.	Pulled - low flow
8/17/2016	No Op.	Pulled - low flow
8/18/2016	No Op.	Pulled - low flow
8/19/2016	No Op.	Pulled - low flow
8/20/2016	No Op.	Pulled - low flow
8/21/2016	No Op.	Pulled - low flow
8/22/2016	No Op.	Pulled - low flow
8/23/2016	No Op.	Pulled - low flow
8/24/2016	No Op.	Pulled - low flow
8/25/2016	No Op.	Pulled - low flow
8/26/2016	No Op.	Pulled - low flow
8/27/2016	No Op.	Pulled - low flow
8/28/2016	No Op.	Pulled - low flow
8/29/2016	No Op.	Pulled - low flow
8/30/2016	No Op.	Pulled - low flow
8/31/2016	No Op.	Pulled - low flow
9/1/2016	No Op.	Pulled - low flow
9/2/2016	No Op.	Pulled - low flow
9/3/2016	No Op.	Pulled - low flow
9/4/2016	No Op.	Pulled - low flow
9/5/2016	No Op.	Pulled - low flow
9/6/2016	No Op.	Pulled - low flow
9/7/2016	No Op.	Pulled - low flow
9/8/2016	No Op.	Pulled - low flow
9/9/2016	No Op.	Pulled - low flow
9/10/2016	No Op.	Pulled - low flow
9/11/2016	No Op.	Pulled - low flow
9/12/2016	No Op.	Pulled - low flow
9/13/2016	No Op.	Stopped - low flow
9/14/2016	No Op.	Pulled - low flow
9/15/2016	No Op.	Pulled - low flow
9/16/2016	No Op.	Pulled - low flow
9/17/2016	No Op.	Pulled - low flow
9/18/2016	No Op.	Pulled - low flow
9/19/2016	No Op.	Pulled - low flow
9/20/2016	No Op.	Pulled - low flow
9/21/2016	No Op.	Pulled - low flow
9/22/2016	No Op.	Pulled - low flow
9/23/2016	No Op.	Pulled - low flow
9/24/2016	No Op.	Pulled - low flow

9/25/2016	No Op.	Pulled - low flow
9/26/2016	No Op.	Pulled - low flow
9/27/2016	No Op.	Pulled - low flow
9/28/2016	No Op.	Pulled - low flow
9/29/2016	No Op.	Pulled - low flow
9/30/2016	No Op.	Pulled - low flow
10/1/2016	No Op.	Pulled - low flow
10/2/2016	No Op.	Pulled - low flow
10/3/2016	No Op.	Pulled - low flow
10/4/2016	No Op.	Pulled - low flow
10/5/2016	No Op.	Pulled - low flow
10/6/2016	No Op.	Pulled - low flow
10/7/2016	No Op.	Pulled - low flow
10/8/2016	No Op.	Pulled - low flow
10/9/2016	No Op.	Pulled - low flow
10/10/2016	Op.	
10/11/2016	Op.	
10/12/2016	Op.	
10/13/2016	No Op.	Stopped - low flow
10/14/2016	Op.	
10/15/2016	No Op.	Stopped - debris
10/16/2016	Op.	
10/17/2016	Op.	
10/18/2016	Op.	
10/19/2016	Op.	
10/20/2016	Op.	
10/21/2016	No Op.	Pulled - high flow
10/22/2016	No Op.	Stopped - debris
10/23/2016	Op.	
10/24/2016	Op.	
10/25/2016	Op.	
10/26/2016	Op.	
10/27/2016	Op.	

10/28/2016	Op.	
10/29/2016	Op.	
10/30/2016	Op.	
10/31/2016	Op.	
11/1/2016	Op.	
11/2/2016	Op.	
11/3/2016	Op.	
11/4/2016	Op.	
11/5/2016	Op.	
11/6/2016	Op.	
11/7/2016	Op.	
11/8/2016	Op.	
11/9/2016	Op.	
11/10/2016	Op.	
11/11/2016	Op.	
11/12/2016	Op.	
11/13/2016	Op.	
11/14/2016	Op.	
11/15/2016	Op.	
11/16/2016	Op.	
11/17/2016	Op.	
11/18/2016	Op.	
11/19/2016	Op.	
11/20/2016	Op.	
11/21/2016	Op.	
11/22/2016	Op.	
11/23/2016	Op.	
11/24/2016	Op.	
11/25/2016	Op.	
11/26/2016	Op.	
11/27/2016	Op.	
11/28/2016	Op.	
11/29/2016	Op.	
11/30/2016	Op.	End Trapping

APPENDIX C. Regression Models

Model: Chinook Yearlings (Spring '06-'14) Back Position, ($r^2 = 0.15$; $p = 0.03$)

Origin/Species/Stage	Age	Date	Trap Position	Mark	Recap	Trap Efficiency (R+1) / M	ASIN Transform	Discharge (m^3/s)
Wild Chinook Smolt	1+	3/31/2007	Back	40	2	0.08	0.28	24.6
Wild Chinook Smolt	1+	4/6/2006	Back	42	9	0.24	0.51	7.5
Wild Chinook Smolt	1+	4/14/2010	Back	42	4	0.12	0.35	4.9
Wild Chinook Smolt	1+	3/31/2012	Back	43	5	0.14	0.38	7.1
Wild Chinook Smolt	1+	4/3/2007	Back	46	1	0.04	0.21	18.6
Wild Chinook Smolt	1+	4/19/2012	Back	48	7	0.17	0.42	12.3
Wild Chinook Smolt	1+	4/10/2007	Back	53	4	0.09	0.31	27.4
Wild Chinook Smolt	1+	4/21/2009	Back	53	0	0.02	0.14	20.7
Wild Chinook Smolt	1+	4/13/2012	Back	53	4	0.09	0.31	10.1
Wild Chinook Smolt	1+	4/16/2012	Back	53	7	0.15	0.40	12.5
Wild Chinook Smolt	1+	4/24/2008	Back	57	8	0.16	0.41	5.9
Wild Chinook Smolt	1+	4/23/2012	Back	58	1	0.03	0.19	39.1
Wild Chinook Smolt	1+	4/24/2006	Back	59	3	0.07	0.26	10.4
Wild Chinook Smolt	1+	3/23/2007	Back	59	7	0.14	0.38	24.8
Wild Chinook Smolt	1+	3/17/2007	Back	64	7	0.13	0.36	26.5
Wild Chinook Smolt	1+	4/18/2010	Back	67	2	0.05	0.21	9.3
Wild Chinook Smolt	1+	4/17/2008	Back	72	13	0.19	0.46	7.8
Wild Chinook Smolt	1+	4/3/2006	Back	81	10	0.14	0.38	5.3
Wild Chinook Smolt	1+	3/20/2007	Back	91	13	0.15	0.40	34.8
Wild Chinook Smolt	1+	5/1/2008	Back	102	16	0.17	0.42	8.9
Wild Chinook Smolt	1+	4/28/2008	Back	127	19	0.16	0.41	7.7
Wild Chinook Smolt	1+	4/14/2008	Back	195	40	0.21	0.48	9.3
Wild Chinook Smolt	1+	3/9/2014	Back	65	4	0.08	0.28	27.1
Wild Chinook Smolt	1+	3/13/2014	Back	67	9	0.15	0.40	16.0

Model: Chinook Subyearling (Fall '06-'13) Back Position, ($r^2 = 0.55$; $p = 0.001$)

Origin/Species/Stage	Age	Date	Trap Position	Mark	Recap	Trap Efficiency (R+1) / M	ASIN Transform	Discharge (m^3/s)
Wild Chinook Parr	0	10/26/2006	Back	183	50	0.28	0.56	1.4
Wild Chinook Parr	0	10/30/2006	Back	168	52	0.32	0.60	1.8
Wild Chinook Parr	0	11/1/2010	Back	254	42	0.17	0.42	5.6
Wild Chinook Parr	0	11/4/2010	Back	287	49	0.17	0.43	6.1
Wild Chinook Parr	0	11/7/2010	Back	168	32	0.20	0.46	6.8
Wild Chinook Parr	0	11/13/2010	Back	185	35	0.19	0.46	3.7
Wild Chinook Parr	0	11/3/2012	Back	201	25	0.13	0.37	11.4

Wild Chinook Parr	0	11/7/2012	Back	233	27	0.12	0.35	11.2
Wild Chinook Parr	0	11/11/2012	Back	328	87	0.27	0.54	6.1
Wild Chinook Parr	0	11/15/2012	Back	195	34	0.18	0.44	6.0
Wild Chinook Parr	0	9/30/2013	Back	171	12	0.08	0.28	15.3
Wild Chinook Parr	0	10/2/2013	Back	213	43	0.21	0.47	9.3
Wild Chinook Parr	0	10/3/2013	Back	181	41	0.23	0.50	8.4
Wild Chinook Parr	0	10/7/2013	Back	242	31	0.13	0.37	6.6
Wild Chinook Parr	0	10/9/2013	Back	203	40	0.20	0.47	8.6
Wild Chinook Parr	0	11/27/2013	Back	241	55	0.23	0.50	5.2

Model: Chinook Subyearling (Fall ’06-’13) Forward Position, ($r^2 = 0.16$; $p = 0.02$)

Origin/Species/Stage	Age	Date	Trap Position	Mark	Recap	Trap Efficiency (R+1) / M	ASIN Transform	Discharge (m^3/s)
Wild Chinook Parr	0	7/13/2006	Back	52	8	0.17	0.43	4.8
Wild Chinook Parr	0	7/17/2006	Back	138	15	0.12	0.35	3.7
Wild Chinook Parr	0	7/20/2006	Back	74	5	0.08	0.29	3.2
Wild Chinook Parr	0	7/28/2006	Back	54	5	0.11	0.34	2.6
Wild Chinook Parr	0	7/31/2006	Back	99	7	0.08	0.29	2.2
Wild Chinook Parr	0	9/18/2006	Back	55	10	0.20	0.46	1.3
Wild Chinook Parr	0	7/31/2008	Back	60	15	0.27	0.54	3.4
Wild Chinook Parr	0	8/12/2008	Back	103	2	0.03	0.17	2.4
Wild Chinook Parr	0	8/22/2008	Back	75	11	0.16	0.41	2.7
Wild Chinook Parr	0	8/28/2008	Back	72	7	0.11	0.34	2.3
Wild Chinook Parr	0	10/9/2008	Back	110	22	0.21	0.48	1.8
Wild Chinook Parr	0	10/27/2008	Back	51	12	0.26	0.53	1.6
Wild Chinook Parr	0	10/30/2008	Back	84	15	0.19	0.45	1.5
Wild Chinook Parr	0	11/6/2008	Back	78	8	0.12	0.35	2.2
Wild Chinook Parr	0	11/10/2008	Back	88	0	0.01	0.11	8.7
Wild Chinook Parr	0	7/14/2009	Back	86	2	0.04	0.19	5.5
Wild Chinook Parr	0	7/15/2009	Back	105	4	0.05	0.22	5.1
Wild Chinook Parr	0	7/17/2009	Back	122	8	0.07	0.28	4.4
Wild Chinook Parr	0	7/20/2009	Back	89	2	0.03	0.19	3.8
Wild Chinook Parr	0	8/17/2009	Back	73	1	0.03	0.17	1.6
Wild Chinook Parr	0	9/10/2009	Back	56	7	0.14	0.39	1.7
Wild Chinook Parr	0	8/8/2010	Back	58	1	0.03	0.19	2.4
Wild Chinook Parr	0	8/11/2010	Back	114	8	0.08	0.29	2.2
Wild Chinook Parr	0	9/11/2010	Back	68	9	0.15	0.39	2.1
Wild Chinook Parr	0	10/12/2010	Back	216	42	0.20	0.46	3.6
Wild Chinook Parr	0	10/15/2010	Back	192	37	0.20	0.46	2.7
Wild Chinook Parr	0	10/18/2010	Back	193	36	0.19	0.45	2.3

Wild Chinook Parr	0	10/22/2010	Back	92	18	0.21	0.47	2.0
Wild Chinook Parr	0	10/25/2010	Back	60	7	0.13	0.37	2.2
Wild Chinook Parr	0	10/29/2010	Back	127	0	0.01	0.09	2.7
Wild Chinook Parr	0	8/19/2011	Back	106	5	0.06	0.24	3.5

Model: Chinook Subyearling (Fall '14-'16) Bolser Site (r^2 = 0.60; p = 0.005)

Origin/Species/Stage	Age	Date	Trap Position	Mark	Recap	Trap Efficiency (R+1)/M	ASIN Transform	Discharge (m^3/s)
Wild Chinook Parr	0	7/14/2014	1	89	7	0.09	0.30	6.8
Wild Chinook Parr	0	7/21/2014	1	74	4	0.07	0.26	4.3
Wild Chinook Parr	0	7/27/2014	1	72	4	0.07	0.27	3.3
Wild Chinook Parr	0	10/24/2014	1	53	4	0.09	0.31	5.0
Wild Chinook Parr	0	10/27/2014	1	71	3	0.06	0.24	5.4
Wild Chinook Parr	0	10/30/2014	1	70	5	0.09	0.30	8.4
Wild Chinook Parr	0	11/1/2014	1	96	6	0.07	0.27	9.6
Wild Chinook Parr	0	10/24/2016	1	59	6	0.12	0.35	8.0
Wild Chinook Parr	0	11/1/2016	1	68	8	0.13	0.37	10.6
Wild Chinook Parr	0	11/15/2016	1	69	11	0.17	0.43	15.3

Model: Summer Steelhead Back Position ('07-'14), (r^2 = 0.35; p = 2.90E-05)

Origin/Species/Stage	Age	Date	Trap Position	Mark	Recap	Trap Efficiency (R+1) / M	ASIN Transform	Discharge (m^3/s)
Wild Steelhead Parr/Smolt	1+	3/20/2007	Back	55	1	0.04	0.19	34.8
Wild Steelhead Parr/Smolt	1+	3/31/2007	Back	56	4	0.09	0.30	24.6
Wild Steelhead Parr/Smolt	1+	4/10/2007	Back	60	8	0.15	0.40	27.4
Wild Steelhead Parr/Smolt	1+	5/1/2007	Back	52	2	0.06	0.24	22.2
Wild Steelhead Parr/Smolt	1+	6/9/2007	Back	71	9	0.14	0.38	23.8
Wild Steelhead Parr/Smolt	1+	6/12/2007	Back	65	8	0.14	0.38	19.9
Wild Steelhead Parr/Smolt	1+	6/14/2007	Back	61	5	0.10	0.32	19.5
Wild Steelhead Parr/Smolt	1+	6/21/2007	Back	67	4	0.07	0.28	21.3
Wild Steelhead Parr/Smolt	1+	4/14/2008	Back	149	46	0.32	0.60	9.3
Wild Steelhead Parr/Smolt	1+	4/17/2008	Back	75	3	0.05	0.23	7.8
Wild Steelhead Parr/Smolt	1+	4/28/2008	Back	74	11	0.16	0.41	7.7
Wild Steelhead Parr/Smolt	1+	5/1/2008	Back	176	29	0.17	0.43	8.9
Wild Steelhead Parr/Smolt	1+	5/12/2008	Back	55	8	0.16	0.42	18.8
Wild Steelhead Parr/Smolt	1+	5/15/2008	Back	57	1	0.04	0.19	39.4
Wild Steelhead Parr/Smolt	1+	6/9/2008	Back	142	20	0.15	0.39	26.6
Wild Steelhead Parr/Smolt	1+	6/12/2008	Back	83	10	0.13	0.37	23.3

Wild Steelhead Parr/Smolt	1+	6/16/2008	Back	81	8	0.11	0.34	32.3
Wild Steelhead Parr/Smolt	1+	4/20/2010	Back	121	11	0.10	0.32	19.1
Wild Steelhead Parr/Smolt	1+	4/22/2010	Back	121	10	0.09	0.31	20.6
Wild Steelhead Parr/Smolt	1+	6/20/2010	Back	128	11	0.09	0.31	26.2
Wild Steelhead Parr/Smolt	1+	4/5/2011	Back	52	1	0.04	0.20	21.5
Wild Steelhead Parr/Smolt	1+	5/22/2011	Back	84	3	0.05	0.22	43.6
Wild Steelhead Parr/Smolt	1+	6/12/2012	Back	69	5	0.09	0.30	33.1
Wild Steelhead Parr/Smolt	1+	7/26/2012	Back	63	4	0.08	0.29	7.9
Wild Steelhead Parr/Smolt	1+	4/22/2013	Back	66	6	0.11	0.33	14.7
Wild Steelhead Parr/Smolt	1+	4/26/2013	Back	50	2	0.06	0.25	18.2
Wild Steelhead Parr/Smolt	1+	4/30/2013	Back	54	2	0.06	0.24	22.0
Wild Steelhead Parr/Smolt	1+	5/8/2013	Back	62	0	0.02	0.13	61.4
Wild Steelhead Parr/Smolt	1+	5/19/2013	Back	122	15	0.13	0.37	32.0
Wild Steelhead Parr/Smolt	1+	5/22/2013	Back	58	4	0.09	0.30	30.6
Wild Steelhead Parr/Smolt	1+	5/26/2013	Back	79	3	0.05	0.23	20.5
Wild Steelhead Parr/Smolt	1+	5/30/2013	Back	92	7	0.09	0.30	24.0
Wild Steelhead Parr/Smolt	1+	6/3/2013	Back	71	6	0.10	0.32	27.2
Wild Steelhead Parr/Smolt	1+	6/7/2013	Back	94	4	0.05	0.23	40.2
Wild Steelhead Parr/Smolt	1+	6/13/2013	Back	64	2	0.05	0.22	21.1
Wild Steelhead Parr/Smolt	1+	6/17/2013	Back	115	5	0.05	0.23	25.0
Wild Steelhead Parr/Smolt	1+	6/29/2013	Back	60	12	0.22	0.48	20.7
Wild Steelhead Parr/Smolt	1+	7/7/2013	Back	75	9	0.13	0.37	9.2
Wild Steelhead Parr/Smolt	1+	5/5/2014	Back	55	3	0.07	0.27	35.7
Wild Steelhead Parr/Smolt	1+	5/20/2014	Back	57	0	0.02	0.13	42.2
Wild Steelhead Parr/Smolt	1+	6/3/2014	Back	75	1	0.03	0.16	45.6

Model: 2013 Summer Steelhead Back Position (In-yr.), ($r^2 = 0.15$; $p = 0.05$)

Origin/Species/Stage	Age	Date	Trap Position	Mark	Recap	Trap Efficiency (R+1) / M	ASIN Transform	Discharge (m^3/s)
Wild Chinook Smolt	1+	3/31/2007	Back	40	2	0.08	0.28	24.6
Wild Chinook Smolt	1+	4/6/2006	Back	42	9	0.24	0.51	7.5
Wild Chinook Smolt	1+	4/14/2010	Back	42	4	0.12	0.35	4.9
Wild Chinook Smolt	1+	3/31/2012	Back	43	5	0.14	0.38	7.1
Wild Chinook Smolt	1+	4/3/2007	Back	46	1	0.04	0.21	18.6
Wild Chinook Smolt	1+	4/19/2012	Back	48	7	0.17	0.42	12.3
Wild Chinook Smolt	1+	4/10/2007	Back	53	4	0.09	0.31	27.4
Wild Chinook Smolt	1+	4/21/2009	Back	53	0	0.02	0.14	20.7
Wild Chinook Smolt	1+	4/13/2012	Back	53	4	0.09	0.31	10.1
Wild Chinook Smolt	1+	4/16/2012	Back	53	7	0.15	0.40	12.5
Wild Chinook Smolt	1+	4/24/2008	Back	57	8	0.16	0.41	5.9

Wild Chinook Smolt	1+	4/23/2012	Back	58	1	0.03	0.19	39.1
Wild Chinook Smolt	1+	4/24/2006	Back	59	3	0.07	0.26	10.4
Wild Chinook Smolt	1+	3/23/2007	Back	59	7	0.14	0.38	24.8
Wild Chinook Smolt	1+	3/17/2007	Back	64	7	0.13	0.36	26.5
Wild Chinook Smolt	1+	4/18/2010	Back	67	2	0.05	0.21	9.3
Wild Chinook Smolt	1+	4/17/2008	Back	72	13	0.19	0.46	7.8
Wild Chinook Smolt	1+	4/3/2006	Back	81	10	0.14	0.38	5.3
Wild Chinook Smolt	1+	3/20/2007	Back	91	13	0.15	0.40	34.8
Wild Chinook Smolt	1+	5/1/2008	Back	102	16	0.17	0.42	8.9
Wild Chinook Smolt	1+	4/28/2008	Back	127	19	0.16	0.41	7.7
Wild Chinook Smolt	1+	4/14/2008	Back	195	40	0.21	0.48	9.3
Wild Chinook Smolt	1+	3/9/2014	Back	65	4	0.08	0.28	27.1
Wild Chinook Smolt	1+	3/13/2014	Back	67	9	0.15	0.40	16.0

Model: Spring Chinook 2010-2014 Non-Trapping Period Array (NAL) – Full Antenna Function, ($r^2 = 0.61$; $p = 0.0002$)

Origin/Species/Stage	Age	Date	Mark	Detections	Trap Efficiency (R+1) / M	ASIN Transform	Discharge (m^3/s)
Wild Chinook Parr	0	11/4/2010	254	95	0.38	0.66	6.3
Wild Chinook Parr	0	11/7/2010	287	70	0.25	0.52	7.0
Wild Chinook Parr	0	11/10/2010	168	74	0.45	0.73	4.8
Wild Chinook Parr	0	11/13/2010	74	41	0.57	0.85	4.0
Wild Chinook Parr	0	11/18/2010	185	22	0.12	0.36	7.9
Wild Chinook Parr	0	11/3/2012	201	21	0.11	0.34	10.9
Wild Chinook Parr	0	11/7/2012	233	31	0.14	0.38	10.7
Wild Chinook Parr	0	11/11/2012	328	66	0.20	0.47	6.3
Wild Chinook Parr	0	11/15/2012	195	68	0.35	0.64	6.2
Wild Chinook Parr	0	11/4/2013	130	51	0.40	0.68	3.7
Wild Chinook Parr	0	11/8/2013	106	39	0.38	0.66	4.2
Wild Chinook Parr	0	3/9/2014	65	4	0.08	0.28	24.9
Wild Chinook Parr	0	3/13/2014	67	5	0.09	0.30	15.3
Wild Chinook Parr	0	11/4/2014	114	5	0.05	0.23	10.5
Wild Chinook Parr	0	11/1/2014	96	5	0.06	0.25	16.5
Wild Chinook Parr	0	11/10/2014	78	8	0.12	0.35	11.3

Model: Spring Chinook 2010-2014 Non-Trapping Period Array (NAL) – Partial Antenna Function, ($r^2 = 0.38$; $p = 0.007$)

Origin/Species/Stage	Age	Date	Mark	Detections			Discharge

					Trap Efficiency (R+1)/M	ASIN Transform	
Wild Chinook Parr	0	11/4/2010	254	39	0.16	0.41	6.3
Wild Chinook Parr	0	11/7/2010	287	16	0.06	0.25	7.0
Wild Chinook Parr	0	11/10/2010	168	34	0.21	0.47	4.8
Wild Chinook Parr	0	11/13/2010	74	17	0.24	0.52	4.0
Wild Chinook Parr	0	11/18/2010	185	8	0.05	0.22	7.9
Wild Chinook Parr	0	11/3/2012	201	7	0.04	0.20	10.9
Wild Chinook Parr	0	11/7/2012	233	8	0.04	0.20	10.7
Wild Chinook Parr	0	11/11/2012	328	24	0.08	0.28	6.3
Wild Chinook Parr	0	11/15/2012	195	30	0.16	0.41	6.2
Wild Chinook Parr	0	11/4/2013	130	40	0.32	0.60	3.7
Wild Chinook Parr	0	11/8/2013	106	30	0.29	0.57	4.2
Wild Chinook Parr	0	3/9/2014	65	1	0.03	0.18	24.9
Wild Chinook Parr	0	3/13/2014	67	5	0.09	0.30	15.3
Wild Chinook Parr	0	11/1/2014	96	1	0.02	0.15	10.5
Wild Chinook Parr	0	11/4/2014	114	4	0.04	0.21	16.5
Wild Chinook Parr	0	11/10/2014	78	3	0.05	0.23	11.3

APPENDIX D. Historical Morphometric Data

Spring Chinook (2004-2016)

Trap Year	Brood Year	Origin/Species/Stage	Fork Length (mm)			Weight (g)			K-factor
			Mean	n	SD	Mean	n	SD	
2004	2002	Wild Chinook Yearling Smolt	93.4	336	12.4	9	337	5	1.1
2004	2003	Wild Chinook Subyearling Fry	39.5	82	5.1	0.6	79	0.3	1
2004	2003	Wild Chinook Subyearling Parr	82.4	792	7.9	6.1	702	2.7	1.1
2005	2003	Wild Chinook Yearling Smolt	93.6	278	7.9	8.7	276	2.1	1.1
2005	2004	Wild Chinook Subyearling Fry	42.1	107	5.6	0.7	102	0.4	0.9
2005	2004	Wild Chinook Subyearling Parr	75.9	924	9.6	4.9	890	3.8	1.1
2006	2004	Wild Chinook Yearling Smolt	91.2	363	7.1	7.5	362	1.8	1
2006	2005	Wild Chinook Subyearling Fry	—	—	—	—	—	—	—
2006	2005	Wild Chinook Subyearling Parr	72.9	1,428	9.6	3.9	1,428	2.3	1
2007	2005	Wild Chinook Yearling Smolt	89	676	8.2	8	675	6.1	1.1
2007	2006	Wild Chinook Subyearling Fry	39	24	3.7	0.6	24	0.5	1
2007	2006	Wild Chinook Subyearling Parr	79.5	686	13.8	6.1	685	2.6	1.2
2008	2006	Wild Chinook Yearling Smolt	96.1	904	6.6	9.5	904	2.1	1.1
2008	2007	Wild Chinook Subyearling Fry	42.8	127	4.6	0.8	127	0.4	1
2008	2007	Wild Chinook Subyearling Parr	75.8	2,049	12.5	5.2	2,049	2.4	1.2
2009	2007	Wild Chinook Yearling Smolt	94.4	198	8.9	9.2	198	2.5	1.1
2009	2008	Wild Chinook Subyearling Fry	44.8	82	4.8	0.9	82	0.6	1
2009	2008	Wild Chinook Subyearling Parr	70.1	2,333	12	4.2	2,333	2	1.2
2010	2008	Wild Chinook Yearling Smolt	96.9	366	7.3	10.2	366	2.3	1.1
2010	2009	Wild Chinook Subyearling Fry	41.8	30	5	1.3	8	0.2	1.8
2010	2009	Wild Chinook Subyearling Parr	80.7	3,021	10.7	6.2	3,021	2.3	1.2
2011	2009	Wild Chinook Yearling Smolt	89.1	152	9.9	7.7	152	1.8	1.1
2011	2010	Wild Chinook Subyearling Fry	39.8	217	6.6	0.6	217	0.5	1
2011	2010	Wild Chinook Subyearling Parr	73.4	1,046	13.1	4.9	1,046	2.5	1.2
2012	2010	Wild Chinook Yearling Smolt	93.3	368	7	9.2	368	2.2	1.1
2012	2011	Wild Chinook Subyearling Fry	42.7	48	9.1	0.9	48	0.6	1.2
2012	2011	Wild Chinook Subyearling Parr	77.9	2,160	10.7	5.3	2,160	1.9	1.1
2013	2011	Wild Chinook Yearling Smolt	90.6	239	75	7.9	239	2.1	1.1
2013	2012	Wild Chinook Subyearling Fry	45.6	1,824	6.8	1	1,803	0.6	1.1
2013	2012	Wild Chinook Subyearling Parr	70	4,422	11.4	3.8	4,409	1.7	1.1
2014	2012	Wild Chinook Yearling Smolt	89.5	464	6.9	7.5	464	1.8	1
2014	2013	Wild Chinook Subyearling Fry	40.1	677	5.2	0.9	221	0.5	1.4
2014	2013	Wild Chinook Subyearling Parr	69.1	1,549	12.3	3.8	1,547	2.3	1.2
2015	2013	Wild Chinook Yearling Smolt	93	152	7	8.4	152	2.2	1
2015	2014	Wild Chinook Subyearling Fry	45	338	9.9	1	338	0.9	0.9

2015	2014	Wild Chinook Subyearling Parr	84	210	8	6.5	209	1.7	1.1
2015	2013	Hatchery Chinook Yearling Smolt	136	284	12.3	29.5	284	8.8	1.1
2016	2014	Wild Chinook Yearling Smolt	96	61	5.5	9.0	61	1.7	1.01
2016	2015	Wild Chinook Subyearling Fry	38	285	3.0	0.5	285	0.2	0.78
2016	2015	Wild Chinook Subyearling Parr	85	491	12.7	6.9	490	2.5	1.07
2016	2014	Hatchery Chinook Yearling Smolt	119	87	13.5	19.6	87	7.6	1.09

Summer Steelhead (2004-2016)

Trap Year	Brood Year	Age	Origin/Species	Fork Length (mm)			Weight (g)			K-factor
				Mean	n	SD	Mean	n	SD	
2004	2004	0	Wild Summer Steelhead	67	358	10	3.5	279	1.5	1.2
2004	2003	1	Wild Summer Steelhead	101.7	394	23.2	13.2	366	27.3	1.3
2004	2002	2	Wild Summer Steelhead	161.6	146	19.8	43.4	141	15.5	1
2004	2001	3	Wild Summer Steelhead	201.6	43	11.2	76	43	21.2	0.9
2004	2003	1	Hat. Summer Steelhead	182.8	523	22.4	62.1	497	21.2	1
2005	2005	0	Wild Summer Steelhead	54.1	649	15.7	2.2	616	3.2	1.4
2005	2004	1	Wild Summer Steelhead	93.6	585	25.6	10.8	575	10.1	1.3
2005	2003	2	Wild Summer Steelhead	153.5	103	21.2	38.1	102	16.4	1.1
2005	2002	3	Wild Summer Steelhead	144	1	—	43.2	1	—	1.4
2005	2004	1	Hat. Summer Steelhead	188.2	343	21.2	66	343	24	1
2006	2006	0	Wild Summer Steelhead	66.3	180	5.8	2.5	180	1	0.9
2006	2005	1	Wild Summer Steelhead	85.2	877	18.7	6.7	877	6.6	1.1
2006	2004	2	Wild Summer Steelhead	155.9	106	26.8	36.1	105	13.5	1
2006	2003	3	Wild Summer Steelhead	197	2	—	73.5	2	—	1
2006	2005	1	Hat. Summer Steelhead	—	—	—	—	—	—	—
2007	2007	0	Wild Summer Steelhead	54.2	329	11.7	2	328	1.4	1.3
2007	2006	1	Wild Summer Steelhead	82.7	1,330	16.8	7.2	1,329	6.3	1.3
2007	2005	2	Wild Summer Steelhead	143.8	102	20.6	31.4	102	11.9	1.1
2007	2004	3	Wild Summer Steelhead	143	1	—	26.8	1	—	0.9
2007	2006	1	Hat. Summer Steelhead	149.3	3	47	33.1	3	29.1	1
2008	2008	0	Wild Summer Steelhead	52.9	930	11.1	1.7	930	1.2	1.1
2008	2007	1	Wild Summer Steelhead	84.5	1,876	17.1	7.4	1,874	6.6	1.2
2008	2006	2	Wild Summer Steelhead	149.9	122	22.9	36	122	15.5	1.1
2008	2005	3	Wild Summer Steelhead	180.3	13	18.9	57.4	13	16.4	1
2008	2007	1	Hat. Summer Steelhead	179.4	389	16.5	55.9	388	14.8	1
2009	2009	0	Wild Summer Steelhead	55.6	843	10.5	2.2	688	1.1	1.3
2009	2008	1	Wild Summer Steelhead	82.6	452	18.6	7.1	447	5.5	1.3
2009	2007	2	Wild Summer Steelhead	156.9	72	22	40.9	72	15.5	1.1

2009	2006	3	Wild Summer Steelhead	195	3	5	73	3	6.7	1
2009	2008	1	Hat. Summer Steelhead	183.1	280	16.7	60.8	280	18.2	1
2010	2010	0	Wild Summer Steelhead	55	1,287	11.1	2.5	917	1.3	1.5
2010	2009	1	Wild Summer Steelhead	89.8	1,079	19.1	9	1,072	7.1	1.2
2010	2008	2	Wild Summer Steelhead	144.9	87	25.1	35	87	17.4	1.2
2010	2007	3	Wild Summer Steelhead	184	8	12.2	61.9	8	10.2	1
2010	2009	1	Hat. Summer Steelhead	183.5	531	19.5	61.3	526	19.6	1
2011	2011	0	Wild Summer Steelhead	43.5	1,093	10.1	1.1	783	0.9	1.3
2011	2010	1	Wild Summer Steelhead	75.7	818	18.5	5.5	811	5.7	1.3
2011	2009	2	Wild Summer Steelhead	144.8	27	41.3	42.1	27	62.1	1.4
2011	2008	3	Wild Summer Steelhead	—	—	—	—	—	—	—
2011	2010	1	Hat. Summer Steelhead	180.7	464	17	59.1	464	17.6	1
2012	2012	0	Wild Summer Steelhead	55.1	589	14.2	2.6	402	1.2	1.6
2012	2011	1	Wild Summer Steelhead	84.7	747	17.4	7.6	741	5.7	1.3
2012	2010	2	Wild Summer Steelhead	127.1	132	27	23.7	132	14.5	1.2
2012	2009	3	Wild Summer Steelhead	161	4	32	40.5	4	15.6	1
2012	2011	1	Hat. Summer Steelhead	154.8	318	20.9	37.7	318	14	1
2013	2013	0	Wild Summer Steelhead	56.1	878	11.3	2.1	777	1.1	1.2
2013	2012	1	Wild Summer Steelhead	44.5	1,777	14.7	5.4	1,772	4.2	1.2
2013	2011	2	Wild Summer Steelhead	144.7	21	15.7	36.1	21	10.2	1
2013	2010	3	Wild Summer Steelhead	—	—	—	—	—	—	—
2013	2012	1	Hat. Summer Steelhead	166.2	365	21.4	49.2	363	18.2	1.1
2014	2014	0	Wild Summer Steelhead	49.6	490	12.8	1.7	389	1.1	1.4
2014	2013	1	Wild Summer Steelhead	82.2	745	13.6	6.3	745	3.5	1.1
2014	2012	2	Wild Summer Steelhead	145.1	30	16.5	33	30	13.4	1.1
2014	2011	3	Wild Summer Steelhead	—	—	—	—	—	—	—
2014	2013	1	Hat. Summer Steelhead	173.4	632	18.7	52.6	633	15.9	1
2015	2015	0	Wild Summer Steelhead	70	182	15.5	4.3	176	2	1.1
2015	2014	1	Wild Summer Steelhead	88	233	20.2	8.3	233	6.7	1
2015	2013	2	Wild Summer Steelhead	149	14	13.5	33.7	14	8.2	1
2015	2012	3	Wild Summer Steelhead	191	1	—	73.8	1	—	1.1
2015	2014	1	Hat. Summer Steelhead	175	273	15.2	51.3	273	12.5	0.9
2016	2016	0	Wild Summer Steelhead	56	674	16.4	2.4	617	1.8	1.0
2016	2015	1	Wild Summer Steelhead	87	278	21.5	8.3	278	5.9	1.1
2016	2014	2	Wild Summer Steelhead	143	19	17.4	31.1	19	9.6	1.0
2016	2013	3	Wild Summer Steelhead	202	1	—	90.1	1	—	1.1
2016	2015	1	Hat. Summer Steelhead	175	95	15.5	55.1	95	16.2	1.0

Coho (2007-2016)

Trap Year	Brood Year	Origin/Species/Stage	Fork Length (mm)			Weight (g)			K-factor
			Mean	n	SD	Mean	n	SD	
2004	2002	Nat. Or. Coho Yearling Smolt	—	—	—	—	—	—	—
2004	2003	Nat. Or. Coho Subyearling Fry	—	—	—	—	—	—	—
2004	2003	Nat. Or. Coho Subyearling Parr	—	—	—	—	—	—	—
2004	2002	Hatchery Coho Yearling Smolt	136.6	847	12.8	27.4	820	7.5	1.1
2005	2003	Nat. Or. Coho Yearling Smolt	114.4	17	8.8	16.2	17	3.6	1.1
2005	2004	Nat. Or. Coho Subyearling Fry	49.1	9	10.4	1.3	9	0.8	1.1
2005	2004	Nat. Or. Coho Subyearling Parr	76.7	9	12.8	4.9	9	2.7	1.1
2005	2003	Hatchery Coho Yearling Smolt	137.3	689	11.3	28.6	690	7.2	1.1
2006	2004	Nat. Or. Coho Yearling Smolt	—	—	—	—	—	—	—
2006	2005	Nat. Or. Coho Subyearling Fry	—	—	—	—	—	—	—
2006	2005	Nat. Or. Coho Subyearling Parr	71	4	13.6	3.8	4	2.9	1.1
2006	2004	Hatchery Coho Yearling Smolt	—	—	—	—	—	—	—
2007	2005	Nat. Or. Coho Yearling Smolt	92.9	36	12.5	8.7	36	4	1.1
2007	2006	Nat. Or. Coho Subyearling Fry	—	—	—	—	—	—	—
2007	2006	Nat. Or. Coho Subyearling Parr	83	1	—	6.2	1	—	1.1
2007	2005	Hatchery Coho Yearling Smolt	116	2	—	16.8	2	—	1.1
2008	2006	Nat. Or. Coho Yearling Smolt	—	—	—	—	—	—	—
2008	2007	Nat. Or. Coho Subyearling Fry	—	—	—	—	—	—	—
2008	2007	Nat. Or. Coho Subyearling Parr	87	1	—	6.4	1	—	1
2008	2006	Hatchery Coho Yearling Smolt	130.2	843	10.4	23.6	843	6.2	1.1
2009	2007	Nat. Or. Coho Yearling Smolt	103	4	9.7	11.7	4	3.4	1.1
2009	2008	Nat. Or. Coho Subyearling Fry	—	—	—	—	—	—	—
2009	2008	Nat. Or. Coho Subyearling Parr	79.6	5	20.1	6.6	5	4.8	1.3
2009	2007	Hatchery Coho Yearling Smolt	135.3	625	8.9	26.2	579	5.2	1.1
2010	2008	Nat. Or. Coho Yearling Smolt	—	—	—	—	—	—	—
2010	2009	Nat. Or. Coho Subyearling Fry	48	2	—	1.3	2	—	1.2
2010	2009	Nat. Or. Coho Subyearling Parr	83.6	27	8.6	6.7	27	2.4	1.1
2010	2008	Hatchery Coho Yearling Smolt	130	1,051	10.1	23.8	1,049	5.3	1.1
2011	2009	Nat. Or. Coho Yearling Smolt	100.2	14	12.7	11.3	14	3.9	1.1
2011	2010	Nat. Or. Coho Subyearling Fry	—	—	—	—	—	—	—
2011	2010	Nat. Or. Coho Subyearling Parr	64.7	3	10.8	3	3	1.5	1.1
2011	2009	Hatchery Coho Yearling Smolt	124.6	969	8.6	21	969	4.8	1.1
2012	2010	Nat. Or. Coho Yearling Smolt	102.1	17	9.1	11.9	17	3	1.1
2012	2011	Nat. Or. Coho Subyearling Fry	36	1	—	—	—	—	—
2012	2011	Nat. Or. Coho Subyearling Parr	78.4	84	9.3	5	84	2.1	1
2012	2010	Hatchery Coho Yearling Smolt	126.2	1,684	7.6	21.5	1,684	5.5	1.1
2013	2011	Nat. Or. Coho Yearling Smolt	97	81	10	10	81	3.1	1.1
2013	2012	Nat. Or. Coho Subyearling Fry	47.3	3	1	1	3	1	0.9
2013	2012	Nat. Or. Coho Subyearling Parr	87.8	4	3.8	6.6	4	1	1

2013	2011	Hatchery Coho Yearling Smolt	130.1	982	8.5	23.3	977	4.9	1.1
2014	2012	Nat. Or. Coho Yearling Smolt	96.3	20	9.8	9.9	20	3	1.1
2014	2013	Nat. Or. Coho Subyearling Fry	36	1	—	—	—	—	—
2014	2013	Nat. Or. Coho Subyearling Parr	73	3	22.5	5.9	3	4.7	1.5
2014	2012	Hatchery Coho Yearling Smolt	127	1,203	9.7	21.7	1,207	5.0	1.1
2015	2013	Nat. Or. Coho Yearling Smolt	109	2	4.9	12.0	2	0.1	0.9
2015	2014	Nat. Or. Coho Subyearling Fry	47	7	13.7	1.4	7	1.5	0.9
2015	2014	Nat. Or. Coho Subyearling Parr	69	3	7	4.0	3	1.3	1.2
2015	2013	Hatchery Coho Yearling Smolt	131	952	9.9	23.3	952	4.8	1.0
2016	2014	Nat. Or. Coho Yearling Smolt	100	6	15.8	11.1	6	5.5	1.0
2016	2015	Nat. Or. Coho Subyearling Fry	—	—	—	—	—	—	—
2016	2015	Nat. Or. Coho Subyearling Parr	—	—	—	—	—	—	—
2016	2014	Hatchery Coho Yearling Smolt	134	302	8.4	24.8	301	5.0	1.0

Appendix M

Fish Trapping at the White River Smolt Trap during 2016

Population Estimates for Juvenile Spring Chinook Salmon in White River, WA

2016 Annual Report

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ABSTRACT

In 2007, Yakama Nation Fisheries Resource Management began monitoring emigration of Endangered Species Act (ESA) listed Upper Columbia River (UCR) spring Chinook salmon in the White River to provide abundance and freshwater survival estimates. This report summarizes data collected between March 1 and November 30, 2016. We used a 1.5 m rotary screw trap to collect 200 juvenile spring Chinook; 50 fry, 147 subyearling parr, and 3 yearling smolts. Daily counts at the trap were expanded via regression analysis derived from mark and recapture trials. We estimated that 386 (± 701; 95% CI) BY2014 wild spring Chinook smolts and 2,430 (± 723; 95% CI) BY2015 wild spring Chinook parr emigrated past the White River trap in 2016. Combined with data collected in 2015, this gives us a total estimate of 2,336 (± 807; 95% CI) BY2014 emigrants. Using spring Chinook spawning ground data collected by Washington Department of Fish and Wildlife (WDFW) in 2014, we estimated egg-to-emigrant survival of BY2014 spring Chinook to be 2.2% (90 smolts-per-redd).

CONTENTS

LIST OF FIGURES iv
LIST OF TABLES v
ACKNOWLEDGEMENTS vi
1.0 INTRODUCTION 1
1.1 Watershed Description 1
2.0 METHODS 5
2.1 Trapping Equipment and Operation 5
2.2 Biological Sampling 5
2.3 Mark-Recapture Trials 6
2.3.1 Marking and PIT tagging 7
2.4 Data Analysis 7
2.4.1 Estimate of Abundance 7
3.0 RESULTS 12
3.1 Dates of Operation 12
3.2 Daily Captures and Biological Sampling 12
3.2.1 Wild Spring Chinook Yearlings (BY2014) 12
3.2.2 Wild Spring Chinook Subyearlings (BY2015) 13
3.3 Trap Efficiency Calibration and Population Estimates 14
3.3.1 Wild Spring Chinook Yearlings (BY 2014) 14
3.3.2 Wild Spring Chinook Subyearling (BY 2015) 14
3.4 PIT Tagging 16
3.5 Incidental Species 17
3.6 ESA Compliance 17
4.0 DISCUSSION 19
5.0 LITERATURE CITED 22
APPENDIX A: White River Temperature and Discharge Data 24
APPENDIX B: Daily Trap Operation Status 28
APPENDIX C: Regression Models i
Appendix D. Historical Morphometric Data ii

LIST OF FIGURES

Figure 1. Map of the Wenatchee River subbasin with White River rotary trap location. .. 2

Figure 2. Mean daily stream discharge at the White River DOE stream monitoring station at Sears Creek Bridge, 2016... 3

Figure 3. Mean daily water temperatures at the White River DOE stream monitoring station at Sears Creek Bridge, 2016... 3

Figure 4. Daily catch of yearling spring Chinook smolt with mean daily stream discharge at the White River rotary trap, March 1 to June 30, 2016. 12

Figure 5. Daily catch of wild subyearling spring Chinook with mean daily stream discharge at the White River rotary trap, July 1 to November 30, 2016. 13

Figure 6. Relationships between estimated egg deposition and total emigrants produced, egg-to-emigrant survival, and emigrants per redd for White River spring Chinook, BY 2007 to 2014. *BY2014 values denoted by red border..................................... 16

Figure 7. White River daily mean and 13-year mean discharge during strong El Niño, 2014-2016. 20

Figure 8. Comparison of wild spring Chinook abundance estimates (BY2007-2014) made at the White R., Nason Cr., and Chiwawa R. smolt traps. Chiwawa R. data provided by Hillman et al. (2015)... 21

LIST OF TABLES

Table 1. Summary of White River smolt trap operation, 2016. 12

Table 2. Summary of length and weight sampling of juvenile spring Chinook captured at the White River rotary trap, 2016. 13

Table 3. Estimated egg-to-emigrant survival and emigrants per redd for White River spring Chinook 15

Table 4. Number of PIT tagged spring Chinook and steelhead with shed rates at the White River rotary trap, 2016. 17

Table 5. Summary of length and weight sampling of incidental species captured at the White River rotary trap, 2016. 17

Table 6. Summary of White River ESA listed species catch and mortality, 2016. 18

ACKNOWLEDGEMENTS

This project is part of a basin-wide monitoring program requiring close coordination between multiple agencies and contractors. We greatly appreciate the hard work of the Yakama Nation FRM crew members including Matthew Clubb, Jamie Hallman, Tim Jeffris and Kevin Swager who maintained and operated the trap during all hours including nights/weekends and inclement weather conditions. Also thank you to Peter Graf (Grant County PUD) for administering contracting and funding as well as Mike Hughes, Mclain Johnson, Andrew Murdoch, and Josh Williams (WDFW) for data sharing and collaboration on smolt trap methodologies.

1.0 INTRODUCTION

White River spring Chinook salmon (tkwínat) *Oncorhynchus tshawytscha* are part of the Upper Columbia River (UCR) spring Chinook salmon Evolutionarily Significant Unit (ESU), which was listed as endangered under the Endangered Species Act (ESA) in 1999. Due to critically low abundance, a captive broodstock program was operated in the White River between 1997 and 2015 as a risk aversion measure. Determining freshwater productivity of spring Chinook salmon in the White River is an essential component to overall population monitoring, and will help contribute to the body of knowledge needed to evaluate if further supplementation in the White River is warranted.

In the fall of 2005, Washington State Department of Fish and Wildlife (WDFW) began smolt trapping in the lower White River in order to provide an estimate of juvenile spring Chinook salmon production. No trapping was conducted in 2006 as there was a transition between trap operators. In 2007, Public Utility District No. 2 of Grant County (GCPUD) contracted with Yakama Nation Fisheries (YNF) to operate a rotary trap in the White River. This document reports data collected between March 1 and November 30, 2016, and provides emigration estimates for spring Chinook salmon yearlings (BY2014) and subyearlings (BY2015) during that time period. Fish trap operations were conducted in compliance with ESA consultation specifically to address abundance and productivity of spring Chinook salmon in the White River.

Within this document, we will report:

1) Juvenile abundance and productivity of spring Chinook salmon in the White River.

2) Emigration timing of spring Chinook salmon emigrating from the White River.

1.1 Watershed Description

The White River drainage encompasses 40,451 ha originating in alpine glaciers and perennial snow fields (Figure 1; USFS 2004). Elevation within the drainage varies from 569 m at the surface of Lake Wenatchee to 2,614 m at Clark Mountain (Andonaegui 2001). As one of two primary tributaries to Lake Wenatchee, the White River flows in a south-easterly direction for 42.9 rkm before emptying into the lake. Precipitation ranges from 79 cm at the mouth to more than 356 cm in the head waters (Andonaegui 2001). Due to its glacial origins, peak runoff for the White River typically occurs between April and July with occasional high

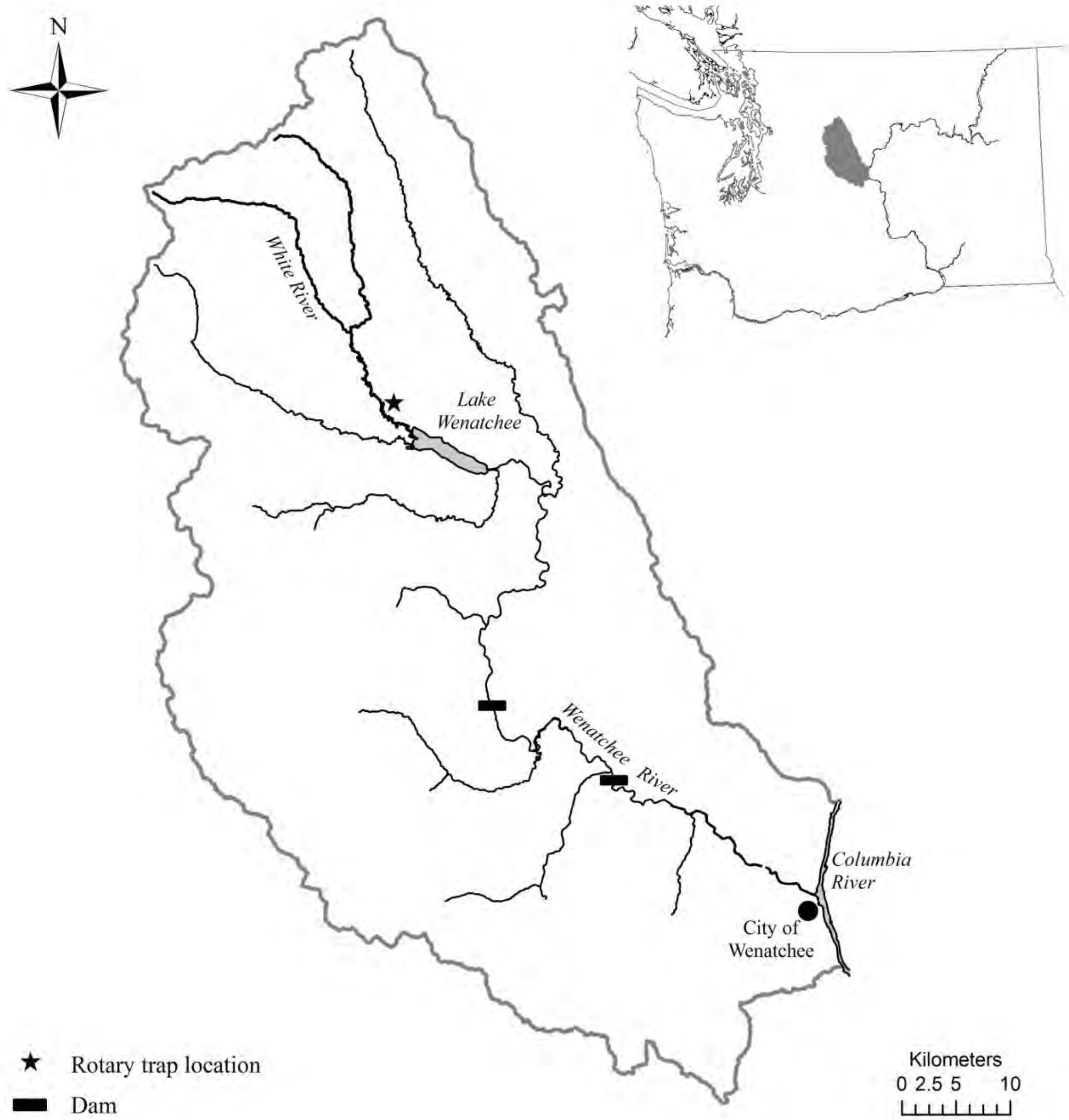


Figure 1. Map of the Wenatchee River subbasin with White River rotary trap location.

flows caused by rain-on-snow events in the fall and winter months. Water temperatures in this watershed tend to be cooler than other tributaries to the upper Wenatchee River subbasin. As of September 2002, Washington State Department of Ecology (WDOE) began operating a stream monitoring station at rkm 9.9. Operation of this station by WDOE is currently maintained with funding provided by GCPUD. In 2016, daily mean stream discharge ranged from 2.5 m^3/s (87 cfs) to 120 m^3/s (4,420 cfs) while mean daily stream temperatures ranged from 0.0°C to 14.6°C (Figs. 2 & 3). Discharge and temperature data provided by WDOE should be considered provisional and are presented in **Appendix A**.

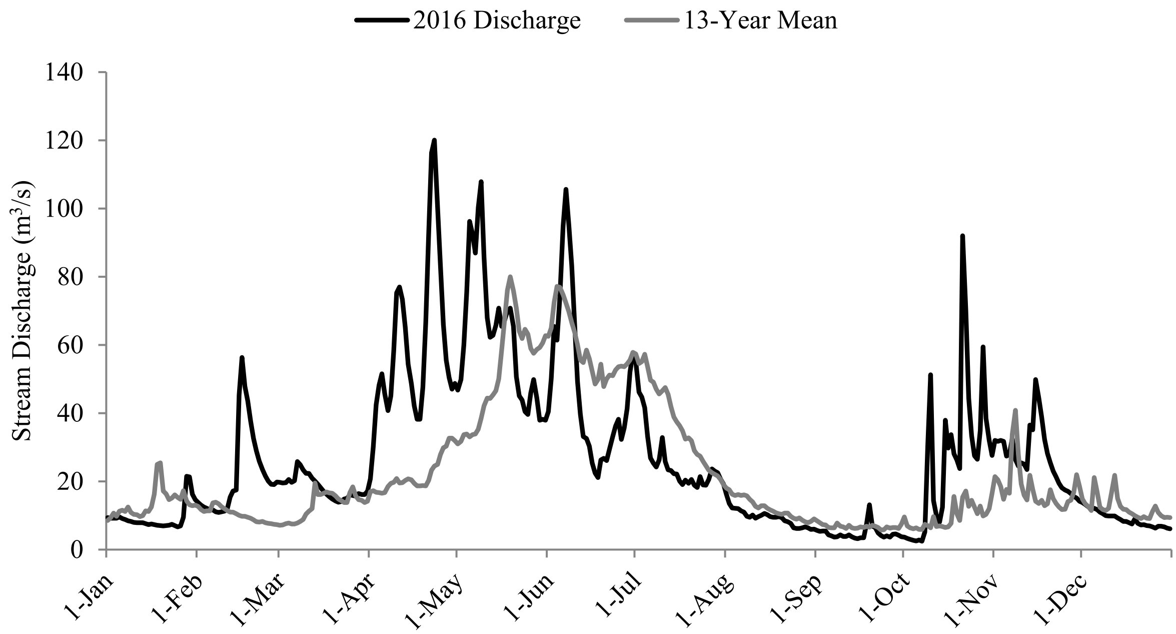


Figure 2. Mean daily stream discharge at the White River DOE stream monitoring station at Sears Creek Bridge, 2016.

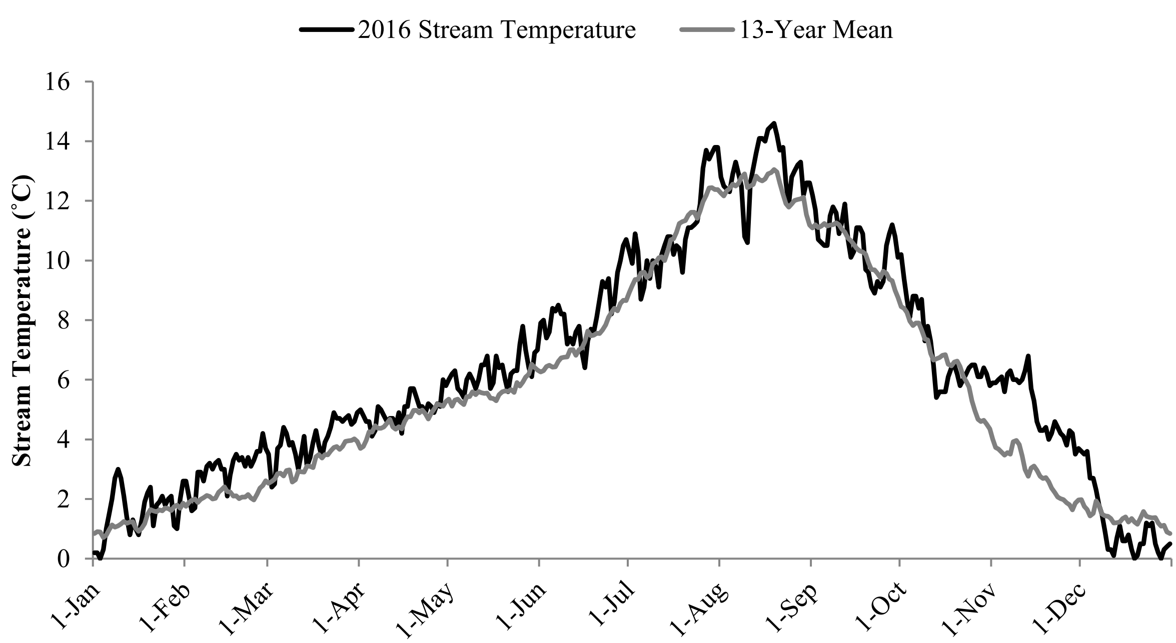


Figure 3. Mean daily water temperatures at the White River DOE stream monitoring station at Sears Creek Bridge, 2016.

The White River drainage has had minimal riparian harvest from the 1950's to the present on federally owned land. Turn of the century settlement and land clearing have impacted the riparian reserve network up to the Napeequa confluence, yet, riparian areas in the mainstem below Panther Creek remain in fair condition (USFS 2004). In the remainder of the watershed, woody debris recruitment, shade, aquatic habitat connectivity, and riparian vegetation appear to be in good condition. Current habitat concerns pertaining to the development of homes and vacation retreats on private lands do exist. Rip-rapping, channel constriction, and stream degradation are considered minor in the watershed. Public ownership comprises 78% of the drainage area; more than half of public land is located within the Glacier Peak Wilderness. The remaining 22% of the drainage is in private ownership (USFS 2004).

Downstream of White River Falls are key spawning grounds for spring Chinook salmon (tkwínat) *Oncorhynchus tshawytscha*, sockeye salmon (kálux) *O. nerka*, and bull trout *Salvelinus confluentus*. Two large tributaries to the White River, Napeequa River and Panther Creek, are also known to support populations of anadromous salmonids (Mullen et al. 1992). For a complete list of known fish species encountered in the White River see (**3.4 Incidental Species**).

2.0 METHODS

2.1 Trapping Equipment and Operation

In 2016, a 1.5m diameter cone rotary trap was operated in a single position at all discharge levels. This revised trapping regime was implemented in 2013 to simplify data analysis by eliminating obsolete trap positions that generated very little data. Past attempts at developing a high flow position generated very few efficiency trials resulting in limited trap efficiency data. Operating season-long at a single position, the trap was suspended from a river-spanning cable from which its position could be adjusted perpendicular to stream flow by hand powered winches anchored on a tree on the river-right bank.

The trap was operated 24 hours per day, seven days per week for the majority of the season. During spring snowmelt, operations only occurred during hours of darkness to minimize trap damage and subsequent capture mortality; still enabling sampling during the hours of peak fish movement. When trap operations were suspended, the cone was raised to avoid damage by debris.

During all ranges of river discharge, fish were removed daily. Additional trap checks were necessary during periods of high discharge in the spring, and in the autumn due to increased leaf litter. Debris in the live-box was removed continually by a rotating drum screen located at the rear of the holding box and hydraulically powered by the cone. A record of daily trap operations is provided in **Appendix B**.

2.2 Biological Sampling

Trap operating procedures and techniques followed a standardized, basin-wide monitoring plan developed by the Upper Columbia Regional Technical Team (UCRTT) for the Upper Columbia Salmon Recovery Board (UCSRB; Hillman 2004), which was adapted from Murdoch & Petersen (2000).

Captured fish were transferred from the rotary trap's live box using covered five-gallon plastic buckets to a stream-side portable sampling station. Fish were anesthetized in a solution of tricaine methanesulfonate (MS-222) to facilitate sampling and reduce handling stress. Fork length (FL) and weight were recorded for all fish, except large numbers of sockeye fry. For these fish, a daily subsample of 25 individuals was measured while the remaining fish were enumerated and released. Weight was measured to the nearest 0.1g with a portable digital scale while FL was recorded to the nearest 1.0 mm using a trough-type measuring board. These data were used to calculate a Fulton-type condition factor (K-factor) for each target species using the formula:

$$K = (W/L^3) \times 100{,}000$$

where K = Fulton-type condition metric;
W = weight in grams;
L = fork length in millimeters;
And 100,000 is a scaling constant.

Portable aerators were used to oxygenate holding water during sampling. All fish were allowed to fully recover from anesthesia before being released. Spring Chinook salmon were classified as either natural or hatchery origin by the presence/absence of coded wire tags (CWT's). Developmental stages (fry, parr, transitional or smolt) were visually identified and assigned to each individual sampled. Transitional juveniles were identified as having both parr and smolt characteristics; visible parr marks, semi-transparent fin coloration along with silvery coloration throughout body. Smolts were identified by a strong silvery coloration over entire body and faint or absent parr marks. Fry were defined as newly emerged fish with or without a visible yolk sac and a FL measuring < 50 mm. Age-0 spring Chinook salmon captured before July 1 were considered 'fry' and excluded from population estimates due to the inconclusive nature of their movement (i.e. active emigration or local distribution in-stream). Age-0 spring Chinook salmon captured after 1 July were considered subyearling emigrants and included in the population estimate (UCRTT, 2001).

Tissue samples (caudal clip) were taken from spring Chinook salmon and applied to blotter sheets. Samples were provided to WDFW for reproductive success analysis. Scale samples were also collected from all steelhead captured. Scale samples were submitted to WDFW for age analysis. Bull trout tissue or scale samples were not collected in 2016.

During periods when the trap operations were suspended (e.g. - high discharge, high debris and/or mechanical problems), passage estimates were generated to account for emigrants during these time periods. This estimate was calculated using the average number of fish captured three days prior and three days after the break in operation (Hillman et al., 2013; Snow et al., 2013).

2.3 Mark-Recapture Trials

Groups of marked spring Chinook salmon were used for trap efficiency trials. Fish were marked by insertion of a passive integrated transponder (PIT) tag into the abdominal cavity. Ideally, marked groups of fish would be released over a broad range of stream discharges in order to determine a trap efficiency-discharge relationship. (See **2.4 Data Analysis**). However, due to low abundance and limited holding time of ESA-listed species (reducing the ability to meet trials size requirements on a more consistent basis), marked groups were released whenever the minimum sample size (≥ 20) was obtained. Mark-recapture (M-R) trials followed the protocol described in Hillman (2004). Although the protocol suggests a minimum sample size of 100 fish for each mark-group, the limited abundance of juvenile emigrants from the White River required that efficiency trials be completed with much smaller sample sizes. YN's continued goal is to increase individual mark-group sizes, when possible, to meet the standard described above.

Number of wild fish included in a marked group was maximized by combining catches from three days of trapping. Fish were held up to 72 hours prior to release in holding boxes located on the river-left bank. Fish to be used in efficiency trials were then transported in five gallon buckets ~1.0 rkm upstream to the release location at Sears Creek Bridge (rkm 10.3). All mark groups are released by hand at nautical twilight.

Each M-R trial was conducted over a three-day (72 hour) period to allow time for passage or capture. Completed trials were only considered invalid if an interruption to trapping occurred or proper pre-release procedures were not followed. Trials resulting in zero recaptures were included in the efficiency regression as allowed by the new method of observed trap efficiency calculation (See equation 3 in **2.5.1 Estimate of Abundance**).

2.3.1 Marking and PIT tagging

All spring Chinook and summer steelhead juveniles with FL ≥ 60mm were PIT tagged unless the health of a specimen was in question. Once anesthetized, each fish was examined for external wounds or descaling and scanned for the presence of a previously implanted PIT tag. If a tag was not detected, a pre-loaded 12mm Digital Angel 134.2 kHz type TX 1411ST PIT tag was inserted into the body cavity using a Biomark MK-25 Rapid Implant Gun. Each unique tag code was electronically recorded with an appropriate tagging date, release date, tagging personnel and biological data. These data were entered into P3 and submitted to the PIT Tag Information System (PTAGIS) at the end of each month. Tagging methods were consistent with methodology described in the PIT Tag Marking Procedures Manual (CBFWA 1999) as well as with 2008 ISEMP protocols (Tussing 2008).

After marking and/or PIT tagging, fish were held for a minimum of 24-hours to a) ensure complete recovery, b) assess tagging mortality and c) determine tag-shed rate. Fish that were not to be used in an efficiency trial were released downstream of the smolt trap.

2.4 Data Analysis

2.4.1 Estimate of Abundance

Seasonal juvenile migration, N, was estimated as the sum of daily migrations, N_i, i.e., $N = \sum_i N_i$, and daily migration was calculated from catch and efficiency:

$$\hat{N}_i = \frac{C_i}{\hat{e}_i}, \qquad \textbf{(1)}$$

where C_i = number of fish caught in period *I*;

$\hat{e}_i$ = trap efficiency estimated from the flow-efficiency relationship, $\sin^2(b_0 + b_1 flow_i)$, where b_0 is estimated intercept and b_1 is the estimated slope of the regression.

The regression parameters b_0 and b_1 are estimated using linear regression for the model:

$$\arcsin\left(\sqrt{e_k^{obs}}\right) = \beta_0 + \beta_1 flow_k + \varepsilon, \qquad \textbf{(2)}$$

where e_k^{obs} = observed trap efficiency of Eq. 2 for trapping period k;

β_0 = intercept of the regression model;

β_1 = slope parameter;

ε = error with mean 0 and variance σ^2.

In Equation 2, the observed trap efficiency, e_k^{obs}, is calculated as follows,

$$e_k^{obs} = \frac{r_k + 1}{m}. \qquad \textbf{(3)}$$

The estimated variance of seasonal migration is calculated from daily estimates as:

$$Var\left(\sum_{i=1}^{n} \hat{N}_i\right) = \underbrace{\sum_i Var(N_i)}_{Part\ A} + \underbrace{\sum_i \sum_j Cov(N_i, N_j)}_{Part\ B},$$

or,

$$Var\left(\sum_{i=1}^{n} \hat{N}_i\right) = \underbrace{\sum_i Var\left(\frac{(C_i + 1)}{\hat{e}_i}\right)}_{Part\ A} + \underbrace{\sum_i \sum_j Cov\left(\frac{(C_i + 1)}{\hat{e}_i}, \frac{(C_j + 1)}{\hat{e}_j}\right)}_{Part\ B}. \qquad \textbf{(4)}$$

Part A of equation 4 is the variance of daily estimates. Part B is the between-day covariance. Note that the between-day covariance exists only for days that use the same trap efficiency model. If, for example, day 1 is estimated with one trap efficiency model, and day 2 estimated from a different model, then there is no covariance between day 1 and day 2. The full expression for the estimated variance:

$$\hat{Var}\left(\sum_{i=1}^{n}\hat{N}_i\right)=\underbrace{\sum_i \hat{N}_i^2\left(\frac{N_i\hat{e}_i(1-\hat{e}_i)}{(C_i+1)^2}+\frac{4(1-\hat{e}_i)}{\hat{e}_i}\hat{Var}(b_0+b_1 flow_i)\right)}_{PartA}+$$

$$\underbrace{\sum_i\sum_j 4\left(\hat{N}_i(1-\hat{e}_i)\right)\left(\hat{N}_j(1-\hat{e}_j)\right)\cdot\left[\hat{Var}(b_0)+flow_i flow_j \hat{Var}(b_1)\right]}_{PartB}$$

where $\hat{Var}(b_0+b_1 flow_i)=M\hat{S}E\left(1+\frac{1}{n}+\frac{\left(flow_i-\overline{flow}\right)^2}{(n-1)s_{flow}^2}\right)$, and $\hat{Var}(b_0)$ and $\hat{Var}(b_1)$ are

obtained from regression results. In Excel, the standard error (SE) of the coefficients is provided. The variance is calculated as the square of the standard error, SE^2.

In cases when there was no significant flow-efficiency relationship (i.e., low correlation), then a pooled, or average trap efficiency will suffice for the stratum. The estimator is calculated as follows:

$$\hat{\hat{e}}=\frac{\sum_{j=1}^{k}r_j}{\sum_{j=1}^{k}m_j}$$

where $\hat{\hat{e}}$ = the average or pooled trap efficiency for the stratum;

m_j = the number of smolts marked and released in efficiency trial j for the stratum;

r_j = the number of smolts recaptured out of m_j marked fish in efficiency trial j.

Abundance for a trapping period is estimated as:

$$\hat{N}_i^{pooled}=\frac{C_i}{\hat{\hat{e}}},$$

,and total stratum abundance is:

$$N^{pooled}=\sum_i \hat{N}_i^{pooled}.$$

The variance of seasonal abundance takes into account the variability in catch numbers that are a result of binomial sampling (Part A), the pooled variance of trap efficiency, $\hat{\bar{e}}$ (Part B), and the covariance in daily estimates that arises from using a common estimate of efficiency across all trapping days (Part C):

$$\hat{Var}\left(\sum_{i=1}^{n}\hat{N}_i^{pooled}\right)=\underbrace{\left(\sum_i \frac{\hat{N}_i\left(1-\hat{\bar{e}}\right)}{\hat{\bar{e}}}\right)}_{PartA}+\underbrace{\frac{Var\left(\hat{\bar{e}}\right)}{\hat{\bar{e}}^2}\sum_i \hat{N}_i^2}_{PartB}+\underbrace{\frac{Var\left(\hat{\bar{e}}\right)}{\hat{\bar{e}}^2}\sum_i\sum_j \hat{N}_i\hat{N}_j}_{PartC}.$$

The Part B and Part C terms are combined in the calculation as a new Part B:

$$\hat{Var}\left(\sum_{i=1}^{n}\hat{N}_i^{pooled}\right)=\underbrace{\left(\sum_i \frac{\hat{N}_i\left(1-\hat{\bar{e}}\right)}{\hat{\bar{e}}}\right)}_{PartA}+\underbrace{\frac{Var\left(\hat{\bar{e}}\right)}{\hat{\bar{e}}^2}\left[\sum_i \hat{N}_i^2+\sum_i\sum_j \hat{N}_i\hat{N}_j\right]}_{PartB}.$$

The variance of $\hat{\bar{e}}$ is calculated as:

$$\hat{Var}\left(\hat{\bar{e}}\right)=\hat{Var}\left(\frac{\sum_{k=1}^{n} r_k}{\sum_{k=1}^{n} m_k}\right)=\frac{\sum_{k=1}^{n}\left(r_k-\hat{\bar{e}}_k m_k\right)^2}{\bar{m}^2 n(n-1)}$$

where $\bar{m}$ is the average release size across all efficiency trial, $\frac{\sum_{k=1}^{n} m_k}{n}$.

Confidence intervals were calculated using the following formulas:

95% confidence interval = $1.96\times\sqrt{\sum \mathrm{var}\left[\hat{N}_i\right]}$

The single M-R estimator of abundance carries a set of well documented assumptions (Everhart and Youngs 1981; Seber 1982),

1. The population is closed to mortality.
2. The probability of capturing a marked or unmarked fish is equal.
3. Marked fish were randomly dispersed in the population prior to recapture.

4. Marking does not affect probabilities of capture.
5. Marks were not lost between the time of release and recapture.
6. All marks are reported upon recapture.
7. The number of fish in the trap, C, is fully enumerated and known without error.

3.0 RESULTS

3.1 Dates of Operation

In 2016, YNF operated a 1.5m rotary trap between March 1 and November 30. During this period, the trap operated 24 hours per day, 7 days per week barring inoperable environmental conditions (i.e. heavy debris loads or high discharge). Trapping was interrupted a total of 29 days (Table 1).

Table 1. Summary of White River smolt trap operation, 2016.

Trap Status	Description	Days
Operating	Continuous data collection	246
Interrupted	Unexpected interruption by debris, etc.	29
Pulled	Intentionally pulled to protect the trap during high flows	0

3.2 Daily Captures and Biological Sampling

3.2.1 Wild Spring Chinook Yearlings (BY2014)

Three wild yearling Chinook smolts were collected between March 1 and June 30 (Figure 4). Mean fork-length (FL) was 106 mm (n = 3; SD = 1.5) and mean weight was 12.4 g (n = 3; SD = 0.3; Table 2). All spring Chinook smolts were implanted with PIT tags and sampled for genetics. There were no BY2014 spring Chinook mortalities incurred (See **3.4 ESA Compliance**).

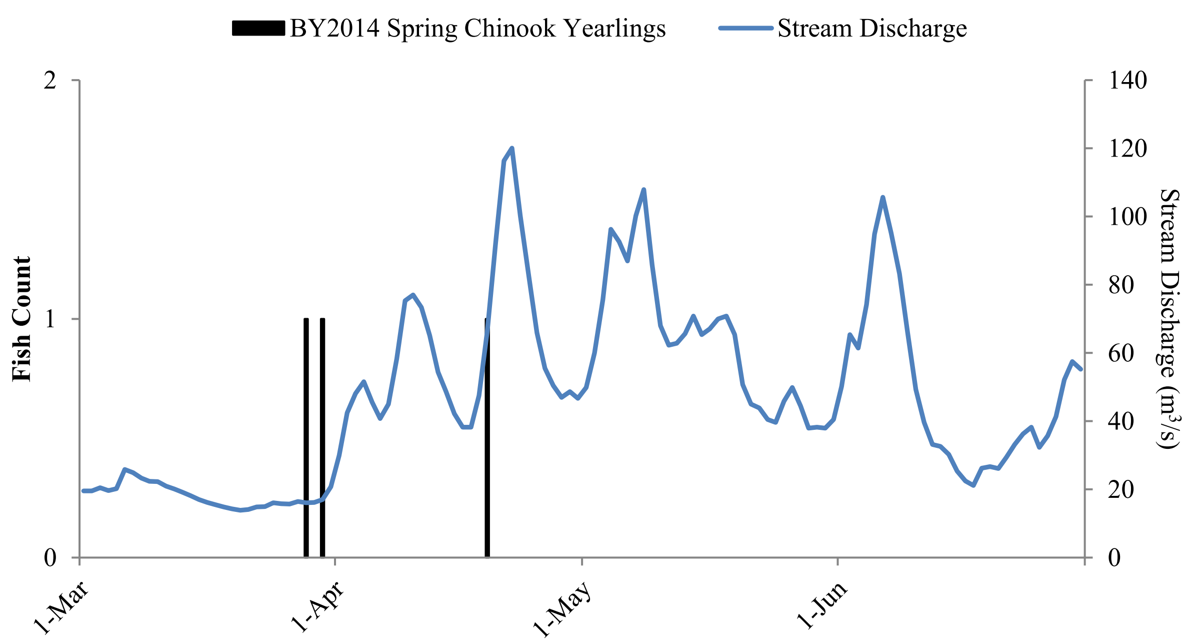


Figure 4. Daily catch of yearling spring Chinook smolt with mean daily stream discharge at the White River rotary trap, March 1 to June 30, 2016.

3.2.2 Wild Spring Chinook Subyearlings (BY2015)

Spring Chinook fry were captured at the trap between March 7 and June 22 (*n* = 49). During this period there were no fry trapping mortalities incurred. One additional subyearling Chinook with FL<50 mm was captured after June 30. Because this fish is considered a "fry" it was excluded from the parr estimate. A total of 147 wild subyearling Chinook parr were collected between May 25 and November 30, with peak catch occurring on August 25 (*n* = 14; Figure 5). The mean FL for subyearling parr was 89 mm (*n* = 147; *SD* = 10.7) and the mean weight was 8.3 g (*n* = 147; *SD* = 2.8); see Table 2. Four of the spring Chinook parr were captured prior to July 1. Because these were therefore considered "fry" they were excluded from the parr estimate. PIT tags were implanted into a total of 137 subyearling Chinook parr. One tag was shed during the 24hr holding period (Table 4). Genetic samples were taken from 137 parr. There were two BY2015 spring Chinook mortalities during the 2016 trapping season (See **3.4 ESA Compliance**).

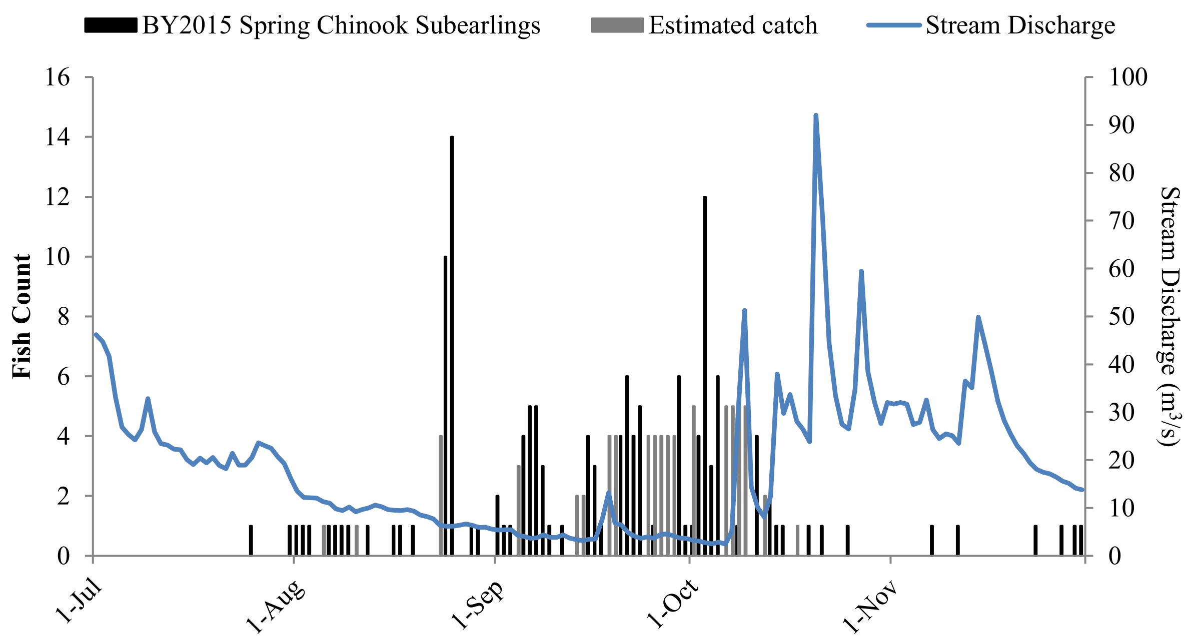


Figure 5. Daily catch of wild subyearling spring Chinook with mean daily stream discharge at the White River rotary trap, July 1 to November 30, 2016.

Table 2. Summary of length and weight sampling of juvenile spring Chinook captured at the White River rotary trap, 2016.

Brood Year	Origin/Species/Stage	Fork Length (mm)			Weight (g)			K-factor
		Mean	n	SD	Mean	n	SD	
2014	Wild Yearling Smolt	106	3	1.5	12.4	3	0.3	1.05
2015	Wild Subyearling Fry	38	50	3.0	0.5	49	0.3	0.82
2015	Wild Subyearling Parr	89	147	10.7	8.3	147	2.8	1.13

3.3 Trap Efficiency Calibration and Population Estimates

3.3.1 Wild Spring Chinook Yearlings (BY 2014)

Due to low abundance, no BY2014 wild yearling Chinook efficiency trials were performed in 2016. A composite regression model using previous year's (2008-2012) efficiency trials showed statistically significant ($r^2 = 0.57$; $p = 0.001$) flow-efficiency relationship, and was used to calculate yearling abundance. Use of a single spring trapping position allowed this regression to be applied to all yearling Chinook captured in 2016. Weighting of this regression via an R script (provided by WDFW) did not affect calculation parameters greatly and yielded the same r-square and *p*-values. In the fall of 2015, we estimated that 1,950 (± 400; 95% CI) BY2014 subyearlings emigrated past the trap. In the spring of 2016, we estimated that 386 (± 701; 95% CI) emigrated past the trap. Combining the two estimates, total BY2014 wild spring Chinook emigrants was 2,336 (± 807; 95% CI; Table 3).

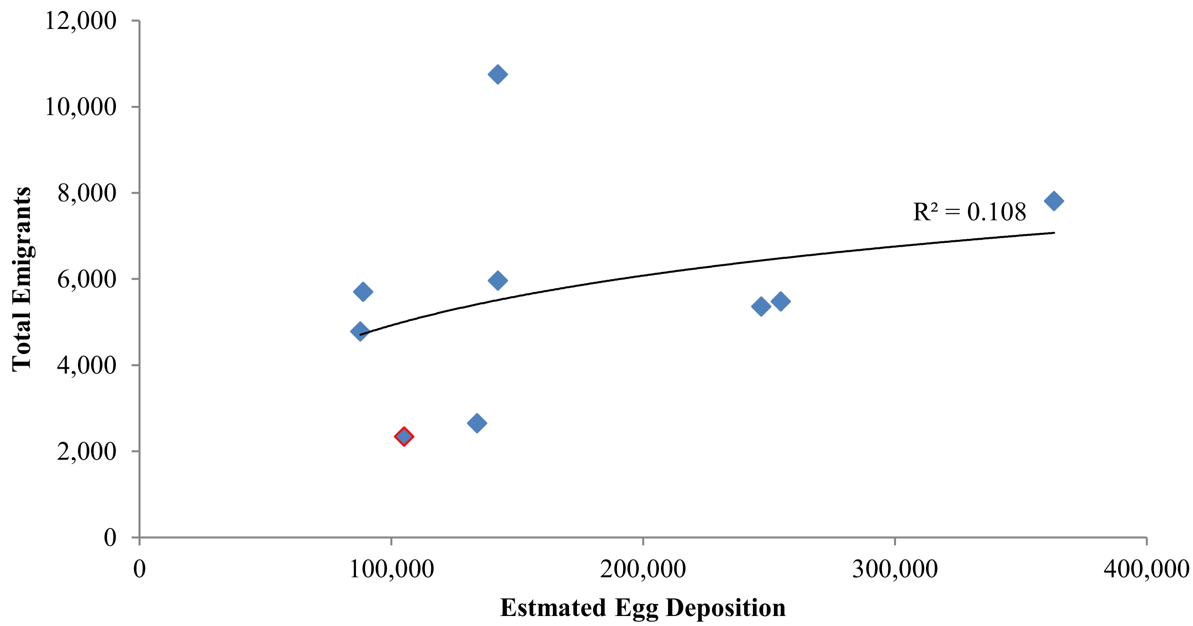
3.3.2 Wild Spring Chinook Subyearling (BY 2015)

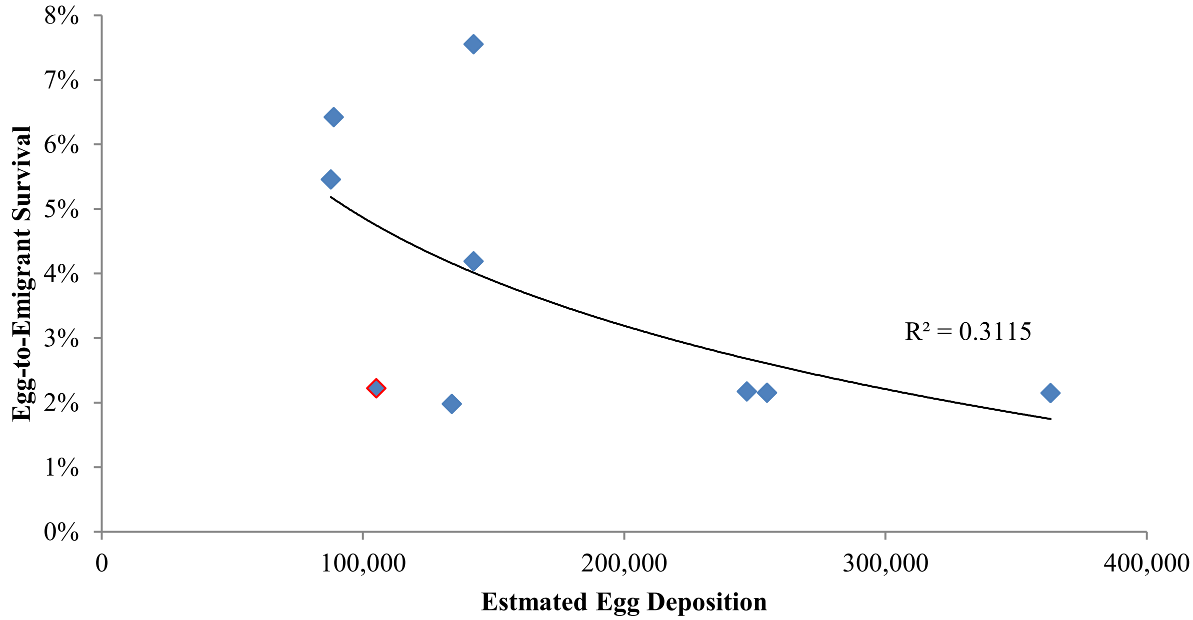
Due to low abundance, no BY2015 wild yearling Chinook efficiency trials were performed in 2016. Instead, a composite regression based on previous year's data (2009-2015) was used to expand daily catch. This regression was comprised of all trails conducted fulfilling the minimum number marked ($n \geq 20$) including efforts in which zero recaptured were made (Appendix C). Mark-groups in which validity of the trial could be called into question (suspected trap stoppage or improper pre-release handling of the mark group) were removed. The weighted regression was not significant ($r^2 = 0.12$; $p = 0.086$) at our accepted limit ($\alpha = 0.05$). However, after comparison with a pooled method and considerations of the pooled estimate limitations, we decided to use the regression model despite its slightly higher *p*-value. This single regression was the only model required to estimate total subyearling migration due to the fact only one fall trapping position was used in 2015. We estimated that in 2016, 2,430 (± 723; 95% CI) spring Chinook subyearling parr moved past the trap (Table 3).

Table 3. Estimated egg-to-emigrant survival and emigrants per redd for White River spring Chinook

Brood Year	No. of Redds[a]	Fecundity[b]	No. of Eggs	No. of Emigrants			Egg-to Emigrant	Emigrants per Redd
				Age-0[c]	Age-1	Total ± 95% CI		
2005	86	4,327	372,122	DNOT[d]	4,856	—		—
2006	31	4,324	134,044	652	2,004	2,656 ± 1,597	2.0%	86
2007	20	4,441	88,820	2,309	3,395	5,704 ± 2,201	6.4%	285
2008	31	4,592	142,352	5,560	5,193	10,753 ± 3,783	7.6%	347
2009	54	4,573	246,942	2,428	2,939	5,367 ± 2,497	2.2%	99
2010	33	4,314	142,362	1,859	4,103	5,962 ± 3,448	4.2%	181
2011	20	4,385	87,700	3,128	1,659	4,787 ± 2,022	5.5%	239
2012	86	4,223	363,178	3,816	3,995	7,811 ± 3,847	2.2%	91
2013	54	4,716	254,664	2,461	3,023	5,484 ± 2,836	2.2%	102
2014	26	4,045	105,170	1,950	386	2,336 ± 807	2.2%	90
2015	70	4,847	339,290	2,430	—	—	—	—
Avg	39	4,401	173,915	2,685	2,966	5,651	3.8%	169

[a] Number of complete redds in White River (Hillman et al. 2015)
[b] Mean annual fecundity of spring Chinook broodstock at Chiwawa River Hatchery
[c] Estimate is based on capture of parr collected during summer/fall and does not include fry captured prior to July1
[d] Did not operate trap; no production estimates were made





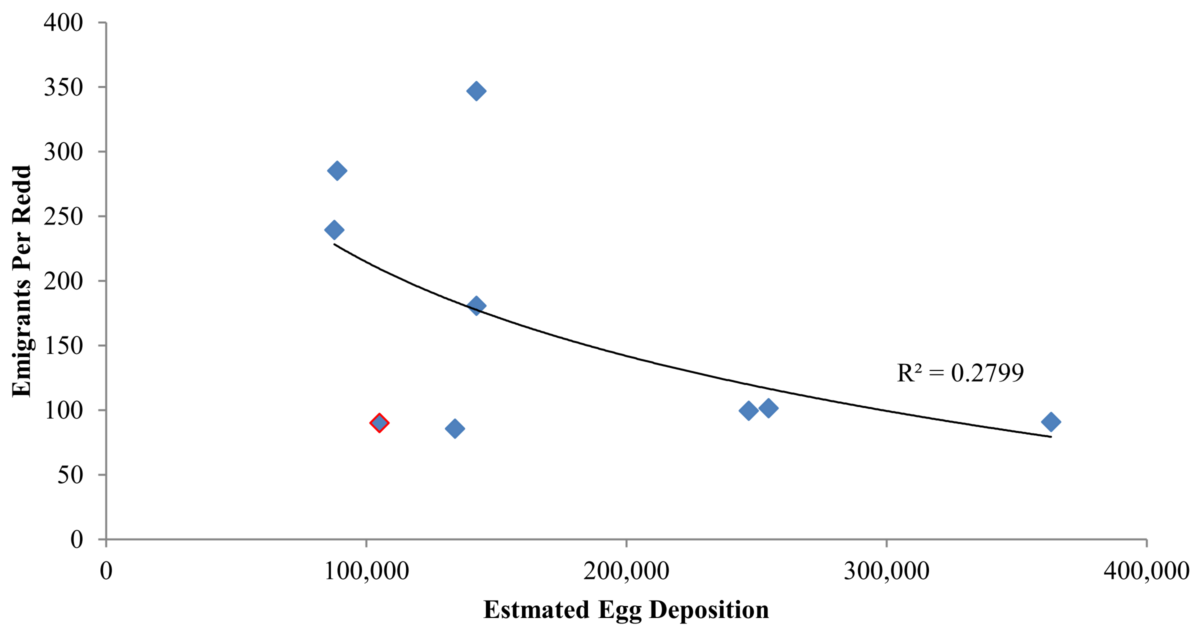


Figure 6. Relationships between estimated egg deposition and total emigrants produced, egg-to-emigrant survival, and emigrants per redd for White River spring Chinook, BY 2007 to 2014. *BY2014 values denoted by red border.

3.4 PIT Tagging

In 2016, a total of 140 spring Chinook and 5 steelhead were PIT tagged at the trap. PIT tag retention after 24 hours of observation yielded only one shed tag (wild spring Chinook parr; Table 4). There no tagging mortalities (Table 6).

Table 4. Number of PIT tagged spring Chinook and steelhead with shed rates at the White River rotary trap, 2016.

Brood Year	Species/Stage	Total Catch	Total PIT Tagged	Percent Tagged	Percent Tags Shed
2014	Yearling Chinook Smolt	3	3	100.0%	0.0%
2015	Subyearling Chinook Parr	147	137	93.2%	0.7%
*	Steelhead Parr	5	5	100.0%	0.0%

* Brood year unknown

3.5 Incidental Species

Incidental species were enumerated and sampled for length and weight (Table 5). Incidental species included: bull trout, longnose dace *Rhinichthys cataractae*, mountain whitefish *Prosopium williamsoni*, northern pikeminnow *Ptychocheilus oregonensis*, steelhead/rainbow trout (shúshaynsh) *Oncorhynchus mykiss*, redside shiner *Richardsonius balteatus*, sculpin *Cottus sp.*, sockeye salmon, sucker *Catostomus sp.*, and westslope cutthroat *Oncorhynchus clarkii lewisi*.

Table 5. Summary of length and weight sampling of incidental species captured at the White River rotary trap, 2016.

Species	Total Count	Fork Length (mm)			Weight (g)		
		Mean	*n*	SD	Mean	*n*	SD
Bull Trout Parr	5	341	5	220.5	98.9	3	89.5
Longnose Dace	4	73	4	24.5	5.9	4	4.7
Mountain Whitefish	93	64	93	29.7	6.2	83	19.6
Northern Pikeminnow	5	211	5	142.8	51.7	4	77.6
Rainbow Trout/Steelhead Parr	5	10	5	23.1	5.6	0	158.8
Redside Shiner	25	67	25	13.8	5.5	25	5.0
Sculpin	60	61	60	16.5	3.1	57	2.4
Sockeye Fry	1,784	27	864	1.1	—	—	—
Sockeye Parr	1	68	1	—	3.1	1	—
Sucker	20	213	20	76.9	159.0	20	109.3
Westslope Cutthroat	6	229	6	75.2	90.3	5	46.8

3.6 ESA Compliance

ESA-listed species mortalities incurred in 2016 included two subyearling Chinook parr (Table 6). At no point during the trapping season did the lethal take of wild spring Chinook exceed the maximum allowed 2%. All fish handled were inspected prior to tagging or further sampling with any sign of injury or stress warranting immediate release.

Table 6. Summary of White River ESA listed species catch and mortality, 2016.

Species/Stage	Total Catch	Total Mortality	Total % Mortality
Yearling Chinook Smolt	3	0	0.0%
Subyearling Chinook Parr	147	2	1.4%
Subyearling Chinook Fry	50	0	0.0%
Total Wild Spring Chinook	**200**	**2**	**1.0%**
Bull Trout	5	0	0.0%
Steelhead/Rainbow Trout	5	0	0.0%

4.0 DISCUSSION

Previously, below-average spring Chinook spawner escapements at the White River have resulted in elevated egg-to-emigrant survival estimates for their respective juveniles produced. Conversely, above-average spawner escapements have trended toward comparatively lowered rates of in-stream survival. Although replication at the highest escapement levels is limited, the trend thus far suggests that density-dependent constraints are influencing in-stream survival in the White River spring Chinook population. An estimated egg deposition in 2014 that fell well-below the White River average failed to produce the expected response of an elevated egg-to-emigrant survival. Instead, the BY2014 egg-to-emigrant survival rate of 2.2% showed no change over the two preceding broods, which had markedly higher estimated egg depositions. Potential explanations of this unexpected result are twofold: 1) the survival estimated is in fact a reflection of decreased survival, and contrary to the density-dependent trend previously noted, and/or 2) catch at the trap during the BY2014 migration did not effectively capture a representative sample of the outmigration. The likelihoods of both of these influences were exacerbated by the strong El Niño occurring during the majority of BY2014's in-stream rearing period (NOAA 2016).

Oceanic Niño Index (ONI) values were particularly high in 2015 and 2016, with levels not experienced since strong El Niño events in 1982/1983 and 1997/1998 (NOAA 2016). Inland manifestations of this oceanic phenomenon at the White River included high fall and winter discharges (Figure 7). High, irregular flows were likely to have produced some degree of increased mortality prior to gravel emergence as a result of redd scouring and sedimentation (Montgomery et al. 1996 & Lotspeich and Everest 1981). Flood events in November 2014 and 2015 were both great (>170 m^3/s [6,000cfs]), and included significant movement of bedload, suspended sediments, and large woody debris (LWD). Though difficult to quantify the impact of this flooding on incubating eggs, a strong negative correlation between egg-to-emigrant survival and peak flow during incubation has been shown in other tributaries (Seiler et al. 2002). Also, low snowpack and early snowmelt brought on by mild winter temperatures caused prolonged periods of summer base flows in 2015 and 2016. Though stream temperatures did not reach levels in which mass die-off was incurred (Max = 17.6ºC), prolonged low stream levels presumably resulted in a higher than average competition for critical resources.

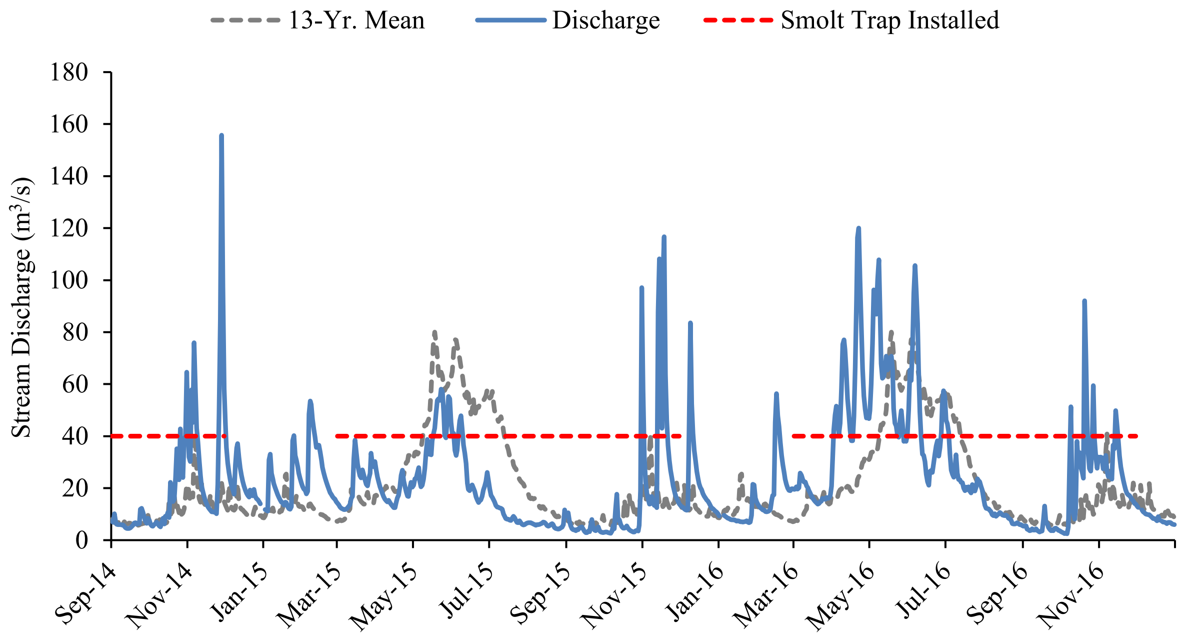


Figure 7. White River daily mean and 13-year mean discharge during strong El Niño, 2014-2016.

In addition to direct decreases to survival, we suspect that irregular weather patterns attributed to El Niño resulted in a potentially large portion of the BY2014 juvenile population being prematurely displaced during periods of low trap efficiency (high discharge), and/or early outmigration during the non-trapping period (December through February). While some displacement below the trap may be a simple function of pre-migratory fish being unable to maintain positioning during high-water events, Chinook populations elsewhere have displayed early migratory behavior in years with early snowmelt and warm water temperatures (Quinn 2005 & Achord et al. 2007). Early outmigration has also been associated with elevated growth, with larger fish tending to emigrate earlier (Achord et al. 2007). BY2014 subyearling parr had the highest average FL of any brood recorded. Given fulfillment of both conditions (warm water temperature and rapid-growth), BY2014 yearlings may have actively emigrated from the White River earlier than in previous years with typical temperature and flow regimes. If the bulk of movement was initiated prior to the start of trapping (March 1), spring operations may have captured a smaller than average proportion of the total outmigration i.e., only the tail-end of the downstream movement.

A comparison of egg-to-emigrant survival rates in the White River, Chiwawa River, and Nason Creek shows that BY2014 survivals deviated markedly from each other in comparison to the preceding two broods (Figure 8). We suspect that this may be explained in-part by differing felt effects of El Niño on each tributary, and capability of each trap to measure outmigration in light of high flows and early migratory behavior. Stronger influence of El Niño on a tributary would therefore cause a lowered estimated survival rate via the aforementioned effects on both survival and smolt trap efficacy. All three tributaries saw smaller spawner escapements in 2014. Based on previous data, all should have in-turn responded with elevated rates of egg-to-emigrant survival. We suspect that although the Chiwawa River did experience some adverse environmental effects, influence of El Niño on the Chiwawa BY2014 emigrant estimate was the least affected of the three tributaries. Nason Creek showed potentially the greatest negative response to El Niño, with a decrease in survival. The smallest of the three tributaries, Nason Creek is listed as impaired due to water temperatures exceeding 303(d) criteria (Cristea and Pelletier 2005). Survival in Nason Creek may have been impacted by the prolonged, extremely warm temperatures to a higher degree than the Whiter River and Chiwawa River; two tributaries with much cooler summer water temperatures. Like Nason Creek, the White River failed to show an increase in survival in-light of a smaller adult return. However, given the assumption that a potentially significant proportion of the run was missed producing an underestimate of abundance, we assume that BY2014 survival did in fact increase over the previous brood, as did the Chiwawa River population.

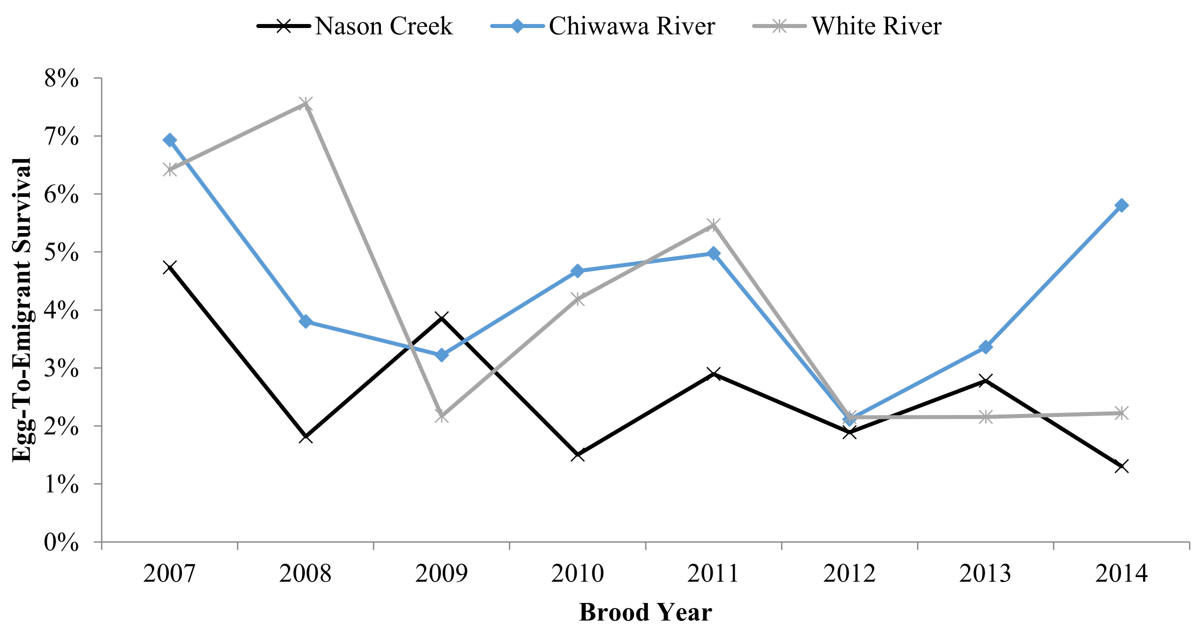


Figure 8. Comparison of wild spring Chinook abundance estimates (BY2007-2014) made at the White R., Nason Cr., and Chiwawa R. smolt traps. Chiwawa R. data provided by Hillman et al. (2015).

The 2015 White River spring Chinook brood in-stream rearing period also coincided partially with the El Niño event. The initial subyearling estimate is below the nine-year mean despite high estimated egg deposition; potentially the result of decreased survival and/or shifts in movement to low-efficiency or suspended periods of trapping. Completion of the migratory period in the spring of 2017 will help to determine the cumulative effect of the anomalous weather trends on the brood estimate. Given a change to cooler conditions associated with non-El Niño periods, we anticipate that the majority of BY2015 smolt emigration will occur after the smolt trap has been installed.

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APPENDIX A: White River Temperature and Discharge Data

Date	Stream Discharge (m^3/s)	Water Temperature (˚C)
3/1/2016	20	2.4
3/2/2016	20	2.5
3/3/2016	21	3.7
3/4/2016	20	3.8
3/5/2016	20	4.4
3/6/2016	26	4.2
3/7/2016	25	3.8
3/8/2016	23	3.9
3/9/2016	22	3.5
3/10/2016	22	3.0
3/11/2016	21	3.5
3/12/2016	20	4.1
3/13/2016	19	3.1
3/14/2016	18	3.4
3/15/2016	17	3.9
3/16/2016	16	4.3
3/17/2016	16	3.8
3/18/2016	15	3.4
3/19/2016	14	3.9
3/20/2016	14	4.1
3/21/2016	14	4.4
3/22/2016	15	4.9
3/23/2016	15	4.7
3/24/2016	16	4.7
3/25/2016	16	4.6
3/26/2016	16	4.7
3/27/2016	16	4.8
3/28/2016	16	4.5
3/29/2016	16	4.6
3/30/2016	17	4.9
3/31/2016	21	5.0
4/1/2016	30	4.8
4/2/2016	42	4.6
4/3/2016	48	4.6
4/4/2016	52	4.1
4/5/2016	46	4.3
4/6/2016	41	5.1
4/7/2016	45	5.0
4/8/2016	58	4.8
4/9/2016	75	4.6
4/10/2016	77	4.7
4/11/2016	73	4.7
4/12/2016	65	4.4
4/13/2016	54	4.9
4/14/2016	49	4.2
4/15/2016	42	5.1
4/16/2016	38	5.1
4/17/2016	38	5.7
4/18/2016	48	5.7
4/19/2016	67	5.4
4/20/2016	92	5.1
4/21/2016	116	5.1
4/22/2016	120	4.9
4/23/2016	100	5.2
4/24/2016	83	5.1
4/25/2016	66	4.9
4/26/2016	56	5.2
4/27/2016	50	5.1
4/28/2016	47	6.0
4/29/2016	49	5.8
4/30/2016	47	6.0
5/1/2016	50	6.2
5/2/2016	60	6.3
5/3/2016	76	5.7
5/4/2016	96	5.6
5/5/2016	93	5.4
5/6/2016	87	6.0
5/7/2016	100	6.2
5/8/2016	108	6.0
5/9/2016	86	5.7
5/10/2016	68	6.0
5/11/2016	62	6.5
5/12/2016	63	6.5
5/13/2016	66	6.8
5/14/2016	71	5.7

5/15/2016	65	5.9	6/29/2016	57	10.7
5/16/2016	67	6.8	6/30/2016	55	10.3
5/17/2016	70	6.4	7/1/2016	46	9.9
5/18/2016	71	6.5	7/2/2016	45	10.9
5/19/2016	65	6.0	7/3/2016	42	10.3
5/20/2016	51	5.6	7/4/2016	33	8.7
5/21/2016	45	6.2	7/5/2016	27	9.1
5/22/2016	44	6.3	7/6/2016	25	10.0
5/23/2016	40	6.3	7/7/2016	24	9.4
5/24/2016	40	7.2	7/8/2016	26	10.0
5/25/2016	46	7.8	7/9/2016	33	9.8
5/26/2016	50	7.0	7/10/2016	26	9.1
5/27/2016	44	6.4	7/11/2016	23	10.2
5/28/2016	38	6.1	7/12/2016	23	10.5
5/29/2016	38	6.9	7/13/2016	22	10.8
5/30/2016	38	7.0	7/14/2016	22	10.8
5/31/2016	40	7.9	7/15/2016	20	10.2
6/1/2016	50	8.0	7/16/2016	19	10.5
6/2/2016	65	7.4	7/17/2016	20	10.4
6/3/2016	61	7.6	7/18/2016	19	9.6
6/4/2016	74	8.4	7/19/2016	21	10.7
6/5/2016	95	8.3	7/20/2016	19	11.1
6/6/2016	106	8.5	7/21/2016	18	11.1
6/7/2016	95	8.2	7/22/2016	21	11.2
6/8/2016	83	8.2	7/23/2016	19	11.3
6/9/2016	66	7.2	7/24/2016	19	11.9
6/10/2016	49	7.4	7/25/2016	21	13.1
6/11/2016	40	7.2	7/26/2016	24	13.7
6/12/2016	33	7.6	7/27/2016	23	13.4
6/13/2016	33	7.8	7/28/2016	23	13.6
6/14/2016	30	6.9	7/29/2016	21	13.8
6/15/2016	25	6.4	7/30/2016	19	13.8
6/16/2016	22	7.3	7/31/2016	16	12.8
6/17/2016	21	7.7	8/1/2016	14	12.5
6/18/2016	26	7.6	8/2/2016	12	12.4
6/19/2016	27	8.1	8/3/2016	12	12.3
6/20/2016	26	8.7	8/4/2016	12	12.9
6/21/2016	29	9.3	8/5/2016	11	13.3
6/22/2016	33	9.1	8/6/2016	11	12.9
6/23/2016	36	9.4	8/7/2016	10	12.5
6/24/2016	38	8.2	8/8/2016	9	10.8
6/25/2016	32	8.6	8/9/2016	10	10.6
6/26/2016	36	9.6	8/10/2016	9	12.6
6/27/2016	41	10.0	8/11/2016	10	13.1
6/28/2016	52	10.5	8/12/2016	10	13.6

8/13/2016	11	14.1	9/27/2016	5	11.2
8/14/2016	10	14.1	9/28/2016	4	10.8
8/15/2016	10	14.0	9/29/2016	4	10.1
8/16/2016	10	14.4	9/30/2016	4	10.2
8/17/2016	9	14.5	10/1/2016	3	9.4
8/18/2016	10	14.6	10/2/2016	3	8.7
8/19/2016	9	14.2	10/3/2016	3	8.1
8/20/2016	8	13.7	10/4/2016	3	8.8
8/21/2016	8	13.8	10/5/2016	3	8.8
8/22/2016	8	12.6	10/6/2016	2	8.4
8/23/2016	6	11.9	10/7/2016	5	8.7
8/24/2016	6	12.8	10/8/2016	30	7.3
8/25/2016	6	13.0	10/9/2016	51	7.8
8/26/2016	6	13.2	10/10/2016	14	7.3
8/27/2016	7	13.3	10/11/2016	10	6.5
8/28/2016	6	12.2	10/12/2016	8	5.4
8/29/2016	6	12.6	10/13/2016	12	5.6
8/30/2016	6	12.6	10/14/2016	38	5.6
8/31/2016	6	12.2	10/15/2016	30	5.6
9/1/2016	5	11.7	10/16/2016	34	6.1
9/2/2016	5	10.7	10/17/2016	28	6.4
9/3/2016	5	10.6	10/18/2016	26	6.5
9/4/2016	4	10.5	10/19/2016	24	6.2
9/5/2016	4	10.5	10/20/2016	92	5.8
9/6/2016	4	11.5	10/21/2016	70	6.0
9/7/2016	4	11.8	10/22/2016	44	6.2
9/8/2016	4	11.6	10/23/2016	33	6.4
9/9/2016	4	10.9	10/24/2016	27	6.5
9/10/2016	4	11.3	10/25/2016	27	6.5
9/11/2016	4	11.9	10/26/2016	35	6.1
9/12/2016	4	10.7	10/27/2016	59	6.1
9/13/2016	3	10.1	10/28/2016	39	6.4
9/14/2016	3	10.3	10/29/2016	32	6.2
9/15/2016	3	11.1	10/30/2016	28	5.8
9/16/2016	4	11.1	10/31/2016	32	5.9
9/17/2016	8	10.9	11/1/2016	32	5.9
9/18/2016	13	9.7	11/2/2016	32	6.0
9/19/2016	7	9.6	11/3/2016	32	6.1
9/20/2016	6	9.1	11/4/2016	27	5.6
9/21/2016	5	8.9	11/5/2016	28	6.2
9/22/2016	4	9.3	11/6/2016	33	6.3
9/23/2016	4	9.1	11/7/2016	26	6.0
9/24/2016	4	9.3	11/8/2016	24	6.0
9/25/2016	4	10.5	11/9/2016	25	5.9
9/26/2016	4	10.9	11/10/2016	25	6.0

11/11/2016	23	6.3
11/12/2016	37	6.8
11/13/2016	35	5.7
11/14/2016	50	5.3
11/15/2016	44	4.6
11/16/2016	39	4.3
11/17/2016	32	4.3
11/18/2016	28	4.4
11/19/2016	25	4.0
11/20/2016	23	4.2
11/21/2016	21	4.6
11/22/2016	19	4.4
11/23/2016	18	4.2
11/24/2016	17	4.1
11/25/2016	17	3.8
11/26/2016	16	4.3
11/27/2016	16	4.2
11/28/2016	15	3.5
11/29/2016	14	3.7
11/30/2016	14	3.6

APPENDIX B: Daily Trap Operation Status

Date	Trap Status	Comments
3/1/2016	Op.	
3/2/2016	Op.	
3/3/2016	Op.	
3/4/2016	Op.	
3/5/2016	Op.	
3/6/2016	Op.	
3/7/2016	Op.	
3/8/2016	Op.	
3/9/2016	Op.	
3/10/2016	Op.	
3/11/2016	Op.	
3/12/2016	Op.	
3/13/2016	Op.	
3/14/2016	Op.	
3/15/2016	Op.	
3/16/2016	Op.	
3/17/2016	Op.	
3/18/2016	Op.	
3/19/2016	Op.	
3/20/2016	Op.	
3/21/2016	Op.	
3/22/2016	Op.	
3/23/2016	Op.	
3/24/2016	Op.	
3/25/2016	Op.	
3/26/2016	Op.	
3/27/2016	Op.	
3/28/2016	Op.	
3/29/2016	Op.	
3/30/2016	Op.	
3/31/2016	Op.	
4/1/2016	Op.	
4/2/2016	Op.	
4/3/2016	Op.	
4/4/2016	Op.	
4/5/2016	Op.	
4/6/2016	Op.	
4/7/2016	Op.	
4/8/2016	Op.	
4/9/2016	Op.	
4/10/2016	Op.	
4/11/2016	Op.	
4/12/2016	Op.	
4/13/2016	Op.	
4/14/2016	Op.	
4/15/2016	Op.	
4/16/2016	Op.	
4/17/2016	Op.	
4/18/2016	Op.	
4/19/2016	Op.	
4/20/2016	No Op.	Stopped-debris
4/21/2016	No Op.	Stopped-debris
4/22/2016	Op.	
4/23/2016	Op.	
4/24/2016	Op.	
4/25/2016	Op.	
4/26/2016	Op.	
4/27/2016	Op.	
4/28/2016	Op.	
4/29/2016	Op.	
4/30/2016	Op.	
5/1/2016	Op.	
5/2/2016	Op.	
5/3/2016	Op.	
5/4/2016	No Op.	Stopped-debris
5/5/2016	Op.	
5/6/2016	Op.	
5/7/2016	Op.	
5/8/2016	Op.	
5/9/2016	Op.	
5/10/2016	Op.	
5/11/2016	Op.	
5/12/2016	Op.	
5/13/2016	Op.	
5/14/2016	Op.	
5/15/2016	Op.	
5/16/2016	Op.	
5/17/2016	Op.	
5/18/2016	Op.	
5/19/2016	Op.	
5/20/2016	Op.	
5/21/2016	Op.	
5/22/2016	Op.	
5/23/2016	Op.	
5/24/2016	Op.	
5/25/2016	Op.	
5/26/2016	Op.	
5/27/2016	Op.	
5/28/2016	Op.	
5/29/2016	Op.	

5/30/2016	Op.	
5/31/2016	Op.	
6/1/2016	Op.	
6/2/2016	Op.	
6/3/2016	Op.	
6/4/2016	Op.	
6/5/2016	Op.	
6/6/2016	Op.	
6/7/2016	Op.	
6/8/2016	Op.	
6/9/2016	Op.	
6/10/2016	Op.	
6/11/2016	Op.	
6/12/2016	Op.	
6/13/2016	Op.	
6/14/2016	Op.	
6/15/2016	Op.	
6/16/2016	Op.	
6/17/2016	Op.	
6/18/2016	Op.	
6/19/2016	Op.	
6/20/2016	Op.	
6/21/2016	Op.	
6/22/2016	Op.	
6/23/2016	Op.	
6/24/2016	Op.	
6/25/2016	Op.	
6/26/2016	Op.	
6/27/2016	Op.	
6/28/2016	Op.	
6/29/2016	Op.	
6/30/2016	Op.	
7/1/2016	Op.	
7/2/2016	Op.	
7/3/2016	Op.	
7/4/2016	Op.	
7/5/2016	Op.	
7/6/2016	Op.	
7/7/2016	Op.	
7/8/2016	Op.	
7/9/2016	Op.	
7/10/2016	Op.	
7/11/2016	Op.	
7/12/2016	Op.	
7/13/2016	Op.	
7/14/2016	Op.	
7/15/2016	Op.	
7/16/2016	Op.	
7/17/2016	Op.	
7/18/2016	Op.	
7/19/2016	Op.	
7/20/2016	Op.	
7/21/2016	Op.	
7/22/2016	Op.	
7/23/2016	Op.	
7/24/2016	Op.	
7/25/2016	Op.	
7/26/2016	Op.	
7/27/2016	Op.	
7/28/2016	Op.	
7/29/2016	Op.	
7/30/2016	Op.	
7/31/2016	Op.	
8/1/2016	Op.	
8/2/2016	Op.	
8/3/2016	Op.	
8/4/2016	Op.	
8/5/2016	No Op.	Stopped-debris
8/6/2016	Op.	
8/7/2016	Op.	
8/8/2016	Op.	
8/9/2016	Op.	
8/10/2016	No Op.	Stopped-debris
8/11/2016	Op.	
8/12/2016	Op.	
8/13/2016	Op.	
8/14/2016	Op.	
8/15/2016	Op.	
8/16/2016	Op.	
8/17/2016	Op.	
8/18/2016	Op.	
8/19/2016	Op.	
8/20/2016	Op.	
8/21/2016	Op.	
8/22/2016	Op.	
8/23/2016	No Op.	Stopped-out of pos.
8/24/2016	Op.	
8/25/2016	Op.	
8/26/2016	Op.	
8/27/2016	Op.	
8/28/2016	Op.	
8/29/2016	Op.	
8/30/2016	Op.	
8/31/2016	Op.	
9/1/2016	Op.	
9/2/2016	Op.	
9/3/2016	Op.	
9/4/2016	No Op.	Stopped-debris
9/5/2016	Op.	
9/6/2016	Op.	

9/7/2016	Op.		10/20/2016	Op.	
9/8/2016	Op.		10/21/2016	No Op.	Stopped-debris
9/9/2016	Op.		10/22/2016	Op.	
9/10/2016	Op.		10/23/2016	No Op.	Stopped-debris
9/11/2016	Op.		10/24/2016	Op.	
9/12/2016	Op.		10/25/2016	No Op.	Stopped-debris
9/13/2016	No Op.	Stopped-debris	10/26/2016	No Op.	Stopped-debris
9/14/2016	No Op.	Stopped-debris	10/27/2016	No Op.	Stopped-debris
9/15/2016	Op.		10/28/2016	Op.	
9/16/2016	Op.		10/29/2016	Op.	
9/17/2016	Op.		10/30/2016	Op.	
9/18/2016	No Op.	Stopped-debris	10/31/2016	Op.	
9/19/2016	No Op.	Stopped-debris	11/1/2016	Op.	
9/20/2016	Op.		11/2/2016	Op.	
9/21/2016	Op.		11/3/2016	Op.	
9/22/2016	Op.		11/4/2016	Op.	
9/23/2016	Op.		11/5/2016	Op.	
9/24/2016	No Op.	Stopped-debris	11/6/2016	Op.	
9/25/2016	No Op.	Stopped-debris	11/7/2016	Op.	
9/26/2016	No Op.	Stopped-debris	11/8/2016	Op.	
9/27/2016	No Op.	Stopped-debris	11/9/2016	No Op.	Stopped-debris
9/28/2016	No Op.	Stopped-debris	11/10/2016	Op.	
9/29/2016	Op.		11/11/2016	Op.	
9/30/2016	Op.		11/12/2016	Op.	
10/1/2016	No Op.	Stopped-debris	11/13/2016	Op.	
10/2/2016	Op.		11/14/2016	Op.	
10/3/2016	Op.		11/15/2016	Op.	
10/4/2016	Op.		11/16/2016	Op.	
10/5/2016	Op.		11/17/2016	Op.	
10/6/2016	No Op.	Stopped-debris	11/18/2016	Op.	
10/7/2016	No Op.	Stopped-debris	11/19/2016	Op.	
10/8/2016	No Op.	Stopped-debris	11/20/2016	Op.	
10/9/2016	No Op.	Stopped-debris	11/21/2016	Op.	
10/10/2016	Op.		11/22/2016	Op.	
10/11/2016	Op.		11/23/2016	Op.	
10/12/2016	No Op.	Stopped-debris	11/24/2016	Op.	
10/13/2016	Op.		11/25/2016	Op.	
10/14/2016	Op.		11/26/2016	Op.	
10/15/2016	Op.		11/27/2016	Op.	
10/16/2016	Op.		11/28/2016	Op.	
10/17/2016	No Op.	Stopped-debris	11/29/2016	Op.	
10/18/2016	Op.		11/30/2016	Op.	
10/19/2016	Op.				

APPENDIX C: Regression Models

Model: Chinook Yearlings (Spring '08-'15) Back Position, (r^2=0.569; p = 0.001)

Origin/Species/Stage	Date	Marked	Recaptured	Trap Efficiency	ASIN Transform	Discharge (m^3/s)
Wild Chinook Yearlings	4/10/2008	25	2	0.12	0.354	6
Wild Chinook Yearlings	3/26/2009	24	5	0.25	0.524	5
Wild Chinook Yearlings	3/30/2009	34	4	0.147	0.394	5
Wild Chinook Yearlings	4/2/2009	37	10	0.297	0.577	6
Wild Chinook Yearlings	4/5/2009	59	15	0.271	0.548	6
Wild Chinook Yearlings	4/10/2009	36	3	0.111	0.34	11
Wild Chinook Yearlings	3/12/2010	25	1	0.08	0.287	8
Wild Chinook Yearlings	3/16/2010	30	5	0.2	0.464	8
Wild Chinook Yearlings	3/20/2010	21	1	0.095	0.314	8
Wild Chinook Yearlings	4/5/2010	37	1	0.054	0.235	10
Wild Chinook Yearlings	4/9/2010	31	4	0.161	0.413	9
Wild Chinook Yearlings	4/12/2010	58	4	0.086	0.298	8
Wild Chinook Yearlings	4/16/2010	73	2	0.041	0.204	11
Wild Chinook Yearlings	4/14/2012	48	1	0.042	0.206	15

Model: Chinook Subyearlings (Fall '09-'15) Back Position, (r^2=0.130; p = 0.086)

Origin/Species/Stage	Date	Marked	Recaptured	Trap Efficiency	ASIN Transform	Discharge (m^3/s)
Wild Chinook Subyearlings	8/20/2009	20	2	15.00%	0.398	9
Wild Chinook Subyearlings	8/29/2009	34	4	14.71%	0.394	6
Wild Chinook Subyearlings	10/7/2009	22	2	13.64%	0.378	3
Wild Chinook Subyearlings	10/16/2009	34	6	20.59%	0.471	4
Wild Chinook Subyearlings	11/17/2009	35	3	11.43%	0.345	11
Wild Chinook Subyearlings	11/23/2009	21	0	4.76%	0.22	9
Wild Chinook Subyearlings	11/21/2011	39	2	7.69%	0.281	5
Wild Chinook Subyearlings	10/4/2012	33	5	18.18%	0.441	4
Wild Chinook Subyearlings	10/24/2012	87	6	8.05%	0.288	8
Wild Chinook Subyearlings	10/28/2012	36	1	5.56%	0.238	20
Wild Chinook Subyearlings	10/31/2013	46	7	17.39%	0.43	7
Wild Chinook Subyearlings	11/6/2013	38	9	26.32%	0.539	7
Wild Chinook Subyearlings	11/9/2013	40	6	17.50%	0.432	7
Wild Chinook Subyearlings	11/13/2013	29	2	10.34%	0.327	12
Wild Chinook Subyearlings	11/23/2013	25	3	16.00%	0.412	11
Wild Chinook Subyearlings	11/27/2013	24	0	4.17%	0.206	9
Wild Chinook Subyearlings	9/17/2015	39	4	12.82%	0.366	3

Appendix D. Historical Morphometric Data

Spring Chinook (2007-2016)

Trap Year	Brood Year	Origin/Species/Stage	Fork Length (mm)			Weight (g)			K-factor
			Mean	n	SD	Mean	n	SD	
2007	2005	Wild Yearling Smolt	93	173	8.5	8.6	173	2.2	1.1
2007	2005	Wild Yearling Precocial Parr	123	4	7.2	22.2	4	5.8	1.2
2007	2005	Hatchery Yearling Smolt*	76	208	17.9	5.4	203	4.2	1.2
2007	2005	Hatchery Yearling Precocial Parr	98	20	8.7	11.1	19	2.2	1.2
2007	2006	Wild Subyearling Fry	35	7	1.6	—	—	—	—
2007	2006	Wild Subyearling Parr	95	33	12.4	9.8	33	4.1	1.1
2008	2006	Wild Yearling Smolt	100	105	12.3	12.5	105	13.5	1.2
2008	2006	Wild Yearling Precocial Parr	126	9	8.4	22.8	9	4.1	1.1
2008	2006	Hatchery Yearling Smolt	117	229	12.7	18.7	228	9.8	1.2
2008	2006	Hatchery Yearling Precocial Parr	155	2	15.6	47.6	2	12.6	1.3
2008	2007	Wild Subyearling Fry	41	10	4.4	—	—	—	—
2008	2007	Wild Subyearling Parr	95	202	9.1	9.4	202	2.5	1.1
2009	2007	Wild Yearling Smolt	104	275	6.4	12.5	274	2.6	1.1
2009	2007	Wild Yearling Precocial Parr	134	5	7.0	28.5	2	2.7	1.2
2009	2007	Hatchery Yearling Precocial Parr	188	2	17.7	81.9	2	27.1	1.2
2009	2008	Wild Subyearling Fry	38	13	2.1	—	—	—	—
2009	2008	Wild Subyearling Parr	85	507	11.8	7.2	499	2.7	1.2
2010	2008	Wild Yearling Smolt	96	345	7.1	11.2	345	2.4	1.3
2010	2008	Wild Yearling Precocial Parr	130	15	10.3	26.4	15	6.6	1.2
2010	2009	Wild Subyearling Fry	40	31	3.6	—	—	—	—
2010	2009	Wild Subyearling Parr	87	166	12.6	7.7	166	3.0	1.2
2011	2009	Wild Yearling Smolt	99	64	7.7	11.3	64	2.8	1.2
2011	2009	Wild Yearling Precocial Parr	137	1	—	32.3	1	—	1.3
2011	2009	Hatchery Yearling Smolt	127	46	10.6	24.3	46	6.5	1.2
2011	2010	Wild Subyearling Fry	37	26	2.5	—	—	—	—
2011	2010	Wild Subyearling Parr	91	159	13.0	9.2	159	7.1	1.2
2012	2010	Wild Yearling Smolt	98	182	7.9	10.9	179	2.8	1.2
2012	2010	Wild Yearling Precocial Parr	123	13	12.7	22.4	13	6.5	1.2
2012	2011	Hatchery Subyearling Fry	84	29	4.4	6.5	2	2.3	1.1
2012	2011	Hatchery Subyearling Parr	110	25	7.4	14.6	25	3.3	1.1
2012	2011	Wild Subyearling Fry	35	18	2.7	—	—	—	—
2012	2011	Wild Subyearling Parr	91	315	10.1	8.8	288	2.8	1.2
2013	2011	Wild Yearling Smolt	103	20	7.0	12.3	20	3.0	1.1
2013	2011	Wild Yearling Precocial Parr	111	2	0.7	13.5	2	3.0	1.0
2013	2011	Hatchery Yearling Precocial Parr	155	4	17.4	43.4	4	17.8	1.2
2013	2012	Wild Subyearling Fry	40	77	8.1	—	—	—	—
2013	2012	Wild Subyearling Parr	84	445	12.3	6.7	444	4.7	1.1

2014	2012	Wild Yearling Smolt	94	43	7.0	9.4	43	2.2	1.1
2014	2012	Wild Yearling Precocial Parr	127	7	13.0	23.2	7	7.4	1.1
2014	2013	Wild Subyearling Fry	40	22	3.8	—	—	—	—
2014	2013	Wild Subyearling Parr	86	185	14.1	7.5	185	3.3	1.2
2015	2013	Wild Yearling Smolt	103	32	6.8	13.0	31	2.8	1.1
2015	2013	Wild Yearling Precocial Parr	145	2	13.4	35.2	2	11.4	1.1
2015	2014	Wild Subyearling Fry	38	11	3.3	0.5	10	0.2	0.9
2015	2014	Wild Subyearling Parr	96	151	7.5	10.4	148	6.3	1.2
2016	2014	Wild Yearling Smolt	106	3	1.5	12.4	3	0.3	1.1
2016	2015	Wild Subyearling Fry	38	50	3.0	0.46	49	0.3	0.8
2016	2015	Wild Subyearling Parr	89	147	10.7	8.29	147	2.8	1.1

[a] Includes residualized non-precocial smolts caught after June 30
[b] "Fry" classification based on age despite FL $\geq$ 50mm

Appendix N

Genetic Diversity of Upper Columbia River Summer Chinook Salmon

Genetic Structure of upper Columbia River Summer Chinook and Evaluation of the Effects of Supplementation Programs

by

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February 2011

Abstract

We investigated genetic relationships among temporally replicated collections of summer Chinook from the Wenatchee River, Methow River, and Okanogan River in the upper Columbia River basin. Samples from the Eastbank Hatchery – Wenatchee stock, Eastbank Hatchery – MEOK stock, and Wells Hatchery were also included in the analysis. Samples of natural- and hatchery-origin summer Chinook were analyzed and compared to determine if the supplementation program has had any impacts to the genetic structure of these populations. We also calculated the effective number of breeders for collection locations of natural- and hatchery-origin summer Chinook from 1993 and 2008. In general, population differentiation was not observed among the temporally replicated collection locations. A single collection from the Okanogan River (1993) was the only collection showing statistically significant differences. The effective number of breeders was not statistically different from the early collection in 1993 in comparison to the late collection in 2008. Overall, these analyses revealed a lack of differentiation among the temporal replicates from the same locations and among the collection from different locations, suggesting the populations have been homogenized or that there has been substantial gene flow among populations. Additional comparisons among summer-run and fall-run Chinook populations in the upper Columbia River were conducted to determine if there was any differentiation between Chinook with different run timing. These analyses revealed pairwise F_{ST} values that were less than 0.01 for the collections of summer Chinook to collections of fall Chinook from Hanford Reach, lower Yakima River, Priest Rapids, and Umatilla. Collections of fall Chinook from Crab Creek, Lyons Ferry Hatchery, Marion Drain, and Snake River had pairwise F_{ST} values that were higher in comparison to the collections of summer Chinook. The consensus clustering analysis did not provide good statistical support to the groupings, but did show relationships among collections based on geographic proximity. Overall the summer and fall run Chinook that have historically been

spawned together were not differentiated while fall Chinook from greater geographic distances were differentiated.

Introduction

The National Marine Fisheries Service (NMFS) recognizes 15 Evolutionary Significant Units (ESU) for Chinook salmon (*Oncorhynchus tshawytscha*) (Myers et al. 1998). The summer Chinook from the upper Columbia River are included in the Upper Columbia River Summer- and Fall-Run ESU, which encompasses all late-run (summer and fall), ocean-type Chinook salmon from the mainstem Columbia River and its tributaries (excluding the Snake River) between Chief Joseph and McNary Dams (Waknitz et al. 1995). Waknitz et al. (1995) concluded that due to high total abundance this ESU was not likely to become at risk from extinction. Yet, a majority of natural spawning activity was in the vicinity of Hanford Reach, and it was unclear whether natural production was self-sustaining given the vast summer Chinook artificial propagation efforts (Waknitz et al. 1995). Additionally, the Biological Review Team expressed concern about potential consequences to genetic and life-history traits from an increasing contribution of hatchery fish to total spawning escapement (Waknitz et al. 1995).

Artificial propagation of ocean-type Chinook from the middle/upper Columbia has been continuous since the implementation of the Grand Coulee Fish Maintenance Project (GCFMP) in 1939 (Myers et al. 1998). The US Fish and Wildlife Service established three hatchery programs for summer/fall Chinook during the GCFMP, Leavenworth NFH, Entiat NFH, and Winthrop NFH. The Washington Department of Fisheries (now Washington Department of Fish and Wildlife) followed with hatchery programs at Rocky Reach (1964), Wells Dam (1967), Priest Rapids (1974), and Eastbank (1990) facilities. Currently, only Leavenworth NFH and Winthrop NFH are not producing summer/fall Chinook. Entiat NFH has resumed production of summer/fall Chinook (Wells FH Stock) in 2009 and released their first yearling summer Chinook smolts in 2010. Since

1941, over 200 million ocean-type Chinook salmon have been released into the middle Columbia River Basin (Myers et al. 1998). Initially, the hatchery programs differentiated between early returning fish (i.e., stream-type) and later returning fish (i.e., ocean-type), but no distinction was made regarding the “summer” and “fall” components of the ocean-type stocks (Waknitz et al. 1995). Therefore, all Chinook salmon now migrating above Rock Island Dam descend from not only a mixture between different stocks from the basin, but also a mixture between the endemic summer and fall life histories. While hatchery protocols have been modified of late to maintain discreet summer and fall Chinook hatchery stocks (Utter et al. 1995; see also HGMP), physical evidence and genetic data suggests that summer and fall Chinook may have become homogenized. During the 1970’s and 80’s, given coded-wire tag recoveries, summer-run Chinook originating from above Rock Island Dam were believed to have spawned extensively with Hanford Reach and Priest Rapids Hatchery fish (Chapman 1994). Stuehrenberg et al. (1995) reported that 10% of their radio tagged summer Chinook were occupying typical fall-run spawning habitat on the mainstem Columbia river, and 25% of fall fish released from Priest Rapids were recovered as summers at (or above) Wells Hatchery. Genetic data reported by Marshall et al. (1995) and Waknitz et al. (1995) corroborate these observations, as genetic distances observed between summer and fall Chinook within the Upper Columbia River Summer- and Fall-Run ESU were essentially zero.

In response to the need for evaluation of the supplementation hatchery programs, both a monitoring and evaluation plan (DCPUD 2005; Murdoch and Peven 2005) and the associated analytical framework (Hays et al. 2006) were developed for the Habitat Conservation Plan’s Hatchery Committee through the joint effort of the fishery co-managers (CCT, NMFS, USFWS, WDFW, and YN) and Chelan County and Douglas County PUDs. These reports outline 10 objectives to be applied to various species assessing the impacts of hatchery operations mitigating the operation of Wells, Rocky Reach, and Rock Island hydroelectric projects. The present monitoring and evaluation study plan differs in scope from previous monitoring and evaluation projects proposed by WDFW Molecular Genetics Lab, in that it does not investigate a single watershed, but instead will encompass all summer Chinook stocks from the upper Columbia River including the three supplementation (Wenatchee, Methow, and Okanogan) and the harvest augmentation program (Wells summer Chinook). The objectives of this study were to determine if genetic diversity, population structure, and effective population size have changed in natural spawning populations as a result of the hatchery programs.

Materials and Methods

Collections

A total of 2,416 summer Chinook were collected from tributaries in the upper Columbia River basin and were analyzed (Table 1). Two collections of natural-origin summer Chinook from 1993 (prior to the supplementation program) were taken from the Wenatchee River Basin and were compared to collections of hatchery and natural-origin from 2006 and 2008 that were post-supplementation. Two pre-supplementation collections from the Methow River (1991 and 1993) were compared to post-supplementation collections from 2006 and 2008. Three pre-supplementation collections from the Okanogan River Basin (1991, 1992, and 1993) were compared with post-supplementation collections from 2006 and 2008. A collection of natural-origin summer Chinook from the Chelan River was also analyzed. Additionally, hatchery collections from Eastbank Hatchery (Wenatchee and MEOK stock) and Wells Hatchery were analyzed and compared to the in-river collections. Summer Chinook data (provided by the USFWS) from the Entiat River was also used for comparison. Lastly, data from eight collections of fall Chinook was compared to the collections of summer Chinook.

Laboratory Analyses

All laboratory analyses were conducted at the WDFW Genetics Laboratory in Olympia, Washington. Genomic DNA was extracted by digesting a small piece of fin tissue using the nucleospin tissue kits obtained from Macherey-Nagel following the recommended conditions in the user manual. Extracted DNA was eluted with a final volume of 100 µL.

Genotype information was generated using thirteen microsatellite markers following standard laboratory protocols and analysis methods. Descriptions of the loci assessed in this study and polymerase chain reaction (PCR) conditions are given in Table 2. PCR reactions were run with a thermal profile consisting of: denaturation at 95°C for 3 min, denaturation at 95°C for 15 sec, anneal for 30 sec at the appropriate temperature for each locus (Table 2), extension at 72°C for 1 min, repeat cycle (steps 2-4), final extension at 72°C for 30 minutes. PCR products were then processed with an ABI-3730 DNA Analyzer. Genotypes were visualized with a known size standard (GS500LIZ 3730) using GENEMAPPER 3.7 software. Alleles were binned in GENEMAPPER using the standardized allele sizes established for the Chinook GAPS dataset (Seeb et al. 2007).

Within-collection Statistical Analyses

Allele frequencies were calculated with CONVERT (version 1.3, Glaubitz 2003). Hardy-Weinberg proportions for all loci within each collection were calculated using GENEPOP (version 3.4, Raymond and Rousset 1995). Heterozygosity (observed and expected) was computed for each collection group using GDA (Lewis and Zaykin 2001).

Allelic richness and F_{IS} (Weir and Cockerham 1984) inbreeding coefficient were calculated using FSTAT (version 2.9.3.2, Goudet 2001). Linkage disequilibrium for each pair of loci in each collection was calculated using GENEPOP v 3.4 (10,000 dememorizations, 100 batches, and 5,000 iterations per batch). Pairwise estimates of genetic differentiation between collection groups were calculated using GENEPOP (version 3.4, Raymond and Rousset 1995). Statistical significance for the tests of Hardy-Weinberg proportions, linkage disequilibrium, and genotypic differentiation was evaluated using a Bonferroni correction of p-values to account for multiple, simultaneous tests (Rice 1989).

Between-collection Statistical Analyses

Pairwise F_{ST} estimates were computed to examine population structure among collections using GENETIX (version 4.03, Belkhir et al. 2001). This estimate uses allelic frequency data and departures from expected heterozygosity to assess differences between pairs of populations.

We used PHYLIP (version 3.5c, Felsenstein 1993) to calculate Cavalli-Sforza and Edwards (1967) pairwise chord distances between collections. Bootstrap calculations were performed using SEQBOOT followed by calculations of genetic distance using GENDIST. The NEIGHBOR-JOINING method of Saitou and Nei (1987) was used to generate the dendrograms and CONSENSE to generate a final consensus tree from the 1,000 replicates. The dendrogram generated in PHYLIP was plotted as an unrooted radial tree using TREEVIEW (version 1.6.6, Page 1996).

Effective Number of Breeders

The effective number of breeders (N_b) was estimated for pre- and post-supplementation program collections (where possible) to investigate whether hatchery programs had affected that genetic metric over the operational period. Wang (2009) derived an equation for effective size (N_e) as a function of the frequency of nested full-sib and half-sib families in a random collection of individuals.

$$\frac{1}{N_e} = \frac{1+3\alpha}{4}\left(Q_1 + Q_2 + 2Q_3\right) - \frac{\alpha}{2}\left(\frac{1}{N_1} + \frac{1}{N_2}\right) \qquad \text{(equation 10)}$$

Where α is a measure of the deviation of genotype frequencies from Hardy-Weinberg expectation (equivalent to Wright's (1969) F_{IS}), Q_i are the probabilities that a pair of offspring are paternal half sibs, maternal half sibs, or full sibs, respectively, and N_1 and N_2 are the number of male and female parents that generation, respectively. Genetic parameters (i.e., sibship distributions) were estimated for summer Chinook collections using algorithms implemented in COLONY (Jones and Wang 2009). To be clear, Wang's (2009) method as implemented here will estimate N_b, given multi-locus genotypes from each collection were partitioned by brood year for this analysis. To obtain an estimate of N_e each N_b value must be multiplied by the mean generation time of that population.

Results

Collections

A total of 2,350 individuals from 32 collections of temporally replicated samples (six locations) were analyzed (Table 1). Temporally replicated collections of hatchery and natural-origin samples were from the Wenatchee, Methow, and Okanogan Rivers. Temporally replicated hatchery-origin summer Chinook were from Wells Hatchery, Eastbank Hatchery - Wenatchee stock, and Eastbank Hatchery - Methow/Okanogan (MEOK) stock. A total of 232 of those individuals were excluded from any analyses because they failed to amplify at nine or more loci. Data for remaining 2,118 individuals were analyzed to assess differences between temporally replicated natural- and hatchery-origin summer Chinook for each location and to compare the differences among the different collection locations. Summer Chinook data from the temporally replicated collection locations were then combined and compared to fall Chinook data from the GAPS v.3.0 dataset.

Statistical Analyses

The population statistics (Hardy-Weinberg equilibrium and F_{IS}) calculated for each of the 32 temporally replicated collection locations were consistent with neutral expectations (i.e., no associations among alleles). Three collections did have a single locus that did not meet expectations (Wenatchee hatchery-origin 2006, Wells hatchery 2006, and Okanogan hatchery-origin 2009). Based on these results we suggest the collections represented randomly breeding groups and were not comprised of mixtures of individuals from different genetic source populations.

Population differentiation was assessed for each of the temporally replicated collections from within each location (Table 3). This analysis revealed the only significant difference observed within a collection location pertained to the collection from 1993 Okanogan River natural-origin samples. Because of the significant difference of this collection to the other temporal replicates it was not included in further analyses.

Given the absence of genetic differentiation observed among the temporally replicated collections, the 32 collections from the Wenatchee, Methow, and Okanogan River were combined to form three location-specific collections for analysis. Population differentiation metrics were compared among the composite Wenatchee, Methow, and Okanogan collections and eight other location-specific collections (11 locations total). Comparing all collections, there were a total of 39 significant genic test comparisons out of a total 496 (Table 4). Thirty-eight of the 39 statistically significant pairwise differences pertained to the Okanogan River and 2006 Wells Hatchery collections (Table 4). F_{ST} results are described further below.

Within-collection genetic metrics were estimated for the 11 location-specific collections of summer Chinook from the upper Columbia River, in addition to eight collections of fall Chinook (Table 1). The population statistics (Hardy-Weinberg equilibrium and F_{IS}) calculated for these collections of summer and fall

Chinook were also consistent with neutral expectations. The collection from Lyons Ferry Hatchery had one locus that did not meet expectations and the collections from Crab Creek and Marion Drain both had three loci that did not meet expectations.

The hatchery collections in general had a higher percentage of significantly linked loci; however the observed genetic diversity were similar for the natural and hatchery-origin collections. Analysis of allelic richness was based on 11 individuals per collection, the minimum number of individuals across all collections with complete multilocus genotypes. The largest number of linked loci occurred in the Crab Creek, Entiat River, and Okanogan natural-origin collections. Allelic richness was on average lower in the collections of summer Chinook (10.7) collections in comparison to the collections of fall Chinook (11.0).

Pairwise F_{ST} (Table 4) estimates revealed low levels of differentiation, where all observed F_{ST} values between the collections of summer Chinook were lower than 0.0096. There were 15 out of 28 comparisons between collections of summer Chinook that were significantly different from zero and occurred primarily from comparisons of the Okanogan River (hatchery and natural-origin) and Wells Hatchery to all other collections. The collection of Eastbank Hatchery – MEOK stock was differentiated from the Wenatchee River natural-origin and Entiat River collections. The collection from the Chelan River had a small sample size of 23 individuals and only differentiated from the Eastbank Hatchery – MEOK stock. F_{ST} estimates regarding pairwise comparisons between each of four fall Chinook collection locations (Crab Creek, Lyons Ferry Hatchery, Marion Drain, and Snake River) to all other collections were significantly different from zero (Table 5). Pairwise comparisons for three other fall Chinook collections (Hanford Reach, lower Yakima River, and Umatilla River) to the collections of summer Chinook were significantly different from zero (Table 6). The only fall Chinook collection that was not significantly differentiated from all of the summer Chinook was Priest Rapids.

The relative genetic relationships among the test groups were assessed using the consensus clustering analysis (Figure 1). Statistical support for the dendrogram topology (i.e., tree shape) was low regarding the branching that separated the collections of summer Chinook from the upper Columbia River. The collections of fall Chinook; however were supported with bootstrap support over 76% with the exception of three collections (lower Yakima River, Crab Creek, and Umatilla River). In other words, 760 of the 1000 bootstrap replicates supported the placement of the node separating summer and fall collections. The collection from the Chelan River had bootstrap support of 68%; however the sample size for that collections was small (N = 23). Even though the bootstrap support was low among the collections of summer Chinook there was concordance between geography and genetic distance.

Where comparisons were possible between pre- and post-supplementation program collections, the effective number of breeders (N_b) estimated to have comprised those collections were slightly lower for contemporary (2008) collections; however in all cases the 95% confidence intervals overlapped between historical and contemporary collections, suggesting statistical equivalency. Regarding Wenatchee River collections, the point estimates of N_b ranged from 134 (08FU) to 190 (93DD), where all collections had overlapping confidence intervals (Table 7). The upper bound of the 1989 brood year for collection 93DD was very large, suggesting the sample size was insufficient for properly inferring the sibship distribution within the collection. Comparing the Okanogan natural collections 93ED and 08GA, the estimated N_b were 142 (CI 102 – 203) and 127 (CI 92 – 180), respectively. For the Eastbank Hatchery MEOK stock comparisons, the N_b estimated for the 93DF collection was 171 (CI 129 – 229), as compared to the 166 (CI 126 – 226) estimated for collection 08MO. In all cases, the estimated N_b can be converted to effective population size (N_e) by multiplying the estimate by the mean generation time.

Discussion

The collections of summer Chinook populations from the upper Columbia River are of interest because census sizes are reduced below historic levels and are the subject of mitigation and supplementation hatchery programs. Concern over the impacts of hatchery supplementation programs on the genetic integrity of natural-origin populations led to our primary objective, which was to evaluate genetic metrics for temporally replicated collections of summer Chinook in the upper Columbia River pre and post hatchery supplementation. A similar analysis by Kassler and Dean (2010) was conducted on spring Chinook in the Tucannon River to evaluate the effects of a supplementation and captive brood program on natural-origin stocks. Additionally, upper Columbia River spring Chinook supplementation programs (Blankenship et al. 2007; Small et al. 2007), spring and fall Chinook populations in the Yakima Basin (Kassler et al. 2008), and a potentially unique population of fall Chinook in Crab Creek (Small et al. 2010) have been evaluated. In the present analysis of summer Chinook populations, collections of pre- and post- supplementation summer Chinook were collected from the Wenatchee River, Methow River, and Okanogan River Basins and analyzed to determine if the genetic profile has changed as a result of the supplementation program. Analysis was then conducted on the collections of summer run to compare the fall run Chinook collections in the upper Columbia River basin.

Allozyme analyses of these three summer run Chinook stocks in the upper Columbia River have identified that each stock was distinct, with a closer relationship detected between the Wenatchee and Methow Rivers (WDF and WDW 1993, Marshall 2002). Wenatchee summer Chinook are thought to be a mixture of native summer Chinook and Chinook from the Grand Coulee Fish Maintenance Project (GCFMP). The goal of the GCFMP project between 1939 and 1943 was to trap migrating Chinook salmon at Rock Island dam (75 miles below Grand Coulee) and homogenize the populations, which reduced the genetic uniqueness of the distinct tributary populations present in the upper Columbia River.

We found allele frequencies for individual temporally replicated hatchery- and natural-origin collection locations of adult summer Chinook were not significantly different from that expected of a single underlying population, except for one collection (1993 Okanogan natural-origin; Table 3). This collection was differentiated to the Okanogan collections in 2006 and 2008; however it was not differentiated from the collection in 1992. The Okanogan collection from 1992 was also not differentiated to any other collection; therefore the difference in the collection from Okanogan 1993 was likely not an indication of genetic change from pre supplementation to post supplementation. The collection was however dropped from further analyses so as to not confuse interpretation of results. The lack of allelic differentiation observed among the temporally replicated collections was interpreted as the genetic metrics from each location in the early 1990's did not differ from the samples collected in 2008. Spanning a few generations, allele frequencies are not expected to change for large populations at genetic equilibrium. In contrast, changes in allele frequencies of small populations may occur due to the stochastic sampling of genes from one generation to the next (i.e., genetic drift).

A second round of analyses was conducted to evaluate the genetic relationships of the summer run collections (temporal collections were combined) with data from the Entiat River, Chelan River, and eight collections of fall Chinook. Assessment of the relationship between the summer run collections in comparison to each other provided very little evidence of genetic differentiation between these collections. While population differentiation did show some significant differences between the Okanogan River and Wells Hatchery collections, all of the pairwise F_{ST} values were below 0.003. Meaning that a very small proportion of the observed genetic variation could be attributed to restrictions in gene flow (i.e., population structure)

The comparison of the hatchery-origin collections revealed a lack of differentiation between the Eastbank Hatchery – Wenatchee stock, Eastbank Hatchery – MEOK stock, and the Wells Hatchery (with exception of the 2006 collection). The genetic similarity or low level of genetic differentiation among these stocks suggests that there has been an integration of natural- and hatchery-origin summer Chinook in the upper Columbia River or a lack of ancestral genetic difference. The difference of the 2006 Wells Hatchery collection to the other collections is most likely a result of sampling effect because of the lack of differentiation among the stocks in the basin. If the 2006 collection had been mixed from different sources of summer Chinook there would not be a detectable level of differentiation as was seen with the 2006 sample.

The analyses to compare summer and fall Chinook collections provided some understanding on the genetic relationships of Chinook with different run timings in the upper Columbia River basin. Historically, the hatchery programs in the upper Columbia River were separated into groups of the early returning fish (i.e., stream-type) and later returning fish (i.e., ocean-type), but the programs did not sort individuals identified as "summer" or "fall" stocks (Waknitz et al. 1995). Now all Chinook salmon that are migrating above Rock Island Dam descend from a mixture of different stocks from the upper Columbia River basin, but also a mixture between the endemic summer and fall life histories.

Small et al. (2010) conducted an analysis on summer run and fall run Chinook in the upper Columbia River and concluded that Crab Creek Chinook in the upper Columbia River were genetically distinct to all other fall and summer run Chinook stocks that were analyzed. They did note a departure from Hardy Weinberg expectation as a result of a null allele at the microsatellite locus *Ogo-4* and a higher linkage disequilibrium value due to the inclusion of family groups in one of their samples. Kassler et al. (2008) found differentiation among spring and fall Chinook populations in the Yakima River.

The tests of pairwise F_{ST} indicated a very low level of genetic differentiation (less than one percent difference) between collections of summer-run Chinook and fall-run Chinook. The range of pairwise F_{ST} values for comparisons between the summer run and fall run collections was 0.0016 – 0.0248. The larger values from the range were associated to the collections from Crab Creek, Lyons Ferry Hatchery, and Marion Drain. Studies by Kassler et al. (2008) and Small et al. (2010) have documented differences among the populations of these collections to others within the upper Columbia River basin. The low pairwise F_{ST} values between Priest Rapids and Hanford Reach collections and the summer run collections were not surprising because summer-run Chinook originating from above Rock Island Dam were believed to have spawned extensively with Hanford Reach and Priest Rapids Hatchery fish during the 1970's and 80's (Chapman 1994). The lack of differentiation among the summer and fall stocks in the Columbia River was also identified by Utter et al. (1995) and the HGMP where they state physical evidence and genetic data suggests that summer and fall Chinook may have become homogenized.

Despite low levels of statistical bootstrap support for dendrogram topology (i.e., tree shape), there was concordance observed between geographic location and the genetic relationships among the summer and fall Chinook populations. The collections from the Okanogan (hatchery and natural-origin) did separate out with collections from Wells Dam Hatchery, Entiat River, and Eastbank Hatchery – MEOK stock, and were next to a group of the Methow and Wenatchee collections. The fall Chinook populations are also separated to the summer collections and the position of all but three of these collections (lower Yakima River, Crab Creek, and Umatilla River) were statistically supported. The geographic proximity of the fall collections seemed to follow the observed pattern in this dendrogram. The relationship of the Snake River and Lyons Ferry Hatchery in proximity to the collection from Marion Drain was not surprising while the relationship between Priest Rapids and Hanford Reach was easily a result of the stocking practices of fall Chinook in the 1970 and 1980's.

A secondary objective of this study was to determine if the effective population size of upper Columbia River summer Chinook populations had changed over time due to supplementation efforts. We observed that the number of effective breeders in the collections from 1993 and 2008 has not changed thus providing reason to believe that the genetic diversity of summer Chinook in the upper Columbia River has not been altered through the supplementation program.

Acknowledgements

Chelan County PUD, Grant County PUD, and Washington State General Funds provided funding for this project. Cherril Bowman (WDFW – Molecular Genetics Laboratory) processed samples in the laboratory. Maureen (Mo) Small provided data for some collections and discussion of the analyses. USFWS provided data from the Entiat River.

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Table 1. Samples of adult hatchery- and natural-origin summer and fall Chinook that were analyzed from the upper Columbia River. Total number of individuals that were analyzed / individuals with data for 9 or more loci that were included in the analysis. Collection statistics (allelic richness, linkage disequilibrium (before and after Bonferroni correction), F_{IS}, heterozygosity (H_O and H_E)) and p-values for deviations from Hardy-Weinberg equilibrium (HWE). P-values were defined as significant after implementation of Bonferroni correction for multiple tests (Rice 1989).

WDFW GSI code[a]	Collection location	N =	Allelic Richness[b]	Linkage Disequilibrium[c]	F_{IS} (p-value)[d]	H_O	H_E
93DD	Wenatchee River upstream of Tumwater Dam - natural origin	51 / 45					
93DE	Wenatchee River downstream of Tumwater Dam - natural origin	88 / 88					
06CQ	Wenatchee River upstream of Tumwater Dam - natural origin	95 / 86					
06CR	Wenatchee River downstream of Tumwater Dam - natural origin	95 / 82					
08FV	Wenatchee River upstream of Tumwater Dam - natural origin	95 / 82					
08FW	Wenatchee River downstream of Tumwater Dam - natural origin	95 / 87					
	Wenatchee River - Natural origin combined	**519 / 470**	**10.7**	**17 / 4**	**0.001 (0.403)**	**0.8504**	**0.8513**
06CP	Wenatchee River - hatchery origin	95 / 70					
08FU	Wenatchee River - hatchery origin	95 / 83					
	Wenatchee River - Hatchery origin combined	**190 / 153**	**10.6**	**18 / 6**	**0.018 (0.013)**	**0.8409**	**0.8561**
93EC	Methow River - natural origin	27 / 27					
06CT	Methow River - natural origin	95 / 90					
08FY	Methow River - natural origin	95 / 88					
09CO	Methow River - natural origin	91 / 80					
	Methow River - Natural origin combined	**308 / 285**	**10.7**	**4 / 1**	**0.006 (0.160)**	**0.8506**	**0.8554**
06CS	Methow River - hatchery origin	14 / 8					
08FX	Methow River - hatchery origin	21 / 18					
09CP	Methow River - hatchery origin	19 / 18					
	Methow River - Hatchery origin combined	**54 / 44**	**10.8**	**11 / 2**	**-0.003 (0.593)**	**0.8553**	**0.8523**

Table 1 continued.							
92FM	Okanogan River - natural origin	49 / 46					
93ED*	Okanogan River - natural origin	103 / 87					
06CV	Okanogan River - natural origin	95 / 88					
08GA	Okanogan River - natural origin	95 / 92					
09CN	Okanogan River - natural origin	133 / 126					
	Okanogan River - Natural origin combined	**475 / 439**	**10.8**	**9 / 4**	**0.003 (0.304)**	**0.8563**	**0.8596**
* - not included in the combined dataset							
06CU	Okanogan River - hatchery origin	58 / 49					
08FZ	Okanogan River - hatchery origin	19 / 18					
09CM	Okanogan River - hatchery origin	117 / 107					
	Okanogan River - hatchery origin combined	**194 / 174**	**10.8**	**31 / 10**	**-0.011 (0.920)**	**0.8678**	**0.8586**
91FL	Wells Hatchery	68 / 42					
92FK	Wells Hatchery	25 / 23					
93DG	Wells Hatchery	11 / 9					
06DM	Wells Hatchery	95 / 91					
08HY	Wells Hatchery	95 / 91					
	Wells Hatchery combined	**294 / 256**	**10.7**	**8 / 3**	**-0.001 (0.529)**	**0.8670**	**0.8665**
08MN	**Eastbank Hatchery - Wenatchee River stock**	**95 / 90**	**10.7**	**6 / 1**	**0.020 (0.024)**	**0.8326**	**0.8498**
92FO	Eastbank Hatchery - Methow / Okanogan (MEOK) stock	36 / 33					
93DF	Eastbank Hatchery - Methow / Okanogan (MEOK) stock	90 / 86					
08MO	Eastbank Hatchery - Methow / Okanogan (MEOK) stock	95 / 88					
	Eastbank Hatchery - MEOK stock combined	**221 / 207**	**10.7**	**2 / 0**	**-0.005 (0.782)**	**0.8647**	**0.8604**
		2,350 / 2,118					

Table 1 continued.

06KN	**Chelan River**	**70 / 23**	**10.3**	**11 / 0**	**0.027 (0.118)**	**0.8334**	**0.8556**
Data provided by USFWS							
	Entiat River - summer Chinook	**190**	**10.9**	**33 / 10**	**0.008 (0.119)**	**0.8553**	**0.8625**
Data from Small et al. (2010)							
08EH	Crab Creek	108					
09AZ	Crab Creek	291					
	Crab Creek	**399**	**10.5**	**35 / 14**	**0.018 (0.000)**	**0.8519**	**0.8676**
GAPS v.3.0 data							
	Priest Rapids Hatchery - fall Chinook	**81**	**11.1**	**3 / 2**	**0.015 (0.079)**	**0.8591**	**0.8723**
	Hanford Reach - fall Chinook	**220**	**11.3**	**4 / 0**	**0.010 (0.068)**	**0.8661**	**0.8746**
	Umatilla - fall Chinook	**96**	**11.2**	**17 / 6**	**-0.003 (0.623)**	**0.8719**	**0.8693**
	lower Yakima River - fall Chinook	**103**	**11.0**	**3 / 1**	**0.000 (0.511)**	**0.8724**	**0.8721**
	Marion Drain - fall Chinook	**190**	**10.8**	**9 / 4**	**0.022 (0.001)**	**0.8586**	**0.8782**
	Lyons Ferry Hatchery - fall Chinook	**186**	**10.6**	**7 / 4**	**0.013 (0.033)**	**0.8527**	**0.8641**
	Snake River - fall Chinook	**521**	**11.1**	**0 / 0**	**-0.001 (0.634)**	**0.8720**	**0.8708**
		NA / 2,009					

[a] - Year that samples were collected is identifed by the two numbers in the WDFW GSI code

[b] - based on a minimum of 11 diploid individuals

[c] - adjusted alpha p-value = 0.0006

[d] - adjusted alpha p-value = 0.0002

Table 2. PCR conditions and microsatellite locus information (number alleles/locus and allele size range) for multiplexed loci used for the analysis of Chinook. Also included are the observed and expected heterozygosity (H_o and H_e) for each locus.

PCR Conditions			Locus statistics		Heterozygosity		
Poolplex	Locus	Dye Label	# Alleles/ Locus	Allele Size Range (bp)	H_o	H_e	References
Ots-M	*Ots-201b*	blue	49	137 - 334	0.9474	0.9544	Unpublished
	Ots-208b	yellow	56	154 - 378	0.9523	0.9672	Greig et al. 2003
	Ssa-408	red	32	184 - 308	0.9177	0.9214	Cairney et al. 2000
Ots-N	*Ogo-2*	red	22	206 - 260	0.8526	0.8673	Olsen et al. 1998
Ots-O	*Ogo-4*	blue	20	128 - 170	0.6694	0.7028	Olsen et al. 1998
	Ots-213	yellow	45	178 - 370	0.9430	0.9525	Greig et al. 2003
	Ots-G474	red	16	152 - 212	0.6816	0.6838	Williamson et al. 2002
Ots-R	*Ots-3M*	blue	15	128 - 158	0.7854	0.7938	Banks et al. 1999
	Omm-1080	green	54	162 - 374	0.9517	0.9670	Rexroad et al. 2001
Ots-S	*Ots-9*	red	9	99 - 115	0.6531	0.6543	Banks et al. 1999
	Ots-212	blue	33	123 - 251	0.9205	0.9360	Greig et al. 2003
Ots-T	*Oki-100*	blue	50	164 - 361	0.9500	0.9567	Unpublished
	Ots-211	red	34	188 - 327	0.9325	0.9414	Greig et al. 2003

Table 3. Tests of population differentiation for temporal collections of summer Chinook from natural and hatchery-origin populations in the upper Columbia River. P-values that are highlighted grey are significantly different after Bonferroni correction (Rice 1989). Adjusted alpha p-value was 0.0001 . The H and W in the collection identifier is for wild or hatchery-origin and the two digit number identifes the year samples were collected.

Wenatchee River

	WenW93U	WenW93D	WenH06	WenW06U	WenW06D	WenH08	WenW08U	WenW08D
WenW93U	****							
WenW93D	0.0162	****						
WenH06	0.0033	0.0102	****					
WenW06U	0.3039	0.1642	0.4795	****				
WenW06D	0.0261	0.0160	0.0678	0.5300	****			
WenH08	0.1126	0.0708	0.0073	0.4359	0.0893	****		
WenW08U	0.2115	0.1148	0.4191	0.7243	0.3830	0.8856	****	
WenW08D	0.1915	0.0014	0.7047	0.4928	0.1671	0.7755	0.7665	****

D - collection was downstream of Tumwater Dam; U - collection was upstream of Tumwater Dam

Methow River

	MetW93	MetH06	MetW06	MetH08	MetW08	MetW09	MetH09
MetW93	****						
MetH06	0.3962	****					
MetW06	0.5481	0.4688	****				
MetH08	0.1408	0.1192	0.2052	****			
MetW08	0.8219	0.8937	0.6156	0.3779	****		
MetW09	0.2564	0.4282	0.2502	0.0328	0.7309	****	
MetH09	0.1543	0.5678	0.0547	0.0017	0.0098	0.0073	****

Okanogan River

	OkanW92	OkanW93	OkanH06	OkanW06	OkanH08	OkanW08	OkanH09	OkanW09
OkanW92	****							
OkanW93	0.0066	****						
OkanH06	0.0193	0.0000	****					
OkanW06	0.2843	0.0082	0.0031	****				
OkanH08	0.1290	0.1106	0.0652	0.7329	****			
OkanW08	0.0106	0.0029	0.0082	0.4075	0.7396	****		
OkanH09	0.0187	0.0001	0.0094	0.0551	0.2214	0.0281	****	
OkanW09	0.0527	0.0000	0.0024	0.7130	0.0262	0.0065	0.0002	****

Table 3 continued.

Wells Dam Hatchery

	Wells91	Wells92	Wells93	Wells06	Wells08
Wells91	****				
Wells92	0.5863	****			
Wells93	0.0490	0.0784	****		
Wells06	0.0089	0.0100	0.0542	****	
Wells08	0.0819	0.1088	0.2552	0.0256	****

Eastbank Hatchery - Wenatchee and MEOK stocks

	EBHWen08	EBHME92	EBHME93	EBHME08
EBHWen08	****			
EBHME92	0.8681	****		
EBHME93	0.0251	0.8661	****	
EBHME08	0.0086	0.9563	0.1895	****

Table 4. F_{ST} pairwise comparisons and genotypic tests of differentiation for hatchery- and natural-origin summer Chinook from the upper Columbia River. Above the diagonol are the F_{ST} values and below are p-values for the test of genotypic differentiation. Non-significant p-values for the result of the genotypic differentiation test are in bold type and F_{ST} values that are not significantly different from zero are in bold type.

	Wenatchee Hatchery	Wenatchee Natural	Methow Hatchery	Methow Natural	Okanogan Hatchery	Okanogan Natural	Wells Hatchery	Eastbank Wenatchee stock	Eastbank MEOK stock	Entiat River	Chelan River
Wenatchee Hatchery	****	**0.0000**	**0.0011**	**0.0000**	**0.0013**	**0.0010**	0.0015	**0.0004**	**0.0007**	**0.0004**	**0.0072**
Wenatchee Natural	**0.4351**	****	**0.0016**	**0.0000**	0.0014	0.0016	0.0024	**0.0006**	0.0012	0.0009	**0.0068**
Methow Hatchery	**0.3800**	**0.0205**	****	**0.0012**	0.0029	**0.0008**	**0.0027**	**0.0014**	**0.0022**	**0.0019**	**0.0078**
Methow Natural	**0.2237**	**0.6566**	**0.1502**	****	**0.0011**	0.0011	0.0013	**0.0007**	**0.0007**	**0.0008**	**0.0053**
Okanogan Hatchery	0.0001	0.0000	**0.0364**	**0.0008**	****	**0.0010**	**0.0014**	0.0029	**0.0000**	**0.0007**	**0.0055**
Okanogan Natural	0.0000	0.0000	**0.1755**	0.0000	**0.0003**	****	0.0016	0.0023	**0.0005**	**0.0008**	**0.0049**
Wells Hatchery	0.0000	0.0000	**0.0129**	0.0000	0.0000	0.0000	****	0.0036	**0.0006**	**0.0008**	**0.0041**
Eastbank Wenatchee	**0.5261**	**0.4102**	**0.1215**	**0.8404**	**0.0015**	0.0000	0.0000	****	**0.0018**	0.0030	0.0096
Eastbank MEOK stock	**0.0485**	0.0000	**0.4246**	**0.0009**	**0.5786**	**0.0051**	0.0000	**0.0065**	****	**0.0005**	**0.0039**
Entiat River	**0.0565**	0.0000	**0.1795**	**0.0044**	**0.0005**	0.0000	**0.0032**	**0.0039**	**0.0042**	****	**0.0052**
Chelan River	**0.0091**	**0.0026**	**0.0182**	**0.0156**	**0.0048**	**0.0030**	**0.0066**	**0.0059**	**0.0493**	**0.0617**	****

Table 5. F_{ST} pairwise comparisons and genotypic tests of differentiation for fall Chinook. Above the diagonol are the F_{ST} values and below are p-values for the test of genotypic differentiation. Non-significant p-values for the result of the genotypic differentiation test are in bold type and F_{ST} values that are not significantly different from zero are in bold type.

	Crab Creek	Hanford Reach Fall	Lyons Ferry Hatchery Fall	lower Yakima River Fall	Marion Drain Fall	Priest Rapids Fall	Umatilla River Fall	Snake River Fall
Crab Creek	****	0.0087	0.0134	0.0079	0.0143	0.0107	0.0073	0.0097
Hanford Reach Fall	0.0000	****	0.0077	**0.0000**	0.0064	**0.0000**	**0.0000**	0.0022
Lyons Ferry Hatchery Fall	0.0000	0.0000	****	0.0063	0.0074	0.0092	0.0062	0.0029
lower Yakima River Fall	0.0000	**0.4140**	0.0000	****	0.0054	**0.0000**	**0.0000**	0.0018
Marion Drain Fall	0.0000	0.0000	0.0000	0.0000	****	0.0067	0.0061	0.0060
Priest Rapids Fall	0.0000	**0.0695**	0.0000	**0.0083**	0.0000	****	**0.0000**	0.0027
Umatilla River Fall	0.0000	**0.4879**	0.0000	**0.4896**	0.0000	**0.2539**	****	0.0011
Snake River Fall	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	****

Table 6. F_{ST} pairwise comparisons and genotypic tests of differentiation for hatchery- and natural-origin summer Chinook from the upper Columbia River and fall Chinook. Above the diagonol are the F_{ST} values and below are p-values for the test of genotypic differentiation. Non-significant p-values for the result of the genotypic differentiation test are in bold type and F_{ST} values that are not significantly different from zero are in bold type.

Population Differentiation

	Wenatchee Hatchery	Wenatchee Natural	Methow Hatchery	Methow Natural	Okanogan Hatchery	Okanogan Natural	Wells Hatchery	Eastbank Wenatchee stock	Eastbank MEOK stock	Entiat River	Chelan River
Crab Creek	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Hanford Reach Fall	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	**0.0349**
Lyons Ferry Hatchery Fall	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
lower Yakima River Fall	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	**0.0074**
Marion Drain Fall	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Priest Rapids Fall	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	**0.0642**
Umatilla River Fall	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	**0.0579**
Snake River Fall	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Table 6 continued.

Pairwise F_{ST}

	Crab Creek	Hanford Reach Fall	Ferry Hatchery	Yakima River	Marion Drain Fall	Priest Rapids Fall	Umatilla River Fall	Snake River Fall
Wenatchee Hatchery	0.0158	0.0054	0.0180	0.0056	0.0153	**0.0025**	0.0053	0.0103
Wenatchee Natural	0.0162	0.0059	0.0185	0.0063	0.0157	0.0030	0.0059	0.0102
Methow Hatchery	0.0191	0.0104	0.0248	0.0095	0.0220	0.0069	0.0107	0.0165
Methow Natural	0.0148	0.0057	0.0182	0.0051	0.0148	0.0033	0.0055	0.0101
Okanogan Hatchery	0.0146	0.0041	0.0166	0.0042	0.0151	**0.0016**	0.0041	0.0082
Okanogan Natural	0.0163	0.0064	0.0187	0.0062	0.0170	0.0035	0.0068	0.0113
Wells Hatchery	0.0120	0.0051	0.0135	0.0044	0.0120	0.0028	0.0046	0.0077
Wenatchee stock	0.0184	0.0073	0.0203	0.0074	0.0167	0.0047	0.0084	0.0128
Eastbank MEOK stock	0.0128	0.0036	0.0143	0.0038	0.0135	**0.0019**	0.0038	0.0079
Entiat River	0.0147	0.0059	0.0176	0.0057	0.0156	0.0028	0.0056	0.0100
Chelan River	0.0074	**0.0046**	0.0110	**0.0040**	0.0160	**0.0047**	**0.0035**	0.0072

Table 7. Effective number of breeders per brood year with the largest number of samples of summer Chinook in the upper Columbia River. Brood years with sample size less than 19 individuals (shown in bold type) were not analyzed with exception of the 2008 Wells Hatchery collection. A comparison could not be made between an early and late collection from Wells Hatchery.

WDFW Code	Collection Location	Sample Size	Nb =	CI95(L) =	CI95(U) =
93DD[A]	Wenatchee Natural - upstream	23 / 19	152 / 190	77 / 87	616 / 2,147,483,647
08FV	Wenatchee Natural - upstream	56	162	112	249
93DE[A]	Wenatchee Natural - downstream	39 / 34	145 / 152	94 / 95	256 / 302
08FW	Wenatchee Natural - downstream	67	140	105	199
08FU	Wenatchee Hatchery	60	134	90	213
93EC[A]	Methow Natural	**10 / 15**	---	---	---
08FY	Methow Natural	62	150	106	218
08FX	Methow Hatchery	**9**	---	---	---
93ED	Okanogan Natural	69	142	102	203
08GA	Okanogan Natural	59	127	92	180
08FZ	Okanogan Hatchery	**16**	---	---	---
93DG	Wells Hatchery	**6**	---	---	---
08HY[B]	Wells Hatchery	24 / 39	---	---	---
08MN	Eastbank Hatchery - Wenatchee	88	190	144	263
93DF	Eastbank Hatchery - MEOK	84	171	129	229
08MO	Eastbank Hatchery - MEOK	88	166	126	226

[A] - calculations were made for samples from brood year 1988 / brood year 1989

[B] - samples were collected from brood year 2003 / brood year 2004

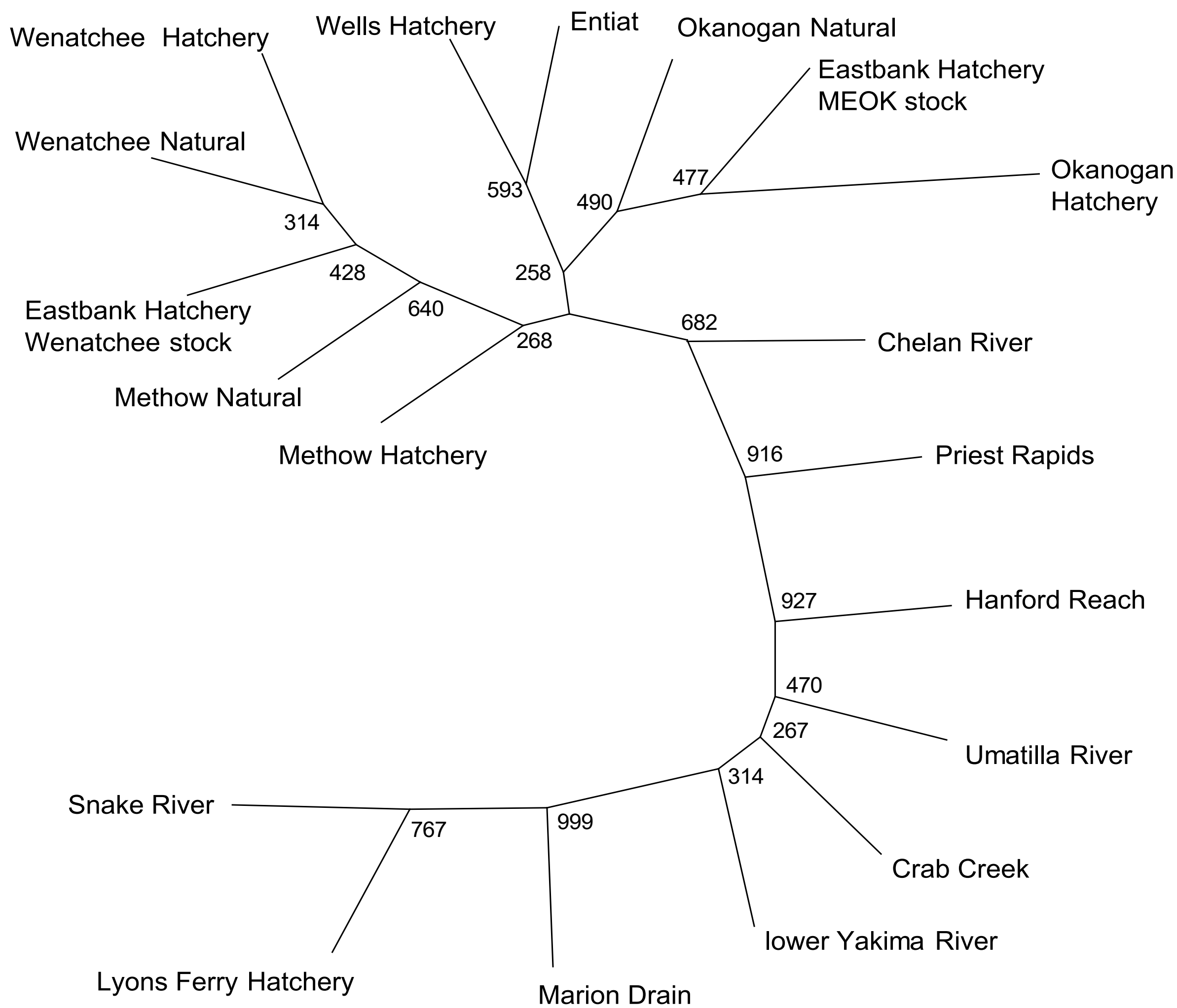

Figure 1. Relationship of natural- and hatchery-origin Chinook collections from the upper Columbia River basin using Cavalli-Sforza and Edwards (1967) chord distance. Bootstrap values are shown at each node.

Appendix O

Summer Chinook Spawning Ground Surveys in the Methow River Basin and Chelan River, 2016

BioAnalysts, Inc.℠
4725 North Cloverdale Road, Ste. 102
Boise ID 83713

March 10, 2017

To: Chelan and Grant Public Utility Districts

From: Denny Snyder and Mark Miller

Re: 2016 Summer Chinook Spawning Ground Surveys in the Methow Basin and Chelan River.

The purpose of this memo is to provide information on the supplemented natural spawning population of summer Chinook in the Methow and Chelan River basins. This work is part of a larger effort focused on monitoring and evaluating Grant and Chelan PUDs' hatchery supplementation programs. The tasks and objectives associated with implementing Grant and Chelan PUDs' Hatchery M&E Plan for 2016 are outlined in Hillman et al. (2013). In 2016, The Okanogan Basin was surveyed by the Colville Confederated Tribes (CCT).

METHODS

Spawning ground surveys were conducted by foot and raft beginning the third week of September and ending late-November. We did not use aerial surveys on the Methow River because past work has demonstrated that ground counts were more accurate than aerial surveys (Miller and Hillman 1997). Ground surveys were used to provide more accurate counts and a complete census of Chinook redds within their spawning distribution. Observers floated or walked through sampling reaches and recorded the location and numbers of redds each week (see Figures 1 and 2). Observers recorded the date, water temperature, river mile, and prepared a drawing of the area where redds were located. A different symbol was used each week to record the number of new and incomplete redds.

To maintain consistency, at least one observer surveyed the same stream reach on successive dates. In areas where numerous summer Chinook spawn, we constructed detailed maps of the river and used the cell-area-method (Hamilton and Bergersen 1984) to identify the number of redds within each cell. Cells were bound by noticeable landmarks along the banks (e.g., bridges or trees) or at stream habitat boundaries (e.g., transitions between pools and riffles). The number of redds were then recorded in the corresponding grid on the map. When possible, observers estimated the number of redds in a large disturbed area by counting females that defended redds. We assumed that the area or territory defended by a female was one redd.

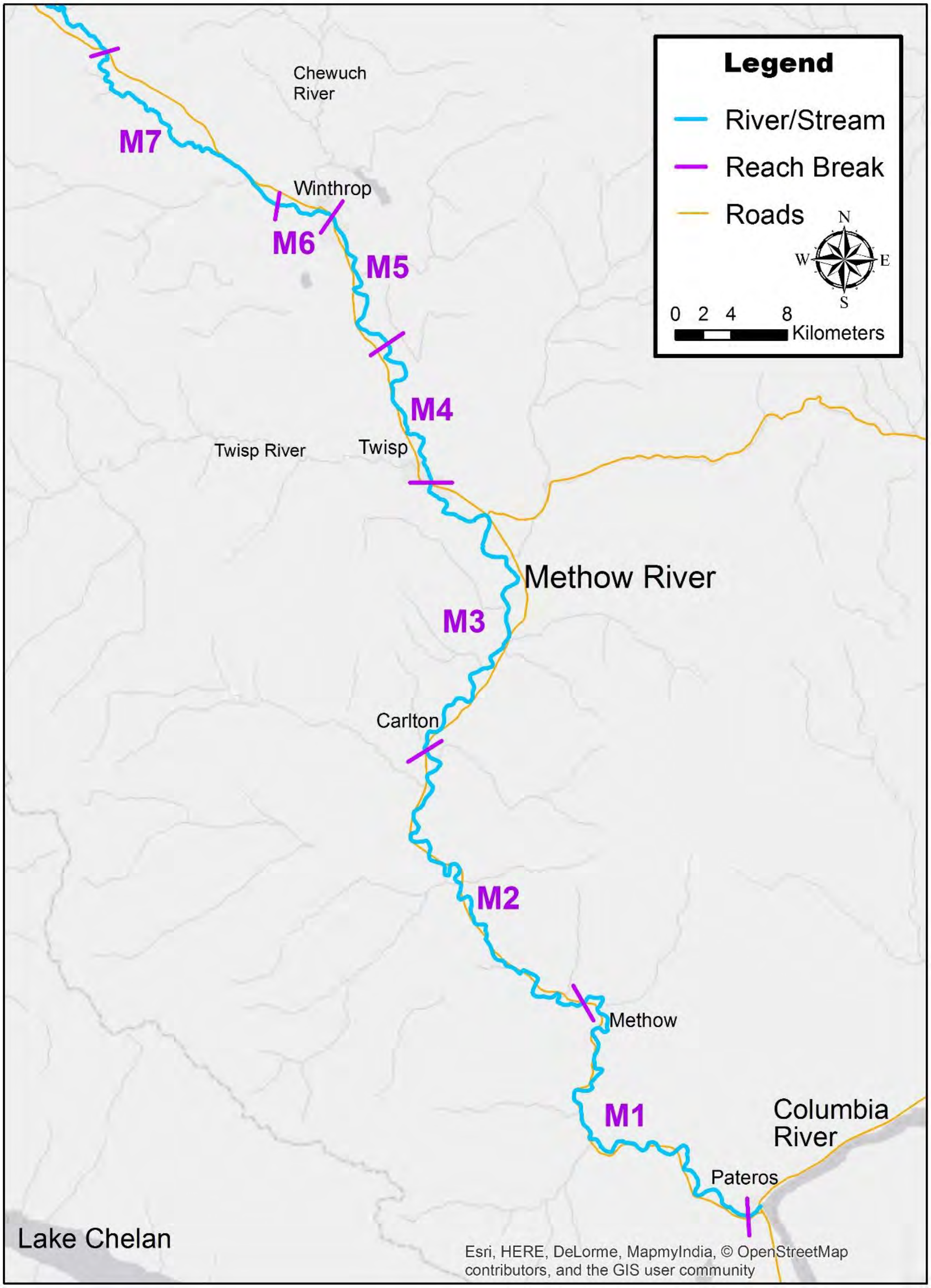

Figure 1. Summer Chinook survey reaches on the Methow River, 2016,

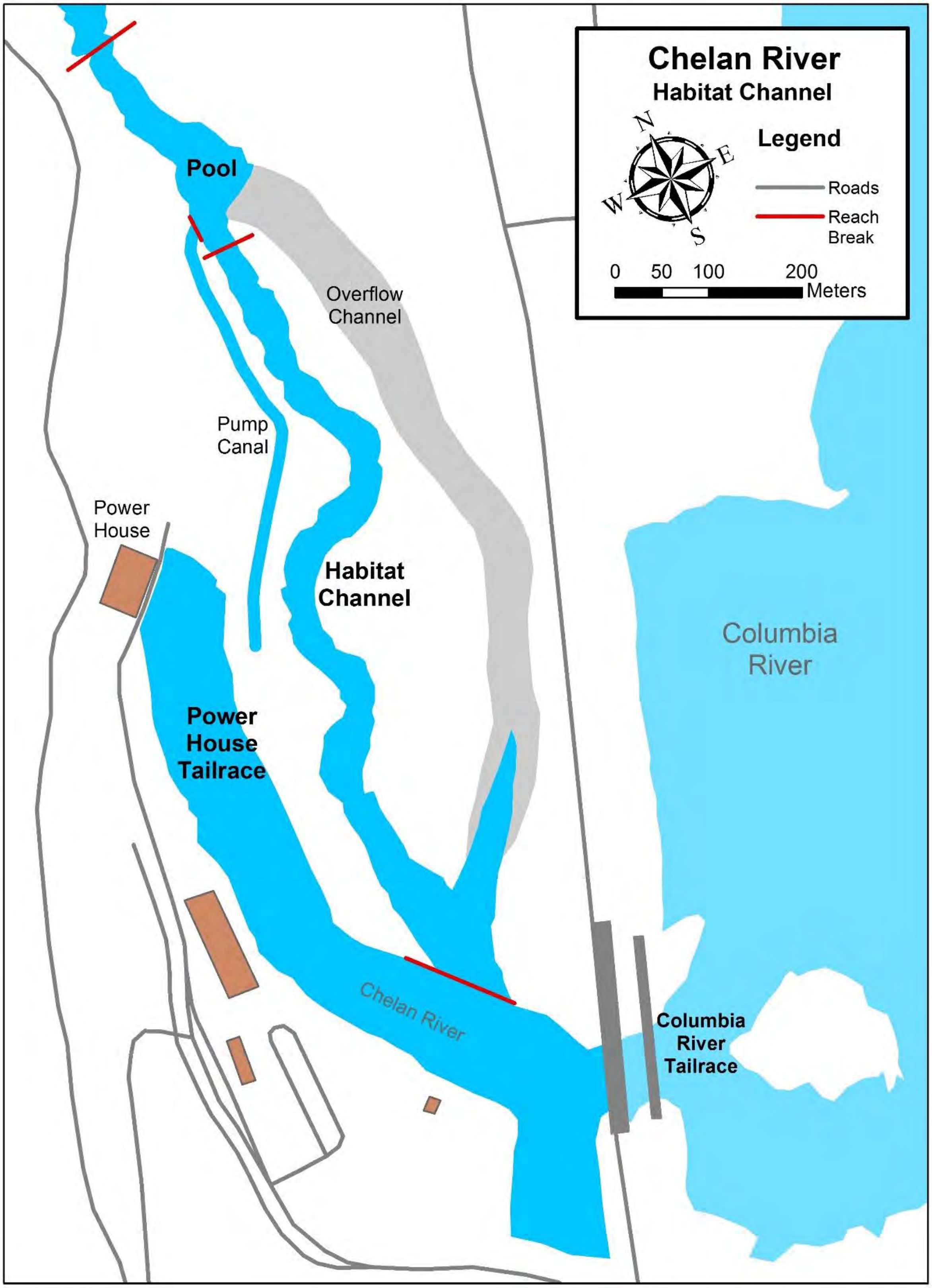

Figure 2. Summer Chinook survey areas on the Chelan River, 2016.

Spawning escapement was estimated as the number of redds times the sex ratio observed at Wells Dam during broodstock collection. In 2016, reach M1 experienced some clarity issues during spawning surveys. Turbidity noticeably increased during rainstorm events and was probably influenced by the Carlton Complex Fires and landslides that occurred in 2014.

Carcasses of summer Chinook were sampled to describe the spawning population. Biological data collection included: scale samples for age analysis, length measurements (POH and FKL), sex, egg voidance, marks, and presence of PIT tags. These data will be used to assess length-at-age, size-at-age, egg voidance, origin (hatchery or naturally produced), and stray rates. No DNA samples were collected on summer Chinook this year. In this report, we only report the number of redds counted in the Okanogan Basin.

RESULTS

Methow

There were 1,115 summer Chinook redds counted within seven reaches on the Methow River (Table 1). Most redds (81%) were located in reaches from the mouth to the town of Twisp (M1-M3). Estimated escapement based on expansion of redd counts from the sex-ratio observed at Wells Dam during broodstock collection indicates that 2,241 summer Chinook (1,115 redds x 2.01 fish/redd) spawned in the Methow River.

Table 1. Number of summer Chinook redds observed each week within the Methow River, 2016. Dashes (--) indicate that no survey occurred.

Reach	Location (Rkm)	Sep	Oct					Nov				Dec	Total	Percent
		18-24	25-1	2-8	9-15	16-22	23-29	30-5	6-12	13-19	20-26	27-3		
		39	40	41	42	43	44	45	46	47	48	49		
M1	0.0-23.8	--	0	3	47	13	54	42	22	1	0	--	182	16
M2	23.8-43.8	--	5	71	146	64	11	8	4	0	--	--	309	28
M3	43.8-63.7	--	6	131	208	48	16	1	--	--	--	--	410	37
M4	63.7-72.3	--	0	12	31	14	0	--	--	--	--	--	57	5
M5	72.3-80.1	--	0	51	70	26	0	--	--	--	--	--	147	13
M6	80.1-83.0	--	0	0	1	0	--	--	--	--	--	--	1	0
M7	83.0-96.1	--	4	5	0	0	0	--	--	--	--	--	9	1
Total:		**--**	**15**	**273**	**503**	**165**	**81**	**51**	**26**	**1**	**0**	**--**	**1,115**	**100**

Time of spawning was assessed as the number of new redds counted each week in the Methow River. Spawning began the last week of September, peaked in early October, and ended the third week of November (Figure 3). Stream temperatures in the Methow River varied from 10.5-11.0°C in September when spawning began. Spawning peaked the first week of October in Reach M7, while peak spawning occurred in reaches M2-M6 the second week of October. Spawning peaked the fourth week of October in reach M1 (Table 1). This was the sixth highest redd count observed in the last 26 years for the Methow River (Appendix A).

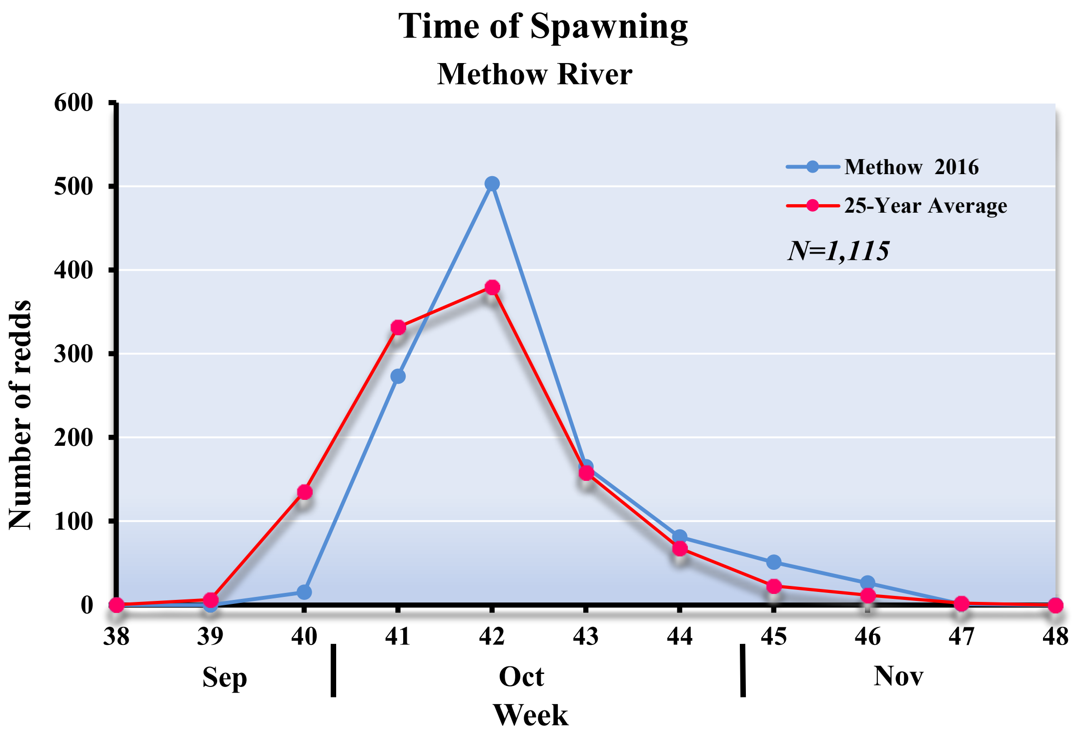

Figure 3. Number of new redds counted each week from late September to late-November in the Methow River, 2016. The figure shows the beginning, peak, and end of spawning for summer Chinook in the Methow River compared to a 25-year average (1991-2015).

There were 587 summer Chinook salmon carcasses sampled within the seven reaches on the Methow River (Table 2). The presence or absence of an adipose fin could not be determined on one fish. Twenty-six percent of the fish returning to the Methow River were sampled based on the estimated escapement of 2,241 summer Chinook. Ad-clipped hatchery fish made up 32% and naturally produced fish (adipose fin present) made up 68% of the fish sampled (Table 2).

Table 2. Number and percent of hatchery (ad-clipped) and naturally produced (ad-present) summer Chinook sampled in the Methow River, 2016.

Reach	Location (Rkm)	Ad-Clipped Hatchery				Naturally Produced				Reach Total
		Male	Female	Total	Percent	Male	Female	Total	Percent	
M1	0.0-23.8	15	14	29	35	26	27	53	65	**82[1]**
M2	23.8-43.8	40	17	57	34	64	47	111	66	**168**
M3	43.8-63.7	12	70	82	38	44	90	134	62	**216**
M4	63.7-72.3	5	6	11	25	20	13	33	75	**44**
M5	72.3-80.1	0	7	7	10	15	48	63	90	**70**
M6	80.1-83.0	0	0	0	0	0	1	1	100	**1**
M7	83.0-96.1	0	0	0	0	3	2	5	100	**5**
Total		**72**	**114**	**186**	**32**	**172**	**228**	**400**	**68**	**586**

[1] **Origin of one female carcass in Reach 1 could not be determined.**

Most (90%) of the ad-clipped hatchery fish were located in reaches M1-M3, while naturally produced fish were sampled within all survey reaches (Figure 4). Naturally produced fish made up 100% of the fish sampled in upper reaches (M6 and M7). Female summer Chinook accounted for 58% of the fish sampled in 2016 (Table 2).

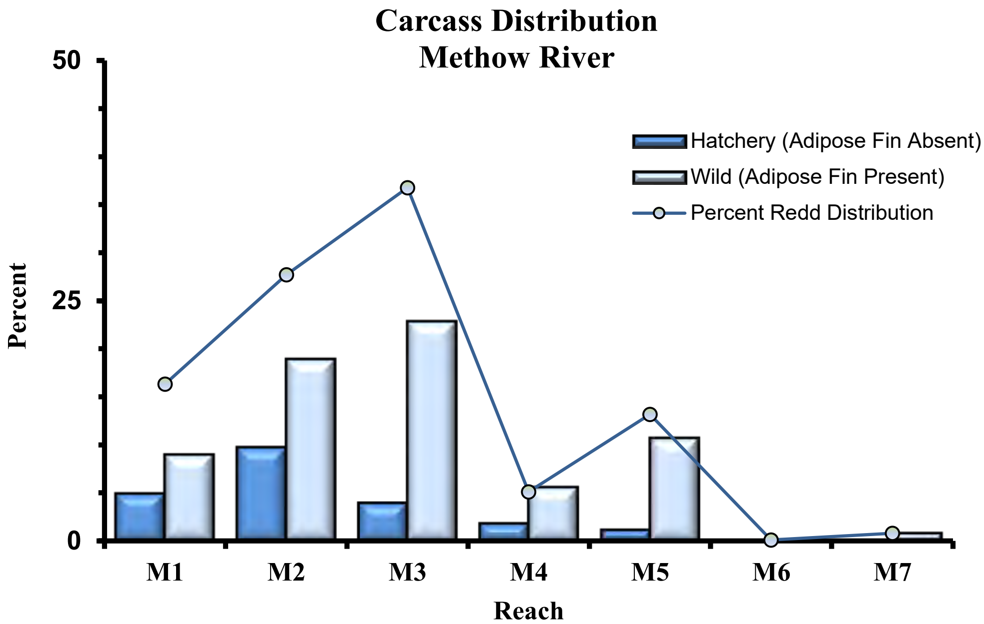

Figure 4. Percent distribution of ad-clipped hatchery and naturally produced fish plotted against the percent distribution of redds observed in reaches on the Methow River, 2016.

Egg voidance was assessed by sampling spawned-out female carcasses. Based on 343 sampled female carcasses, average egg voidance was 98%. Four females (1%) died before spawning (i.e., they retained all their eggs).

Chelan River

There were 448 redds counted in the Chelan River. This is the second highest redd count observed for summer Chinook in the Chelan River since 2000. The majority of spawning occurred in the powerhouse tailrace (46%), habitat channel (24%), and in the Columbia River tailrace (16%) (Table 3). Estimated escapement based on expansion of counts from the sex-ratio observed at Wells Dam during broodstock collection indicates that 900 summer Chinook (448 redds x 2.01 fish/redd) spawned in the Chelan River.

Table 3. Number of summer Chinook redds observed each week within the Chelan and Columbia rivers, 2016. Dashes (--) indicate that no survey occurred.

Reach	Location (Rkm)	Sep		Oct				Nov				Dec	Total	Percent
		18-24	25-1	2-8	9-15	16-22	23-29	30-5	6-12	13-19	20-26	27-3		
		39	40	41	42	43	44	45	46	47	48	49		
Powerhouse Tailrace		--	0	2	28	85	62	21	8	1	0	0	207	46
Columbia R. Tailrace		--	0	0	1	30	31	10	2	0	0	0	74	16
Pool		--	0	1	22	16	14	5	2	1	0	0	61	14
Habitat Channel		--	0	2	21	38	30	11	3	1	0	0	106	24
Total:		**--**	**0**	**5**	**72**	**169**	**137**	**47**	**15**	**3**	**0**	**0**	**448**	**100**

Time of spawning was assessed as the number of new redds counted each week in the Chelan River. Spawning activity began the first week of October and peaked two weeks later (Figure 5). Spawning ended the third week of November. An exceptionally high redd count in 2013 (792 redds) and late spawning in 2014 currently influence the average time of spawning. As more years of information are collected, average time of spawning will likely not appear bimodal.

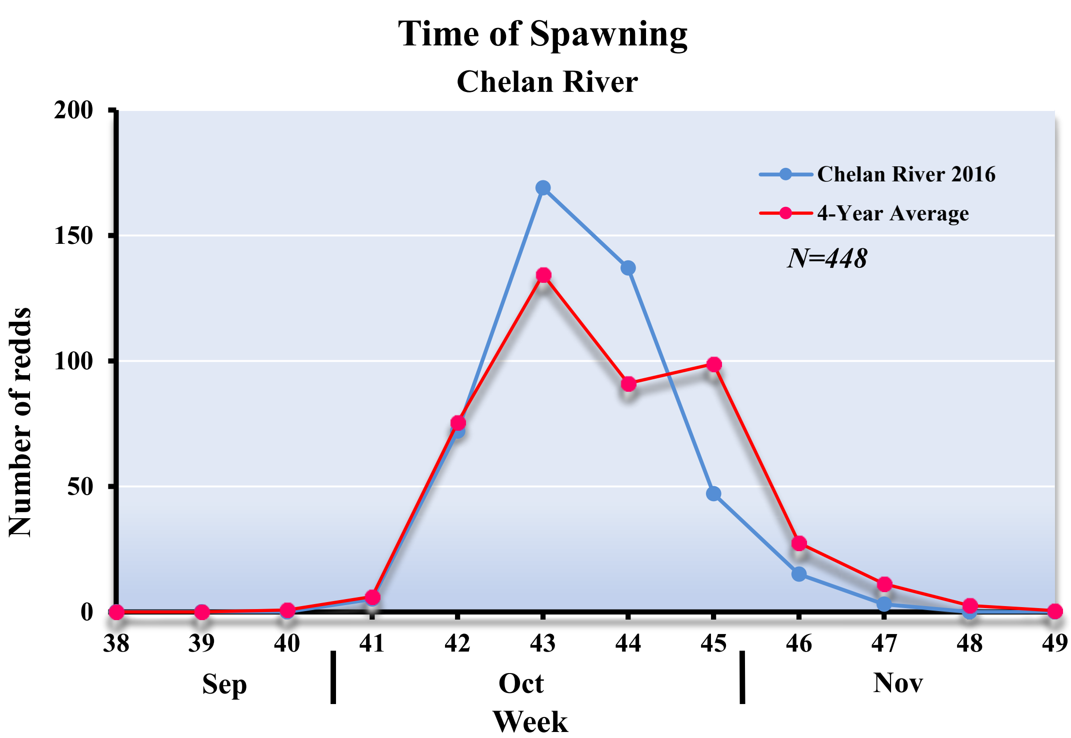

Figure 5. Number of new summer Chinook redds counted each week in the Chelan River from late September to mid-November. The figure displays the beginning, peak, and end of spawning for summer Chinook in the Chelan River in 2016 compared to a 4-year average (2012-2015).

There were 253 summer Chinook carcasses sampled in the Chelan River (Table 4). Twenty-eight percent of the summer Chinook returning to the Chelan River were sampled based on the estimated spawning escapement of 900 fish. Based on the absence of their adipose fin, hatchery fish made up 52% and naturally produced (ad-present) fish made up 48% of the fish examined. Females made up 73% of the carcasses examined (Table 4).

Table 4. Number and percent of hatchery (ad-clipped) and naturally produced (ad-present) summer Chinook collected in the Chelan River, 2016. The origin of one fish sampled could not be determined in the Chelan River.

Reach	Location (Rkm)	Ad-Clipped Hatchery				Naturally Produced				Reach Total
		Male	Female	Total	Percent	Male	Female	Total	Percent	
Powerhouse Tailrace		0	8	8	30	4	15	19	70	**27**
Columbia R. Tailrace		21	43	64	50	12	52	64	50	**128**
Pool		10	15	25	73	3	6	9	27	**34**
Habitat Channel		9	26	35	56	9	19	28	44	**63[1]**
Total		**40**	**92**	**132**	**52**	**28**	**92**	**120**	**48**	**253**

[1] **Origin of one female carcass in habitat channel could not be assigned.**

The distribution of ad-clipped hatchery fish and naturally produced fish varied within the Chelan River (Figure 6). A disproportionate number of fish (compared to redds counts) were sampled in the Columbia River tailrace. This likely occurred because carcasses drifted from upstream spawning areas and settle in the Columbia River tailrace. More hatchery fish were sampled in the habitat channel and pool upstream. Conversely, more wild fish were sampled in the powerhouse tailrace than hatchery summer Chinook.

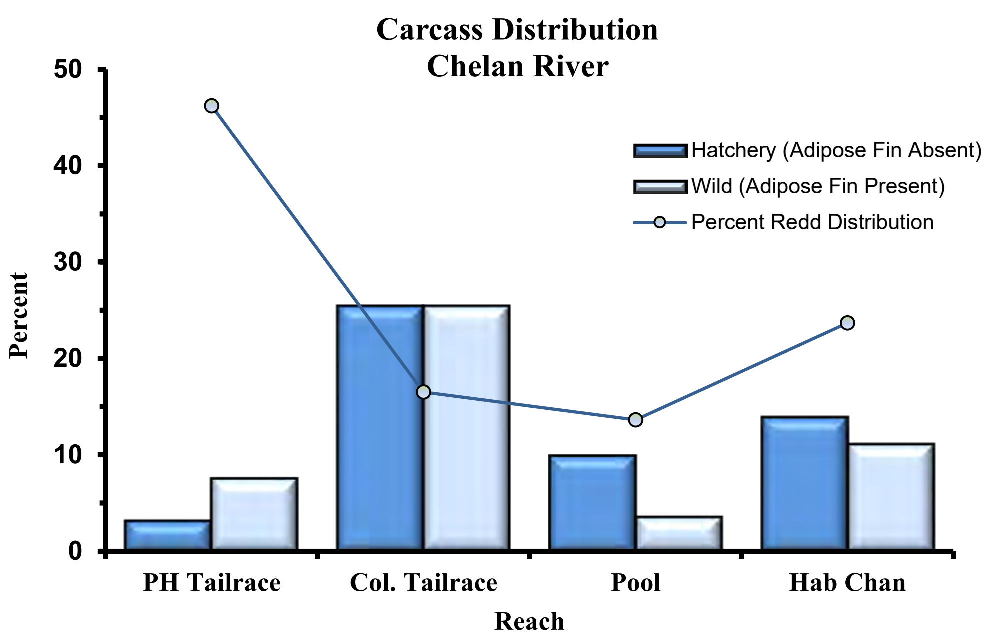

Figure 6. Percent distribution of ad-clipped hatchery and naturally produced fish plotted against the percent distribution of redds observed in reaches on the Chelan River, 2016.

In 2016, about 50 summer Chinook were collected as broodstock from the pool area upstream from the habitat channel.

Mean egg voidance assessed from 181 female carcasses was 81%. Egg voidance from four females could not be determined and seventeen females (17%) died before spawning. No Coho were sampled in 2016.

Okanogan Basin

In 2016, CCT conducted summer Chinook surveys in the Okanogan River basin. A total of 5,276 redds were counted in the Okanogan Basin (Personal Communication, Andrea Pearl, CCT).

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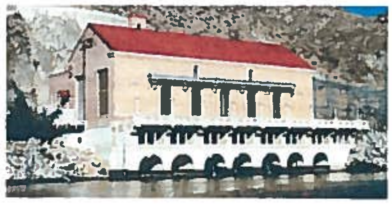
Appendix A. Historical aerial and ground redd counts of summer Chinook in the Methow, Chelan, Okanogan, and Similkameen rivers, 1956-2016.

Year	Methow		Okanogan		Similkameen		Chelan	
	Aerial	Ground	Aerial	Ground	Aerial	Ground	Aerial	Ground
1956	109	--	37	--	30	--	--	--
1957	451	--	53	--	30	--	--	--
1958	335	--	94	--	31	--	--	--
1959	130	--	50	--	23	--	--	--
1960	194	--	29	--	--	--	--	--
1961	120	--	--	--	--	--	--	--
1962	678	--	--	--	17	--	--	--
1963	298	--	9	--	51	--	--	--
1964	795	--	112	--	67	--	--	--
1965	562	--	109	--	154	--	--	--
1966	1,275	--	389	--	77	--	--	--
1967	733	--	149	--	107	--	--	--
1968	659	--	232	--	83	--	--	--
1969	329	--	103	--	357	--	--	--
1970	705	--	656	--	210	--	--	--
1971	562	--	310	--	55	--	--	--
1972	325	--	182	--	64	--	--	--
1973	366	--	138	--	130	--	--	--
1974	223	--	112	--	201	--	--	--
1975	432	--	273	--	184	--	--	--
1976	191	--	107	--	139	--	--	--
1977	365	--	276	--	268	--	--	--
1978	507	--	195	--	268	--	--	--
1979	622	--	173	--	138	--	--	--
1980	345	--	118	--	172	--	--	--
1981	195	--	55	--	121	--	--	--
1982	142	--	23	--	56	--	--	--
1983	65	--	36	--	57	--	--	--
1984	162	--	235	--	301	--	--	--
1985	164	--	138	--	309	--	--	--
1986	169	--	197	--	300	--	--	--
1987	211	--	201	--	164	--	--	--
1988	123	--	113	--	191	--	--	--
1989	126	--	134	--	221	370	--	--
1990	229	--	88	47	94	147	--	--
1991	--	153	55	64	68	91	--	--
1992	--	107	35	53	48	57	--	--
1993	--	154	144	162	152	288	--	--
1994	--	310	372	375	463	777	--	--
1995	--	357	260	267	337	616	--	--

Year	Methow		Okanogan		Similkameen		Chelan	
	Aerial	Ground	Aerial	Ground	Aerial	Ground	Aerial	Ground
1996	--	181	100	116	252	419	--	--
1997	--	205	149	158	297	486	--	--
1998	--	225	75	88	238	276	--	--
1999	--	448	222	369	903	1,275	--	--
2000	--	500	384	549	549	993	--	196
2001	--	675	883	1,108	865	1,540	--	240
2002	--	2,013	1,958	2,667	2,000	3,358	--	253
2003	--	1,624	1,099	1,035	103	378	--	173
2004	--	973	1,310	1,327	2,127	1,660	--	185
2005	--	874	1,084	1,611	1,111	1,423	--	179
2006	--	1,353	1,857	2,592	1,337	1,666	--	208
2007	--	620	1,265	1,301	523	707	--	86
2008	--	599	1,019	1,146	673	1,000	--	153
2009	--	692	1,109	1,672	907	1,298	--	246
2010	--	887	688	1,011	642	1,107	--	398
2011	--	941	1,203	1,714	1,047	1,409	--	413
2012	--	960	1,170	1,613	762	1,066	--	426
2013	--	1,551	NA	2,267	NA	1,280	--	729
2014	--	591	NA	2,231	NA	2,022	--	400
2015	--	1,231	NA	4,276[1]	NA	--	--	448
2016	--	1,115	729	2757	141	1649		448

[1.] The redd count is for the entire Okanogan Basin (Similkameen + Okanogan rivers).

Appendix R
Rock Island Hydro Project Habitat Conservation Plan 2017 Annual Financial Report, Plan Species Account

PUBLIC UTILITY DISTRICT NO. 1 of CHELAN COUNTY
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MEMORANDUM

DATE: **January 15, 2018**

TO: **Becky Gallaher, Natural Resources Program Analyst**
Alene Underwood, Fish & Wildlife Manager

FROM: **Debbie Litchfield, Treasurer/Director – Treasury** Debbie Litchfield

RE: **Rock Island Hydro Project Habitat Conservation Plan**
2017 Annual Financial Report, Plan Species Account

In accordance with Section 7.4.3 of the Rock Island Habitat Conservation Plan attached is the 2017 year end annual financial report of the Plan Species Account activity completed by Chelan County Public Utility District No. 1.

Chelan County PUD
Rock Island Hydroelectric Project
Habitat Conservation Plan
Plan Species Cash Account Activity
Annual Financial Report Per Section 7.4.3
Reporting Year: 2017

Beginning Balance:	**1/1/2017**		**$ 5,897,144.62**
Transfers In:			
Rock Island Funding		737,452.00	
Interest Earnings		31,692.34	
Total Transfers In			769,144.34
Transfers Out:			
Payments		(105,188.49)	
Bank Service Fees		(70.90)	
Total Transfers Out			(105,259.39)
Ending Balance:	**12/31/2017**		**$ 6,561,029.57**

The Plan Species Account was established per the Rock Island Habitat Conservation Plan, Section 7.4.
Interest earnings shall remain in the Account in accordance with Appendix E, Section 7.4.1.