2018

Annual Operating Plan

FINAL

HATCHERY AND SUPPLEMENTATION PROGRAM

NORTH FORK LEWIS RIVER

Prepared by
the
North Fork Lewis River
Hatchery and Supplementation Subgroup

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DEFINITION OF TERMS AND ACRONYMS

Area Under the Curve (AUC): a method for estimating salmon escapement by dividing the integral of the escapement curve by the average residence time in the survey area.

Annual Operating Plan (AOP): An annual planning document that describes the methods and protocols needed to implement the North Fork Lewis River Hatchery and Supplementation Plan and Program.

Aquatic Coordination Committee (ACC): Committee formed after signing of the North Fork Lewis River Settlement Agreement (Settlement Agreement) and composed of its signatories. Many of the measures contained in the Settlement Agreement require review and consultation with the ACC prior to implementation. Thus, the committee acts as the governing body for implementing aquatic measures contained within the Settlement Agreement. The committee also approves aquatic habitat funds on an annual basis.

Aquatic Monitoring and Evaluation Plan (AMEP): A comprehensive planning document required by the North Fork Lewis River Settlement Agreement (Section 9). The purpose of the AMEP is to develop methods to evaluate aquatic monitoring and evaluation objectives contained within the North Fork Lewis River Settlement Agreement. These objectives relate to fish passage, reintroduction outcome goals, anadromous and resident species monitoring, and development of the North Fork Lewis River Hatchery and Supplementation Plan.

Bacterial Coldwater Disease (BCD): Bacterial disease of salmonid fish caused by *Flavobacterium psychrophilum*.

Bacterial Kidney Disease (BKD): Bacterial disease of salmonid fish caused by *Renibacterium salmoninarum.*

Bayesian Goodness of Fit (GOF): a test used to determine whether sample data are consistent with a hypothesized distribution.

Blank wire tag (BWT): A small wire that is uncoded (blank), inserted in the snout of fish, and detectible with handheld wire detection wands or devices.

Brood year (BY): year in which spawning occurs, used to track a single cohort over time.

Coded wire tag (CWT): A small wire with unique codes etched onto the wire, inserted in the snout of fish, and detectible with handheld wire detection wands or devices.

Coefficient of Variation (CV): The ratio of the population standard deviation (σ) to the population mean (μ) *or* in instances when only a sample of data from the population is available CV is estimated by using the sample standard deviation (S) to the sample mean ($\bar{x}$) which shows the extent of variability in relation to the mean of the population. The absolute value of the CV, sometimes known as relative standard deviation, is expressed as a percentage.

- Population CV = σ/μ
- Sample CV = $s/\bar{x}$

Columbia Basin PIT Tag Information System (PTAGIS): A regional database that stores and tracks data from fish with passive integrated transponder (PIT) tags.

Condition factor (K): Fulton's condition factor, K, is a measure of individual fish health that assumes the standard weight of a fish is proportional to the cube of its length:

$$K = 100\left(\frac{W}{L^3}\right)$$

where *W* is the whole body wet weight in grams and *L* is the length in centimeters; the factor 100 is used to bring K close to a value of one (Fulton, 1904).

Distinct Population Segment (DPS): A population or group of populations that is discrete from other populations of the species and significant in relation to the entire species. This along with Evolutionarily Significant Unit (ESU) are used to define Endangered Species Act-listed species (DPS for steelhead and ESU for salmon species).

Effective Population Size (N_e): The average size of a population in terms of the number of individuals that can contribute genes equally to the next generation. Therefore, the effective population size is typically smaller than the actual census size of the population.

Enzyme-Linked Immunosorbent Assay (ELISA): This test uses antibodies and color change to identify viral antigens present in sampled fish tissues.

Ecosystem Diagnostic and Treatment (EDT) model: An analytical habitat-based model that evaluates environmental constraints on a fish population(s) and used to predict the carrying capacity or production potential of specific areas of the North Fork Lewis River such as upstream of Swift Dam.

Endangered Species Act (ESA): Passed in 1973, this piece of United States legislation was designed to protect species from extinction as well as the ecosystems upon which they depend. Listed species are classified as "threatened" or "endangered." The ESA is administered by the U.S. Fish and Wildlife Service and the National Marine Fisheries Service.

Evolutionarily Significant Unit (ESU): A distinct population unit that is reproductively isolated and an important component for the legacy of a species, considered a separate "species" for the purposes of conservation.

F1 generation: First generation offspring, in this case, typically referring to offspring of fish spawned in the hatchery and therefore of hatchery-origin.

F2 generation: Offspring of F1 parents that have spawned naturally and therefore of natural-origin.

Feed conversion ratio (FCR): The amount of feed an animal must consume to gain one kilogram of body weight.

Fish per pound (fpp): Number of juvenile salmon per pound batch weight

Floy tag: Visible tags with unique codes and colors applied to the dorsal side of fish to identify individual fish upon capture or through visual surveys. Floy tags are inserted near the posterior side of the dorsal fin and are intended to lock within the dorsal skeletal bones by means of a T-anchor.

Generalized Random Tessellation Stratified (GRTS) design: provides a probability sample with design-based variance estimators by establishing a spatially balanced, random sample allowing for unequal probability sampling to accommodate field implementation issues.

Hatchery and Genetic Management Plan (HGMP): a technical document that describes artificial propagation management strategies that ensure conservation and recovery of ESA-listed salmon and steelhead populations.

Hatchery and Supplementation Plan (H&S Plan): A 5-year planning document intended to provide the plan and process for implementing the goals of Section 8 (Hatchery and Supplementation Program) of the North Fork Lewis River Settlement Agreement.

Hatchery and Supplementation Program (Program): Defined in Section 8 of the Lewis River Settlement Agreement. The goals of the program are to support (i) self-sustaining, naturally producing, harvestable native anadromous salmonid species throughout their historical range in the North Fork Lewis River Basin, and (ii) the continued harvest of resident and native anadromous fish species.

Hatchery and Supplementation Subgroup (H&S Subgroup): A group composed of representatives of North Fork Lewis River Settlement Agreement signatories formed under the Aquatic Coordination Committee to draft and finalize Hatchery and Supplementation Plans and develop Annual Operating Plans for the Hatchery and Supplementation Program.

Hatchery origin (HOR): Fish that are spawned in a hatchery or reared in a controlled environment prior to release into the natural environment.

Hatchery Production: Describes the artificial propagation of fish that occurs in a hatchery as opposed to propagation resulting from natural reproduction. In the North Fork Lewis River, the hatchery production program is designed to maintain harvest opportunities downstream of Merwin Dam and in project reservoirs (residents) and to provide both adult and juvenile anadromous fish for early supplementation efforts in the basin.

Hatchery Scientific Review Group (HSRG): An independent scientific review group established by the United States Congress to initiate hatchery reform that balances both conservation and harvest goals.

Infectious hematopoietic necrosis virus (IHNV): Severe viral disease in the *Novirhabdovirus* genus affecting salmonid fish, particularly smolts and younger life stages.

Infectious pancreatic necrosis virus (IPNV): Severe viral disease in the *Birnaviridae* family affecting salmonid fish, particularly smolts and younger life stages.

Jolly-Seber (JS) mark-recapture model: Provides estimates of abundance, survival, and capture rates from capture-recapture experiments. A fully open-population model (allows for births, deaths, immigration and emigration from a population) estimating both recruitment to the population and survival.

Juvenile life stages (parr, transitional, smolt, precocious male):

- Parr – Juvenile salmonid in a non-migratory stage adapted for freshwater residence. Exhibits distinct parr marks, yellow to brown body and fin coloration, or no signs of smoltification.
- Transitional – Juvenile salmonid exhibiting initial signs of smoltification (i.e., a silvery sheen with visible parr marks). Black pigment may be present on dorsal and caudal fins.
- Smolt – Juvenile salmonid that is entering a stage of seaward migration and adapted for survival in sea water. Exhibits a silvery sheen, mostly or completely absent of parr marks, deciduous scales, white or transparent abdominal fins, and black pigment on dorsal and caudal fins.
- Precocious male – Juvenile male fish that mature in their first or second year, prior to going to sea. Fully mature males have soft abdomens and milt may be expressed. Deeper body morphology compared to smolts. Dark body color. Parr marks may be visible. Dark body and abdomen coloration compared to parr and smolt life stages.
- Post smolt – A salmonid that has previously undergone smoltification and has reverted to a freshwater-adapted stage, typically due to being held in captivity in freshwater. Visual indicators of this phenotype are not well described in the literature. Some fading of silver coloration. Parr marks are not expected to re-emerge. Some yellow or brown-orange coloration of the fins. Fading of intense black pigmentation in the fins.

Kelt: A post-spawn iteroparous fish such as a steelhead or cutthroat.

Lewis River Hatchery Complex: Hatchery fish production in the Lewis River Basin originates from the Lewis River, Speelyai, and Merwin hatcheries, collectively known as the Lewis River Hatchery Complex. The three hatcheries share adult return, rearing, and release functions. A detailed description of each of these facilities is presented in Appendix A of the H&S Plan.

Lower Columbia River (LCR): for the purposes of salmon recovery, referring to the Sub-domain of the Columbia River Basin that includes the estuary and all sub-basins upstream to the towns of While Salmon, Washington and Hood River, Oregon.

Major Population Group (MPG): Group of populations, or strata, sharing similar genetic, life-history, and spatial distribution that make up a subgroup of an Endangered Species Act-listed species (e.g., Coastal MPG, Cascade MPG). Viability of all MPGs are necessary for viability of Endangered Species Act-listed species.

Merwin Collection Facility (MCF): A trapping, collection, and sorting facility located at the base of Merwin Dam. The MCF processes fish for transport upstream as well as broodstock for hatchery operations.

Microsatellite (mSAT) genotyping: Microsatellites are commonly used and are versatile genetic markers composed of arrays of DNA sequences (or loci). DNA is extracted from tissue cells and specific polymorphic regions of the DNA are amplified by means of the polymerase chain reaction. Once resolved by electrophoresis, DNA can be visualized by fluorescent dyes and compared to established markers or baselines. Microsatellite analysis can detect differences in closely related species and determine origin of individuals using established markers (or baselines).

Native (or indigenous): Fish species that have become established in the North Fork Lewis River Basin without human intervention or being substantially affected by genetic interactions through non-native stocks. Native North Fork Lewis River stocks may be present in areas outside the North Fork Lewis River Basin.

Natural Origin (NOR): Offspring of fish that have spawned naturally in the North Fork Lewis River, but not necessarily native to the area and, in many cases, may be progeny from hatchery origin fish or strays that spawn naturally with native stocks. For fish management purposes, fish possessing an adipose fin (and have no tags) are considered NORs and are generally considered to be part of the Endangered Species Act-listed Distinct Population Segment or Evolutionarily Significant Unit. Genotyping is the only method to confirm whether these fish are native.

Natural Production: Describes fish that result from reproduction that occurs naturally in the North Fork Lewis River as opposed to artificial propagation in a hatchery.

North Fork Lewis River (Lewis River): The section of the Lewis River upstream of the confluence with the East Fork Lewis River (river mile 3.5) and downstream of Merwin Dam (river mile 19.6) is often referred to as the North Fork Lewis River or Lewis River when referenced in this Annual Operating Plan.

North Fork Lewis River Settlement Agreement (Settlement Agreement): A binding agreement between the utilities; federal, state, and regional regulatory entities; tribal entities; and non-governmental organizations. The Settlement Agreement establishes the collective agreement of all signatories with respect to the utilities' obligations in mitigating effects of hydropower operation on fisheries, wildlife, recreation, and cultural and aesthetic resources. The Settlement Agreement forms the basis for issuing hydroelectric operating licenses by the Federal Energy Regulatory Commission for the four hydroelectric projects on the North Fork Lewis River.

Ocean Recruits: Total escapement of hatchery- and natural-origin fish including those harvested in the ocean, Columbia River, and terminal fisheries.

Proportion of Hatchery Origin Spawners (pHOS): Annual proportion of natural spawners in a watershed or stream composed of hatchery origin adults each year.

Proportion of Natural Origin Brood (pNOB): Mean proportion of natural origin spawners contributing to broodstock in a hatchery program.

Passive Integrated Transponder (PIT) tags: Electronic tags inserted into the dorsal sinus or body cavity of fish that transmit data indefinitely when activated by a specialized antenna or reader. All PIT tags have a unique code allowing on-site identification of individual tagged fish.

Proportion of Natural Influence (PNI): An estimate of the proportion of natural influence on a population composed of hatchery- and natural-origin fish. Calculated as Proportion of Natural Origin Brood divided by the sum of Proportion of Natural Origin Brood and Proportion of Hatchery Origin Spawners or pNOB/(pNOB+pHOS).

Regional Mark Information System (RMIS): a collection of online databases that maintain records of coded wire tag release, recoveries and locations.

Residual or Residualism: Salmonids that fail to migrate from their natal streams or stream basin after the majority of their cohort have emigrated in a given year. Depending on the species, residuals may take on several different life-histories including precocious sexual maturation, freshwater residence for a season (e.g., to overwinter) or for an additional year followed by anadromy, or in steelhead, permanent freshwater residence and spawning in multiple years. Salmonids with the potential to express anadromy are considered residuals as long as they reside in freshwater and do not become anadromous.

Returns: Adult steelhead or salmon that have spent at least 1 year at sea and have become sexually mature and have returned to the North Fork Lewis River to spawn.

Smolt Index: A number assigned to juvenile salmon that describes the stage of smolt development based on a visual assessment of skin and fin pigmentation (silvering) and body shape. 1 = parr, 2 = transitional, 3 = smolt, 4 = precocious male, 5 = post-smolt or residual (modified from Gorbman et al., 1982).

Smolt to Adult Ratio (SAR): Survival from the beginning point as a smolt (release) to an ending point as an adult.

Supplementation: The use of artificial propagation to develop, maintain, or increase natural production while maintaining the long-term fitness of the target population, and keeping the ecological and genetic impacts to non-target populations within specified biological limits. In the North Fork Lewis River, the supplementation program is designed to reintroduce spring Chinook, late winter steelhead, and early coho to habitat upstream of Merwin Dam.

Single Nucleotide Polymorphism (SNP): SNP genotyping is the measurement of genetic variations of between members of a species. A SNP is a single base pair mutation at a specific locus, usually consisting of two alleles. SNP arrays can be used to analyze large numbers of samples such as outmigrating smolts or transported steelhead upstream of Swift Dam for less cost than microsatellite genotyping.

Steelhead broodstock: Steelhead captured either through traps or in-river netting that meet predetermined genetic assignment probabilities.

Stubby dorsal fin: A dorsal fin in which the rays have become crooked especially along the leading edge and depressed as compared to naturally produced fish. Stubby dorsal fins are indicative of fish reared in a hatchery environment.

Swift Floating Surface Collector (FSC): A trap and haul facility used to collect, sort, sample, and tag outmigrating smolts from adult and juvenile supplementation programs upstream of Swift Dam. The FSC is located on the forebay of Swift Reservoir and has the ability to operate year-round and through fluctuating reservoir levels. All fish are sorted in the FSC and trucked either downstream of Merwin Dam or returned to the reservoir.

Tangle net: A net designed to entangle the snout (not the gills) of target species through use of smaller mesh sizes. This method is considered a safer alternative to traditional gill netting in which the net material may become wedged under the fish operculum, potentially causing lacerations of the gill lamellae.

Viral hemorrhagic septicemia virus (VHSV): Virus in the genus *Novirhabdovirus,* exclusive to fish and related to IHNV.

EXECUTIVE SUMMARY

The purpose of this Annual Operating Plan (AOP) is to describe the methods and protocols necessary to implement the Hatchery and Supplementation Plan (H&S Plan). The methods described in this plan represent the collaborative efforts and input of the Hatchery and Supplementation Subgroup (H&S Subgroup). The H&S Subgroup was formed under the North Fork Lewis River (Lewis River) Aquatic Coordination Committee to finalize the H&S Plan, monitor hatchery practices and production, and to guide reintroduction of anadromous species upstream of the hydroelectric projects on the Lewis River. This AOP is required under Section 8.2.3 of the Lewis River Settlement Agreement (Settlement Agreement). Section 8.2.3 states that, at a minimum, the AOP must contain the following information:

1. A production section specifying the species and broodstock sources
2. Current hatchery target and juvenile production targets
3. A release section identifying, by species, the rearing schedule and planned distribution of fish and the schedules and location for release
4. A list of facility upgrades to be undertaken in the current year
5. A description of relevant monitoring and evaluation to be undertaken

Sections A, B, and C of this plan are dedicated to each hatchery production species: Late winter steelhead, spring Chinook, and coho salmon. Each section is organized similarly to maintain consistency within this document and make it easier to locate information for each species. Other sections include Monitoring and Evaluation (Section D) and Reporting Requirements (Section E). Appendices A and B illustrate handling protocols for both trapped and tangle netted fish. Appendix C provides a summary of monitoring objectives. Appendix D provides the Rearing and Release Plan for spring Chinook. Appendix E describes the proposal to monitor total dissolved gas and temperature at Lewis River Hatchery. Appendix F provides a literature review of volitional release methods applicable to the Lewis River system.

The monitoring and evaluation section of the AOP (Section D) includes 17 objectives. Objectives provided in Section D represent the minimum monitoring benchmarks necessary to meet the requirements of the Settlement Agreement as well as recommendations from the Hatchery and Scientific Review Group. The H&S Subgroup is responsible for developing monitoring methods to meet the objectives of the H&S Plan. To maintain consistency with the objective numbering in the H&S Plan, Objectives 1 and 13 are included as placeholders in the AOP, but the monitoring requirements for Objectives 1 and 13 are included as part of the Aquatic Monitoring and Evaluation Plan relevant to fish passage, reintroduction outcome goals, and anadromous and resident species monitoring. All results from Section D Monitoring and Evaluation objectives are presented annually in the Lewis River Annual Operations Report.

INTRODUCTION

The Annual Operating Plan (AOP) focuses on developing methods and protocols for monitoring and evaluating objectives of the North Fork Lewis River Hatchery and Supplementation program (Program). The AOP is not intended to develop program objectives or goals, rather, the AOP describes 'how' these objectives will be implemented, monitored, and evaluated. The goals of the Program are identified and described in the Hatchery and Supplementation Plan (H&S Plan), which is updated every 5 years, most recently in 2014. The AOP is updated annually through a collaborative effort and participation of resource agency and utility representatives collectively referred to as the Hatchery and Supplementation Subgroup (H&S Subgroup). Any variances from this plan are reported in annual hatchery operations reports.

This AOP is required under Section 8.2.3 of the North Fork Lewis River Settlement Agreement (Settlement Agreement). Section 8.2.3 states that, at a minimum, the AOP must contain the following information:

1. A production section specifying the species and broodstock sources
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4. A list of facility upgrades to be undertaken in the current year
5. A description of relevant monitoring and evaluation to be undertaken

HATCHERY AND SUPPLEMENTATION SUBGROUP RECOMMENDATIONS AND ADAPTIVE MANAGEMENT

The methods described in this plan represent the collaborative efforts and input of the H&S Subgroup. The H&S Subgroup was formed under the North Fork Lewis River (Lewis River) Aquatic Coordination Committee (ACC) to finalize the H&S Plan, monitor hatchery practices and production, and guide reintroduction of anadromous species upstream of the hydroelectric projects on the Lewis River.

The H&S Subgroup meets regularly to discuss implementation of the H&S Plan as well as development of the AOP and is tasked with adaptively managing plans and recommending changes. It is important to note that the H&S Subgroup is not a decision-making entity recognized under the Settlement Agreement. Therefore, recommendations made by the H&S Subgroup that result in program changes must be brought to the ACC for approval and documented in the meeting notes.

AREA OF FOCUS

The area of focus of this AOP is the lower Lewis River, Washington, downstream of Merwin Dam at river mile (RM) 19.5. Two major tributaries, Cedar Creek and the East Fork Lewis River, enter the Lewis River at RM 15.7 and 3.5, respectively. The section of the Lewis River between the confluence of the East Fork Lewis River and Merwin Dam is often referred to as the North Fork Lewis River or more simply, Lewis River, when referenced in this Annual Operating Plan.

Hatchery fish production in the Lewis River Basin originates from the Lewis River, Speelyai, and Merwin hatcheries (collectively known as the Lewis River Hatchery Complex). The three hatcheries are currently operated as a complex, sharing adult return, rearing, and release functions. A detailed description of each of these facilities is presented in Appendix A of the H&S Plan.

SECTION A. LATE WINTER STEELHEAD

1.0 INTRODUCTION

The Lewis River late winter steelhead hatchery program has three main components: 1) broodstock collection; 2) adult supplementation upstream of Swift Dam; and 3) juvenile production. Late winter hatchery steelhead are referred to as "late" because their run timing is distinct from the non-endemic, earlier returning hatchery winter steelhead stock (i.e., Chambers Creek stock). The late winter steelhead program only selects broodstock of natural origin (NOR) late winter steelhead. This is accomplished by performing genetic analysis of 13 microsatellite (mSAT) loci for each potential broodstock parent prior to spawning (see Section 2.8). All smolts produced from these broodstock are tagged with a blank wire tag (BWT) in their snout prior to release. This mark identifies these fish as late winter hatchery origin (HOR) steelhead when they are subsequently recaptured.

All BWT positive steelhead adults trapped at either at the Merwin Collection Facility (MCF) or Lewis River Hatchery ladder are released upstream of Swift Dam to distribute naturally and spawn. Late winter steelhead adults are captured using two primary methods, traps and in-river tangle netting. BWT positive steelhead captured through in-river tangle netting are passive integrated transponder (PIT) tagged in the dorsal sinus and released on site to estimate the proportion of hatchery origin spawners (pHOS; see Appendix D, objective 2). A portion of steelhead captured have 'stubby' dorsal fins (Figure A1) but lack a BWT. These fish are assumed to be strays, or program fish that have lost their snout tag. Steelhead with stubby dorsal fins are never used as broodstock but may be passed upstream even though they do not possess a BWT (see Section 2.6.1).

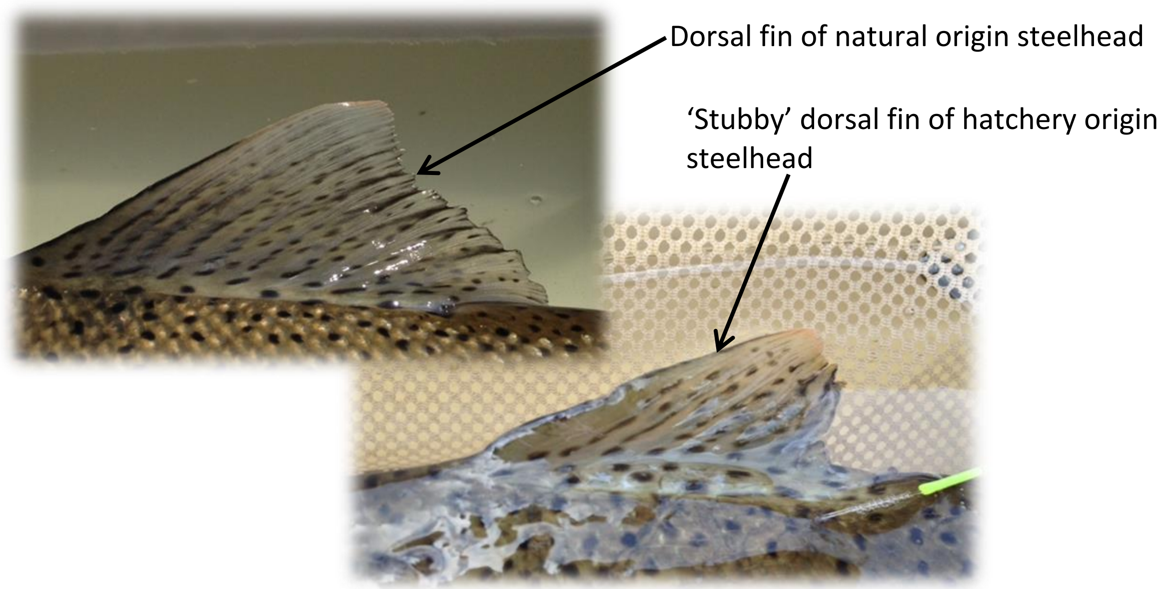

Figure A1.Images of dorsal fins from natural and hatchery origin steelhead illustrating differences in shape and size

The primary goal of the late winter steelhead program is to reintroduce winter steelhead to the Lewis River upstream of Swift Dam. The annual transport goal upstream of Swift Dam is 500 adult late winter steelhead (PacifiCorp and Cowlitz County PUD, 2014). The current broodstock component goal is to collect 25 pairs of adult steelhead and obtain up to 90,000 eggs (± 20%). The production goal is to release 50,000 (± 20%) yearling smolts into the Lewis River downstream of Merwin Dam. The long-term program goal is to increase the natural production of steelhead upstream of Swift Reservoir and become less reliant on hatchery production.

2.0 PROGRAM IMPLEMENTATION

The following sections describe the protocols for implementing the Lewis River late winter steelhead portion of the Hatchery and Supplementation Plan (H&S Plan; PacifiCorp and Cowlitz County PUD, 2014).

2.1 Broodstock Source

To produce smolts with the highest genetic adaptability to the Lewis River Basin, the program should strive to capture broodstock with the least amount of influence from hatchery steelhead programs and rely only on NOR Lewis River stock when possible. Lewis River late winter steelhead are part of the Lower Columbia River (LCR) Steelhead distinct population segment (DPS; Figure A2). The LCR Steelhead DPS includes four major population groups (MPGs): Winter-Run Cascade, Summer-Run Cascade, Winter-Run Gorge, and Summer-Run Gorge. Lewis River late winter steelhead are part of the Winter-Run Cascade MPG. While it is preferred to use only broodstock native to the Lewis River or its tributary, Cedar Creek, this is not always possible. To achieve broodstock targets, it may be necessary to use NOR fish from adjacent basins within the Cascade and Gorge MPGs.

Broodstock collection is divided into two phases. The first phase of broodstock collection (January 30 to March 31) incorporates only steelhead with genetic assignment to the Cascade MPG. However, priority is always given to those steelhead that have the highest probability of genetic assignment to Lewis River or Cedar Creek baselines. Phase II broodstock collection (April 1 through the end of collection) will also give priority to steelhead with genetic assignment to Lewis River or Cedar Creek stock; however, if insufficient broodstock are available from the Cascade MPG, then broodstock representing the Gorge MPG may also be used. Any steelhead indicating primary assignment to Coastal DPS streams may not be used as broodstock because this MPG represents a separate DPS as defined by the National Marine Fisheries Service (NMFS). Typically, genetic assignment probability includes some probability to Coastal DPS. However, these probabilities represent a very small percentage of the genotype and consequently low confidence is placed in these assignment probability values once they fall below 20 % (Winans 2015). Thus, steelhead having assignment probabilities of 20 % or less to Coastal MPG may be used in Phase II only. Further, remaining assignment probability must include either the Cascade or Gorge MPGs. For example, a steelhead with Coastal MPG assignment of less than 20 %, but with any assignment outside the Cascade or Gorge MPG would not be acceptable broodstock.

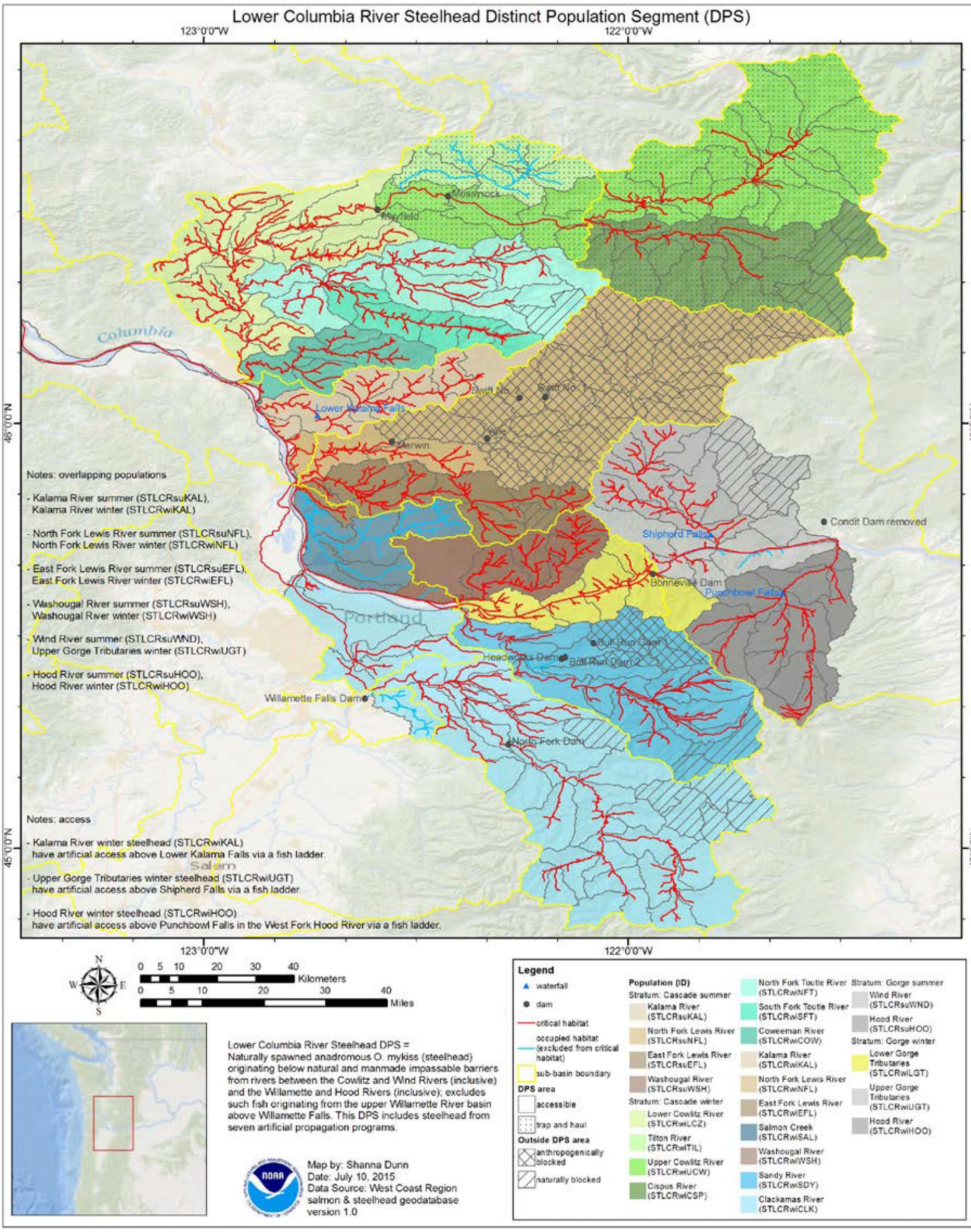

Figure A2. Lower Columbia River steelhead distinct population segment structure
Source: NMFS, 2016

Ripe Females: The potential of encountering unmarked early winter hatchery steelhead derivatives during Phase II is rare based on genetic sampling results since 2009. Therefore, ripe females caught in-river or by trap after March 30 may be available for broodstock prior to genetic assignment. In these instances, ripe females will be spawned with males having genetic assignment to the Lewis River or Cedar Creek stock. If females collected during Phase II are not ripe, they will undergo the routine genetic assignment protocol before spawning. Any females that ripen before genetic assignment is complete prior to April 1 will be released as the potential of encountering hatchery derivatives is higher during the early part of the run.

Table A1. Priority for late winter steelhead broodstock source during Phase I and II collection based on genetic assignment probabilities

Phase	Priority	River or MPG
Phase I (Jan – Mar)	**1**	North Fork Lewis River
	2	Cedar Creek
	3	Cascade MPG
Phase II (Apr – May)	**1**	North Fork Lewis River
	2	Cedar Creek
	3	Cascade MPG
	4	Gorge MPG
	5	*Coastal MPG @ < 20 %

Note:
** Coastal MPG may be used to achieve broodstock goals, as long as total Coastal MPG assignment probability remains less than 20 % AND remaining assignment probability represents Cascade or Gorge MPGs.*

2.2 Broodstock Collection

Broodstock collection relies on the use of NOR late winter steelhead returning to the Lewis River each year.[1] Broodstock are collected in traps at the MCF, the Lewis River Hatchery ladder, and through in-river tangle netting. Potential broodstock are held at Merwin Hatchery and sampled for mSAT genotyping. Steelhead possessing a BWT are never used as broodstock as these fish represent program (F1 generation) returns and are passed upstream of Swift Dam to spawn naturally. However, F2 generation returns (offspring from F1 parents that have spawned naturally) may be incorporated as broodstock as there is no cost-effective method to determine parentage of F2 returning adults. Additionally, parentage evaluations would have limited practical value as the broodstock collection for the late winter steelhead program is expected to end in 2021 as defined in the current H&S Plan (PacifiCorp and Cowlitz County PUD, 2014).

[1] In 2018, NOR broodstock may be the F2 offspring of HOR F1 parents released by the juvenile supplementation program as recently as 2015. Program returns (or residuals) had the first opportunity to spawn with native stocks beginning in 2012. These composite steelhead cannot be distinguished genetically from native fish and have no marks, tags, or stubby dorsal fin. Therefore, this plan refers to adipose-intact, non-stubby dorsal fin steelhead as 'natural origin' rather than 'native'.

If a ripe female is spawned prior to a genetic assignment and found to assign to the Cascade or Gorge MPGs with a probability greater than 10%, eggs will be incubated and unfed fry will be released back to the Lewis River. No eggs will be destroyed under this program unless the infectious pancreatic necrosis virus (IPNV) is detected by Fish Pathology screening.

Because hatchery smolts are marked with a BWT and are not adipose-clipped, all unclipped (adipose-present) steelhead adults captured will be wanded for the presence of a BWT and PIT tags (see handling protocols, Appendices A and B). All unclipped winter steelhead captured at the MCF with positive wire detections shall be assumed to be HOR and will be transported upstream of Swift Dam to spawn naturally.[2] BWT fish collected through tangle netting will be PIT-tagged and released on site to evaluate pHOS (see Section D, objective 2). All winter steelhead that are PIT tagged and released downstream of Merwin Dam will be measured, sampled for scales and genetics, and recorded as male or female. All PIT-tag data are loaded into the Columbia Basin PIT Tag Information System (PTAGIS) daily.

There is known BWT loss that occurs for each brood year (BY). Based on previous genetic assignment results collected since 2009, the number of stubby dorsal fish lacking a BWT that assign to MPGs outside the basin is low (~2%). The probability of encountering out-of-basin hatchery steelhead after March 1 diminishes due to the separation of spawn timing between early-run timed hatchery derivatives and NOR steelhead. Therefore, prior to March 1, captured fish that lack a BWT, but have a stubby dorsal fin, will be taken to Merwin Hatchery and genetically assigned. If results meet the minimum genetic assignment probability threshold, those fish will be transported upstream. After March 1, stubby dorsal fin fish captured that lack a BWT but have intact adipose fins most likely represent F1 returns that have lost their BWT and will be transported upstream without any genetic assignment.

2.3 Broodstock Collection Goal

The goal is to spawn 25 females and 25 males using a 2 x 2 factorial mating protocol. However, it is often not possible to have 2 ripe males and 2 ripe females at the same time. Therefore, 1 female x 2 male mating crosses occur due to varying ripeness among held broodstock. Because of this variability, additional males are held on site to ensure that ripe females will, at a minimum, have one male to cross with along with a backup male. Up to 50 males may be held on site during the spawning period.

2.4 Broodstock Collection Methods

Two methods are used to collect steelhead for both broodstock and upriver transport. These methods include trapping at the MCF, Lewis Hatchery ladder, or through in-river tangle netting. All NOR adults with intact adipose fins that return to MCF will be assumed to be F1 offspring of adults from the upstream supplementation program that are attempting to return to the upper basin.

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[2] The Lewis River program is the only known source of winter steelhead with BWTs in Washington. Therefore, steelhead that are positive for BWTs are assumed to be returns from Lewis River program releases.

The trapping facilities at Merwin Dam and Lewis Hatchery ladder offer the most practical means of capturing NOR winter steelhead; however, recent annual returns confirm that relying on collections from the traps alone may not provide sufficient numbers or sex ratios of winter steelhead to meet collection targets. In addition, it is desirable to collect broodstock from multiple locations to increase the probability that the genetic diversity of the stock is represented in the broodstock. Therefore, in-river tangle netting is conducted weekly for collecting NOR steelhead for broodstock.

2.4.1 Traps and Weirs

The MCF is the main collection point for winter steelhead. The Lewis River ladder collects some winter steelhead, but is not a primary capture point. The MCF is cleared daily and sorting of fish occurs on site. Either Washington Department of Fish and Wildlife (WDFW) or PacifiCorp drivers will perform transportation of potential broodstock to Merwin Hatchery (from MCF or the Lewis River ladder). PacifiCorp staff will transport all BWT steelhead captured in the MCF upstream for adult supplementation. Potential broodstock captured at the Lewis River ladder are not sampled on site. These fish will either be released back to the river upstream of Merwin Dam (e.g., ripe or broodstock not needed) or transported to Merwin Hatchery for sampling and genetic analysis. WDFW or PacifiCorp drivers will transport potential broodstock from the Lewis River Hatchery to Merwin Hatchery.

2.4.2 Lower North Fork Lewis River Tangle Netting

Tangle netting will be the only method used for in-river capture. Success in collecting fish downstream of Merwin Dam depends on river flow conditions and visibility.

Monofilament tangle nets of 4-inch stretch mesh are drifted in known steelhead holding areas between Merwin Dam and the upstream end of Eagle Island. Nets vary between 75 and 150 feet long with a depth of approximately 6 feet. Nets should be dyed dark green and have approximate monofilament test strength of no more than 8 pounds to reduce rigidity and increase effectiveness. Boats are used to drift nets in established holding areas. Each boat is comprised of one boat operator and at least one net handler.

Netting will occur once weekly beginning March 1 and ending as late as May 30. This collection window allows fish to be captured throughout their entire run timing and provides the opportunity to PIT tag BWT steelhead over the run timing to evaluate pHOS (objective 2). Additional netting days may be scheduled during the collection period as broodstock or monitoring needs dictate.

Boat crews will determine whether to release tangle net caught adipose-clipped winter steelhead. This determination is made in the field and based on the following protocol: a hatchery fish will be released if it is determined to be a kelt or a green “bright” hatchery fish; all adipose fin clipped steelhead that are ripe or near ripe will be transported to Merwin Hatchery.

2.4.3 In-River Transport of Captured Steelhead

Transport tanks (e.g., Yeti® insulated coolers) are used on boats to protect and hold captured fish. To reduce stress, lids will remain closed and air stones are used during holding and transit to aerated holding tanks on shore. Rubber mesh dip nets are used to transport steelhead from the boats to the aerated tank on shore. The gravel bar at Lewis River Hatchery is the primary location for the aerated tank as it represents a central location for collection activities. Hatchery staff are notified when fish are placed in the aeration tank. Fish are transported to Merwin Hatchery by hatchery staff and held in the adult holding area to await genetic assignment results or to be transported upstream for adult supplementation if they are BWT positive. This handling protocol applies to all fish captured and retained during in-river netting (Appendix B).

2.5 Broodstock Collection Timing and Goals

Broodstock collection at all locations should occur proportionately over the entire run timing of the Lewis River late winter steelhead return. The proposed collection curve (Figure A3) for the NOR late winter steelhead portion of this plan is based on observations between 2009 and 2017 during in-river tangle netting, trap counts, and fish condition. Collection goals are established for each collection location at 15-day intervals (periods) to maximize genetic variation and minimize localized impacts for each location (Table A2). The annual collection curve may be updated annually to best approximate the actual run timing, which is variable.

Table A2. Winter steelhead collection targets by period indicating cumulative totals required to meet annual goals

Phase	Period	Captures by Period	Females	Males	Cumulative Total
1	Jan 30 – Feb 28	3	1	2	3
	Mar 1 – 15	6	2	4	9
	Mar 16 – 31	9	3	6	18
2	Apr 1 – 15	21	7	14	39
	Apr 16 – 30	24	8	16	63
	May 1 – 15	9	3	6	72
	May 16 – 31	3	1	2	75

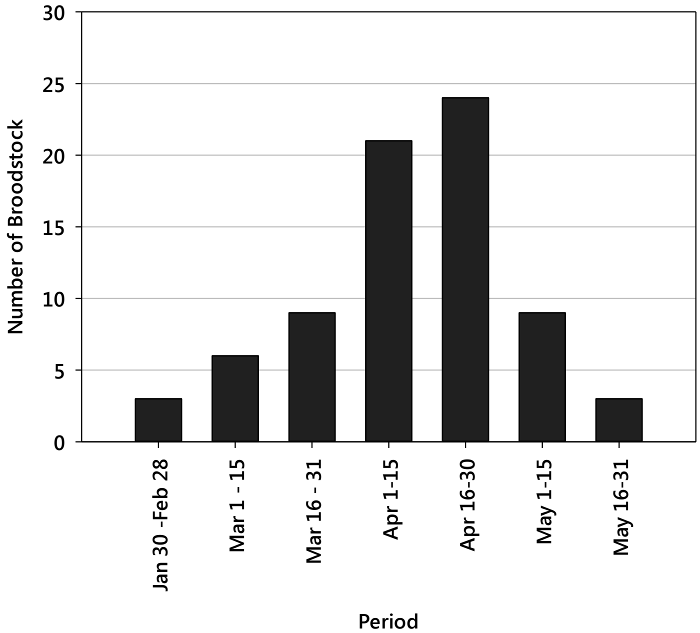

Figure A3. Number of late winter steelhead broodstock required for each period during the collection window (the collection curve)

Collection goals are intended to be a guide to direct in-season collections. There are a number of factors that may affect the number of broodstock retained during each period. For example, if only one female is available for a spawning cross, our factorial mating protocols require two males to complete this cross. This is also necessary to prevent the loss of eggs due to sterile males. This protocol may result in additional males held at the hatchery that exceed the collection curve provided in Figure A3. These types of events typically only occur in the early phases of collection when the number of broodstock available is limited. Other factors that may affect actual collections include weather, high runoff river flows, unexpected sex ratios, and mechanical failures at the traps or with tangle netting boats. Therefore, a weekly review of collections should occur to determine if additional in river collection efforts are needed. In-season management decisions pertaining to collection goals by location and collection periods are made by the Hatchery and Supplementation steelhead program coordinator in consultation with hatchery staff. Hatchery staff may consult with the Hatchery and Supplementation Subgroup (H&S Subgroup) prior to making decisions related to collection goals.

Fish collected prior to February 1 may contain a higher proportion of individuals with genetic assignment to early winter hatchery stocks due to the advanced run/spawn timing of these stocks and the likelihood that some hatchery fish successfully spawn naturally (Glaser, 2009). Genetic analysis of fish captured prior to January 25 will provide valuable information pertaining to the proportion of NOR Lewis River stocks prior to the collection window. Therefore, unmarked steelhead captured in either the Lewis River trap or MCF between December 15 and January 29 will be PIT tagged and have a genetic sample taken before release back to the river. Recaptures will continually be released unharmed from the traps during this period. After January 30, 2018, unmarked steelhead will be held at Merwin Hatchery pending genetic results for possible use as broodstock.

Progeny from broodstock spawned towards the end of the spawning period in late May through June may be difficult to rear to appropriate release size by May of the following year. Risks of releasing under-sized fish include decreased survival and a potential increase in residualism (Hausch and Melnychuk 2012), which may increase ecological interaction with other Endangered Species Act (ESA) listed salmonid populations (i.e., competition and predation). This risk should be balanced with the need to preserve the genetic diversity represented by late arriving or spawning fish. Adaptive management should be used to direct collections of broodstock from these early and late "tails" of the run as more information is gathered from this annual effort. Currently, broodstock collection ends on or before May 31 (Table A2).

2.6 Sampling, Marking, and Handling Protocols of Captured Steelhead

Protocols differ slightly between trap caught steelhead and those captured through in-river netting. Handling protocols for each capture method are provided in Appendices A and B.

For all steelhead captured that possess an adipose fin, biological data will be collected. Biological data includes the following metrics and applies to all collection methods:

1. Date of capture
2. Capture method
3. Capture location (in-river netting)
4. Gender
5. Fork length measurement (mm)
6. Scale sample (3 per fish, see below)
7. Ripeness
8. Presence of stubby dorsal fin
9. Race (i.e., summer or winter steelhead)
10. Noted as residual or anadromous[3] (Figure A4)
11. Other notes or comments that are unique to each fish (e.g., kelts, fish condition)
12. Presence of marks (e.g., adipose clip) or tags (e.g., BWT, floy, or PIT tags)

[3] Residuals are identified by color, body shape, and size. Residuals exhibit deep (and often vibrant) coloration and spotting as opposed to anadromous fish that possess silvery sheens and subdued spotting. Residuals also possess a distinct red or pink lateral stripe. Body shape of residuals is more rotund and are always smaller in size, typically less than 500 mm in length (Figure A4).

Figure A4. Residual steelhead encountered during annual tangle netting (note stubby dorsal fin)

Scale samples will be taken from up to 100 BWT and all NOR steelhead captured in either the traps or in-river netting. For 2018, scale samples will be taken from fish that are radio tagged, as these fish will already be handled. Scale samples from both NOR and program fish will be used to determine if differences in age structure exists between the two groups (e.g., program returns are younger than NOR returns).

All steelhead handled at the trap or through in-river netting will receive a PIT tag in the dorsal sinus. This provides survival information for repeat spawners in the lower river and overwintering survival of adult supplementation steelhead upon recapture at the Swift Floating Surface Collector (FSC) or through bull trout netting activities.

2.6.1 Traps

Appendix A illustrates the procedures for handling and sampling specific steelhead captured at the MCF. These procedures do not apply to steelhead captured at the Lewis River ladder. All sampling is performed at Merwin Hatchery upon delivery of steelhead from the Lewis River ladder or MCF.

All fish entering the MCF are scanned for coded wire and PIT tags. Crews sample and distribute steelhead either to Merwin Hatchery as potential broodstock or upstream as supplementation adults.

A systematic subsampling approach is used to obtain genetic samples of captured BWT steelhead. Every fifth fish handled will have a punch taken from the caudal fin to be used as a genetic sample. These samples will provide the proportion of families represented in returning and subsequently transported BWT steelhead. Because this sampling will occur daily over the entire collection period, there is no need for randomization or stratification of the collection subsample.

All potential broodstock will be transferred to Merwin Hatchery for sampling. Any unclipped fish with a stubby dorsal and lacking a BWT prior to March 1 will have a genetic punch taken and either passed upstream for adult supplementation or removed pending genetic assignment results (see Section 2.8). After March 1, all stubby dorsal fin steelhead lacking a BWT but possessing an adipose will be passed upstream for adult supplementation without genetic assignment (Appendix A).

PIT tagging will be performed using injectors and tag trays provided by Biomark® to ensure sterility. All PIT tags are inserted into the dorsal sinus cavity of each fish. PIT tag code verification will take place prior to insertion. All PIT tag data will be uploaded into PTAGIS within 24 hours.

2.6.2 In-River Netting

Handling during in-river netting will follow similar procedures as those captured in the MCF (Appendix B).

Up to 100 BWT positive steelhead (if available) will be biologically-sampled, PIT tagged, and released back to the river for pHOS evaluations (see Objective 2). Any BWT fish not released back to the river will be retained and transported upstream for adult supplementation (e.g., residuals). Residuals, for purposes of this program, are defined as all steelhead (including HOR and NOR) less than 500 mm in fork length.

2.7 Genetic Assignment and Analysis

The H&S Subgroup concluded that the most appropriate stock(s) for use in the steelhead reintroduction program are those native to the Lewis River Basin. The Lower Columbia Fish Recovery Board's Lower Columbia Salmon Recovery & Fish and Wildlife Subbasin Plan identifies the lower Lewis River late winter steelhead population (including Cedar Creek) as a unique population for recovery (rated as "contributing") and recommends its use for reintroduction into the Lewis River Basin upstream for adult supplementation (LCFRB 2010).

The H&S Subgroup also concluded that genetic screening of NOR steelhead collected for broodstock should occur for three purposes:

1. To identify fish that may be derivatives of, or show influence from, hatchery steelhead stocks propagated in Washington's LCR hatcheries (i.e., Chambers Creek early winter steelhead and Skamania stock summer steelhead)
2. To identify fish with a high likelihood of origin from Lewis River and Cedar Creek stock(s) as compared to other LCR steelhead populations

3. To ensure summer steelhead are not used as broodstock

A genetic approach will be used to identify the origin of potential broodstock captured at the MCF or through tangle netting. Each fish will be genotyped at the National Oceanic and Atmospheric Administration (NOAA) Northwest Fisheries Science Center genetics laboratory by Dr. Gary Winans and staff for 13 mSAT loci that have been standardized within the Columbia River Basin using standard binning protocols (Stephenson, et al. 2008). The origin of each fish is compared against established baselines and assigned origin probabilities with the ONCOR program[4] following the method of Rannala and Mountain (Rannala and Mountain 1997).

Single nucleotide polymorphism (SNP) protocol will be used to sample BWT steelhead transported upstream for adult supplementation. This method is more efficient and cost effective when large sample sizes are anticipated. SNP analysis will indicate the extent of family representation among spawning crosses within the population of captured BWT steelhead. SNPs will also provide an estimate of the effective population size (N_e) for returning BWT steelhead (see Section D, objective 11 for more detail about N_e).

Outmigrating steelhead smolts collected at the FSC will also be sampled using SNP protocol, starting in 2018. Genotypes of outmigrating smolts will be compared to baselines established prior to anadromous reintroduction for rainbow (including HOR Goldendale and Spokane stocks) and cutthroat trout. This analysis will determine the extent of spawning interaction between resident species and reintroduced anadromous steelhead. The actual number of smolts selected for testing will be based on capture rates, but the target is to collect at least 200 samples during the outmigration period. This sampling will be performed in 2018 and 2019.

For the purpose of establishing a broodstock for reintroduction upstream for adult supplementation, the H&S Subgroup has determined that each fish used for broodstock must show probability of assignment of 50% or greater to the Lewis River or Cedar Creek stock(s) combined. In most instances, the primary probability (the probability with the highest likelihood value) of either Lewis River or Cedar Creek stocks exceeds the 50% threshold. Fish with primary assignment to the Lewis River will be given priority over fish with probabilities exceeding 50% comprised from both Lewis River and Cedar Creek. The only exception to this rule is for fish indicating assignment to hatchery stocks. Any winter steelhead with assignment to hatchery stocks at levels greater than 5% will not be incorporated into the broodstock despite genetic probability assignment of 50% or greater to the Lewis River winter steelhead stock.

For each broodstock collection period with excess fish, hatchery staff—in consultation with the program coordinator and WDFW staff—will select the appropriate number of males and

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[4] Steven Kalinowski, Montana State University; http://www.montana.edu/kalinowski/Software/ONCOR.htm

females for release based on (weaker) genetic assignment probabilities. Collection goals for each location and period (Table A1) will be used as guidance.

2.8 Genetic Sampling Procedures

Genetic sampling will consist of removal of a portion of the caudal fin (round punch). The fin sample is placed in genetic sample vials filled with ethanol. Genetic samples are assembled and sent every Tuesday, via express overnight mail, to the NMFS genetics lab for assignment analysis. For tangle netting captures and those fish processed at Merwin Hatchery (potential broodstock), a distinct alphanumeric code is assigned. For example, each location or method will have a distinct alpha code (e.g., TN = tangle netting, MCF = Merwin Collection Facility) followed by two-digit year and sequential numbering. For BWT steelhead returning to the MCF, genetic clips will be pooled by week. That is, for each week, every fifth BWT steelhead will be sampled and all samples for the week will be placed into a single bottle or vial representing that week's captures.

Every fish sampled will be PIT tagged to provide permanent and unique identification of each fish until genetic testing results are known. Biological information on each fish will be linked with the corresponding PIT tag code and be archived in spreadsheet format. PIT tag codes are uploaded into PTAGIS each sampling day.

2.9 Broodstock Holding Protocols

The following list represents recommendations from WDFW hatchery staff that will be used to reduce handling related stress, injury, or mortality of steelhead held at the Merwin Hatchery. Other methods or procedures that may be employed include:

1. The use of only rubberized nets to hold or move steelhead: Rubberized nets are known to reduce descaling and abrasion.
2. Eliminating the use of cotton gloves to handle steelhead in favor of bare hands: Cotton gloves are abrasive on fish and remove the protective mucous on the skin of fish.
3. MS-222 is used for the safety of the employee and to prevent injury and stress to fish during air spawning from the females and live spawning of the males.
4. Floy tags are used to identify acceptable broodstock. PIT tags are inserted into all steelhead returned to the river from Merwin Hatchery already sampled for genetic analysis. By doing so, any fish that are recaptured will easily be identified and will not be subjected to further genetic testing.
5. Salt and Formalin are used in holding raceways or circular tanks for steelhead. Salt reduces stress and improves oxygen uptake. Formalin is used to control fungi and parasites.

All NOR winter steelhead broodstock will be held at the Merwin Hatchery. Steelhead will be held in separate existing adult raceways (e.g., ponds 2A, 2B, or 2C) or circular tanks (if available) depending on capture site, until genetic assignments are complete. Hatchery staff will check broodstock weekly for maturity. Once DNA results are confirmed, hatchery staff will follow one of the following steps.

1. NOR winter steelhead identified for use as broodstock from the MCF or tangle netting will be placed in adult pond 3 or circular tank.
2. Within each collection period, genetically eligible fish in excess of broodstock needs may be held in separate ponds for one additional period to ensure collection goals of the next period are met (see Release Protocols below).
3. Fish collected at MCF and lower Lewis River that will not be used for broodstock will be returned to the river (some intended to be used for broodstock may also be returned to the river according to Spawning Protocol 8 in Section 2.13).
4. Unclipped steelhead that assign to a hatchery stock (greater or equal to 50%) will be removed and not released back into the river.

2.10 Broodstock Release Protocols

Once the cumulative broodstock collection goal for females and males with sufficient genetic assignment is met for a collection period (Table A2), excess fish up to the number needed for the next period may be held until collection goals for the following period are met. Surplus fish in excess of this need may be released based on genetic assignment probabilities. That is, fish with the highest probability to Lewis River stock shall be retained over fish with lower probabilities or fish with assignment to other stocks. If cumulative goals are met with newly arriving fish, all excess fish held from the previous period will be released to the river downstream of Merwin Dam after assignment is confirmed for the newly arriving fish. If fish sustain injury or have the appearance or behavior consistent with infection or illness, those fish shall be released immediately if green.

If a female becomes ripe to spawn and no male broodstock are available or the fish is being held as excess and has not yet been incorporated into broodstock that fish will be returned to the river; however, all possible precautions will be made to prevent this situation from occurring. The Hatchery and Supplementation steelhead program coordinator in consultation with hatchery management staff will make decisions regarding release of fish. Collection goals should be reviewed to evaluate the risk to project goals of releasing the fish (i.e., will more females likely be available through future collections).

2.11 Egg Take Goals

The egg take goal for this program is 90,000 +/- 20%. Fecundity is highly variable among native females and this goal is intended to be flexible; however, total egg take should never exceed the maximum level of 108,000. In-season adaptive management will be used to meet egg collection goals through broodstock management. Depending on fecundity levels, partial spawning may occur with females to assist in meeting the 25-female target without exceeding the egg take goal. However, this decision must be coordinated with WDFW and NMFS prior to implementation. The last available spawning day will be approximately June 1, 2018, in order to meet the program size goals at release. If the rearing goal is exceeded, surplus fish will continue to be reared and released with the program fish. However, this will require notification of NMFS prior to release. The intention of the spawning program is to never exceed the egg take goal and precautions should be employed (e.g., partial spawning) if it is in jeopardy of exceeding the production limits set in this plan.

2.12 Spawning Protocols

All collected fully mature broodstock will be spawned according to the following protocols, without regard to age, size, or other physical characteristics:

1. No fish shall be excluded except for those with overt disease symptoms or physical injuries that may compromise gamete fertility or viability.
2. All spawned fish will be returned to the river.
3. Females will be air spawned.
4. Use fully randomized mating protocols to avoid or reduce selection biases.
5. 2x2 factorial crosses are preferred (if available) to reduce the potential of and concerns with infertile males.
6. In the event that two females and only one male fish are ripe, a 2x1 cross can occur, but is not preferred and efforts should be made immediately to collect additional males either through in-river netting or from the MCF if in Phase II collection.
7. Holding males for additional spawning crosses is not permissible.
8. In the event that a ripe spawning female has no mate, that fish will be returned to the river downstream of Merwin Dam in hopes of spawning naturally (see Section 2.10 Release Protocols). All precautions will be taken to prevent this situation from occurring. Whenever possible the decision to release females should occur prior to the female becoming ripe.
9. During spawning, a pathologist will take the necessary viral samples according to standard protocols.
10. Ovarian fluid will not be drained prior to fertilization.
11. Eliminate green egg samples: Total egg mass weight will be used to estimate fecundity.

The use of factorial mating crosses may require additional males to be held at the hatchery to ensure that more than one male is available when a female becomes ripe. This reduces the risk of infertile males and resulting egg loss. This action may increase the total number of male broodstock held at the hatchery, but female targets will remain unchanged at 25.

2.13 Disposition Protocols of Adults

Fish that are subject to mortality through lethal removal or other causes will be disposed of at the direction of WDFW. All other fish are live spawned and returned to the river or returned to the river unspawned.

2.14 Disease Protocols

Ovarian fluid will continue to be sampled for regulated viral pathogens. No lethal pathogen screening is proposed. During the initial 3-year broodstock collection, the WDFW lethally sampled all males for IPNV, but all samples were negative.

2.15 Egg Incubation

Incubation rearing will consist of dividing each egg tray in half and only having one female per tray to increase egg density in an effort to reduce agitation and consequently reduce Bacterial

Coldwater Disease (BCD). This helps reduce the risk of BCD by reducing flow and mobility of the eggs. Each spawned fish will have its own ozonated water supply. Eggs or fish will not be combined until viral results are known. Fish or eggs testing positive for IPNV will be destroyed.

2.16 Rearing and Release Program Schedule

Hatchery staff will begin feeding, monitoring rearing densities, and recording all data necessary for this stock. Eggs and juvenile fish may be reared in heated water as needed to speed development and assist in achieving a uniform size. These fish will be raised in intermediate raceways on ozone treated water for 6 to 8 months or until they outgrow the rearing vessels. Once these fish outgrow the intermediate raceways they will be placed outside into standard raceways where they will be subject to untreated water. Standard protocols will be used in the case of a disease outbreak. Table A3 presents a timeline for movement of fish by life history stage through the Merwin Hatchery.

Rearing strategies should employ recommendations from the Hatchery Scientific Review Group (HSRG) to mimic, when possible, aspects of the natural environment such as cover or feeding. The intent is to rear steelhead that mimic closely both the size and behavior of the natural population, which is consistent with current HSRG recommendations (HSRG 2014).

In addition to monitoring rearing densities and feeding, hatchery staff assesses performance and growth by implementing sampling methods to calculate condition factor (K), estimated coefficient of variation (CV), and feed conversion factor (FCR) for each raceway. For this stock, these assessments are typically completed prior to first feeding and prior to release. This is done by randomly sampling 100 fish from the general population in each raceway from three locations for a total of 300 fish per raceway. If needed, fish are sedated using MS-222. Individual lengths and total sample group weight are recorded. These data are used to estimate K, CV, and FCR for each raceway. About a month prior to release, the quality assurance and quality control (QA/QC) protocol extends this process to 500 fish from each raceway. Again, individual lengths and total sample group weights are recorded as well as a visual confirmation of adipose clip and note visual cues of precocity (dark and/or bronze coloring, rounded and robust body size, milt release).

Table A3. Hatchery production and collection timeline for late winter steelhead

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Adult Collection												
Spawning												
Incubation												
Ponding												
Tagging (BWT)												
Volitional Release												

2.17 Feeding Type and Requirements

All fish that are ponded for rearing at Merwin Hatchery will be fed the best quality feed available through WDFW vendors. These formulations provide high protein and fat percentages and have proven to provide optimal growth from start to finish (Roberts, 2013).

There will be a combination of feeding methods used to enhance growth. One option will be hand feeding 2 to 8 times per day depending on fish life stage. During their rearing in the troughs and intermediate raceways, belt feeders may be employed for an extended feeding schedule. Once these fish are transferred to the raceways outside, only hand feedings will occur. When fish are transferred to the large rearing pond, demand feeders will be used along with hand feedings 2 to 3 times per week if needed. More natural types of feeding (e.g., underwater or demand feeders) and rearing strategies may be explored and evaluated in the future.

2.18 Juvenile Marking and Tagging

Once these fish reach a size of 20 to 25 fish per pound (fpp) they will be tagged with BWTs and placed into the rearing ponds until their scheduled release.

A subset of juvenile steelhead that are collected at the FSC will be PIT tagged to provide additional information on juvenile transport survival at the release ponds and preliminary information on smolt out-migration timing (based on lower Col. River detections) and out-of-basin avian predation (based on detections at bird colonies such as East Sand Island). The target is to tag approximately 10-15% of the parr or smolts (> 90mm) that are passed downstream from the Swift FSC. Juveniles captured at the FSC may be offspring of supplementation program adults.

2.19 Target Release Size and Number

Target release size is 5 to 8 fpp. Some fish released may be smaller than the target depending on growth rates achieved while reared at the Merwin Hatchery. The target number released shall be 50,000 smolts +/- 20%.

2.20 Release Timing and Locations

Volitional release of smolts is scheduled to begin on April 15. Releases will continue through June 1. A review of smolt size (fpp) will be conducted prior to beginning volitional release.

Fish that actively migrate during the volitional release window will be trucked to the Merwin boat ramp (RM 19) for planting. Once the volitional window has ended, the remaining fish will be hauled and planted at Pekins Ferry Boat Ramp (RM 3.1). Volumetric methods are used to enumerate fish planted and the estimates are reported in WDFW Fishbooks and annual reports.

2.21 Adult Supplementation Protocol

All winter steelhead captured possessing a BWT will be transported upstream for adult supplementation except for steelhead that are radio tagged (or PIT tagged) and released back to the river (see Section D, objective 2).

Transported steelhead will be released at different locations upstream of Swift Dam to enhance their distribution into tributaries of Swift Reservoir. Eagle Cliff, Muddy River Bridge, Clear Creek Bridge, and Curly Creek Bridge will be used to release an approximately equal portion of the transported steelhead. This will include equal distribution of radio tagged steelhead at each location. To simplify the logistics, truckloads will work on a rotating basis for each haul. For example, the first load will be released at Eagle Cliff, the second at Muddy River Bridge, and so on. This may not equate to equal portions for each site, but it should be reasonably close.

No kelts captured below Merwin Dam will be transported upstream. All kelts regardless of origin will immediately be returned back to the river. All residuals that lack a BWT will also be returned to the river.

SECTION B. SPRING CHINOOK

1.0 INTRODUCTION

The Lewis River spring Chinook salmon program is composed of two parts: adult supplementation upstream of Swift Dam and juvenile hatchery production, primarily for release downstream of Merwin Dam. Adult supplementation will provide up to 2,000 adults for release upstream of Swift Dam each year to spawn naturally. This target number of adults was selected through the Ecosystem Diagnostic and Treatment (EDT) process to define the spawning capacity upstream of Swift Dam. Juvenile supplementation will rear up to 1,350,000 spring Chinook for release downstream of Merwin Dam[5]. Release timing of juvenile supplementation fish will vary depending on planned evaluations described in Appendix D. Returns from both the adult and juvenile supplementation programs comprise the foundation to meet the primary goal of creating a self-sustaining population that does not rely on hatchery support. This section describes the implementation of both the supplementation and hatchery programs for 2018.

2.0 PROGRAM IMPLEMENTATION

The following sections describe the detailed protocols for implementation of the spring Chinook portion of the H&S Plan.

2.1 Broodstock Source

Broodstock will involve the collection of both HOR and NOR spring Chinook at the MCF and Lewis River Hatchery ladder. These two origins have different priorities as described below.

1. NOR (adipose fin intact, no snout coded wire tag [CWT]). Adult returns identified as NOR will be transported upstream of Swift Dam to help meet the adult supplementation target of 2,000 captures. No NOR Chinook are used to meet juvenile production needs at the hatchery.

2. HOR (adipose fin missing, or adipose fin intact AND CWT snout tag). Adult hatchery spring Chinook returns will be used to meet juvenile production (mitigation) targets. Broodstock will be selected over the course of the run, and any surplus spring Chinook will be transported upstream to adult supplementation targets. In years when hatchery returns are weak, it may be necessary to hold surplus Chinook at Lewis River Hatchery in the early portion of the run until it becomes clear the annual broodstock goal will be met. After 50% of the run has been realized, a decision will be made on whether to transport all (or a portion of) surplus Chinook being held at Lewis River Hatchery upstream of Swift Reservoir.

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[5] Beginning in 2018, juvenile supplementation was modified by the ACC to release of all juveniles downstream of Merwin Dam for a period of at least 5 years. Annual review of this modification will occur annually between the ACC and H&S Subgroup

Planning should be coordinated with hatchery staff to ensure that broodstock are collected proportionately over the run curve.

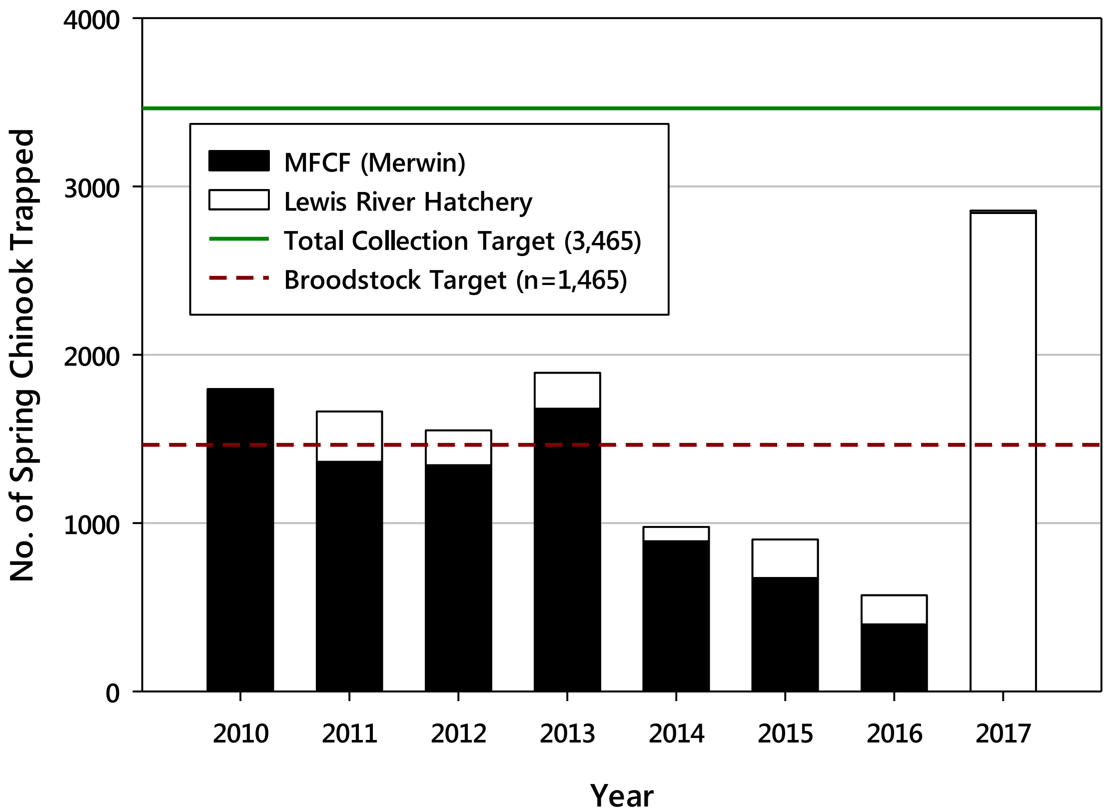

Figure B1. Total number of spring Chinook trapped annually between 2010 and 2017 at both the Merwin Collection Facility and Lewis Hatchery ladder

*Note: *Total collection target line includes adult supplementation targets upstream of Swift Dam.*

2.2 Broodstock Collection Goal

The 2018 run prediction for spring Chinook salmon is 3,600 fish. Spring Chinook broodstock collection goals for the Lewis River programs are as follows:

- Adult Supplementation: Up to 2,000 adults over the full range of the run.
- Hatchery Broodstock: Approximately 1,465, depending on fecundity and sex ratios, over the full range of the run.
- June Release: Up to 50 adults over the full range of the run (if available).

Collection for hatchery broodstock will be given priority each week. All fish allocated for hatchery broodstock will be transported and held at Speelyai Hatchery. If the weekly quota for hatchery broodstock is not met, then all fish collected during subsequent weeks will be allocated for broodstock until the quota is on track.

All HOR fish collected prior to the week ending May 26, 2018, designated as adult supplementation (upstream) fish will be transported and held at Lewis River Hatchery. All fish containing CWTs will be allocated to hatchery broodstock, and transported to Speelyai Hatchery. A meeting will be held between PacifiCorp Aquatics Team and WDFW Fish Managers during that week to discuss current run numbers and whether fish being held at Lewis River Hatchery can be taken upstream. If adult spring Chinook are returning at a rate at or above the projected running curve for that period, then all fish being held at Lewis River Hatchery will be taken upstream as well as any subsequent fish allocated for adult supplementation. If it appears that adult spring Chinook are returning at a rate well beyond the projected run curve, then it is possible that adults being held at Lewis River Hatchery could be taken upstream earlier. If it is decided that fish being held at Lewis River Hatchery will not be transported upstream by May 26, 2018, they will continue to be held until hatchery brood stock goals have been met. Fish allocated for adult supplementation may be reallocated for hatchery broodstock if the adult return rate remains below the projected number.

All available NOR fish are to be used for adult supplementation upstream of Swift Dam.

As part of the spring Chinook rearing evaluation, up to 50 adults may be used to produce a June release group of approximately 50,000 smolts. Broodstock for this group will not be collected until all other program goals are met. For example, no broodstock is available for this program if adult supplementation targets (n=2,000) are not met.

All spring Chinook less than 24 inches will be considered jacks. Jacks will not comprise more than 5% of the broodstock collection or adult supplementation.

2.3 Broodstock Collection Timing

Broodstock collection for the juvenile supplementation program should occur proportionately over the entire run timing. NOR Chinook that are not used for juvenile supplementation should be transported upstream at the time of capture. Figure B2 illustrates the trap timing of spring Chinook entering the MCF. Table B1 illustrates the 2018 spring Chinook generalized collection curve for each part of the program described in the previous section.

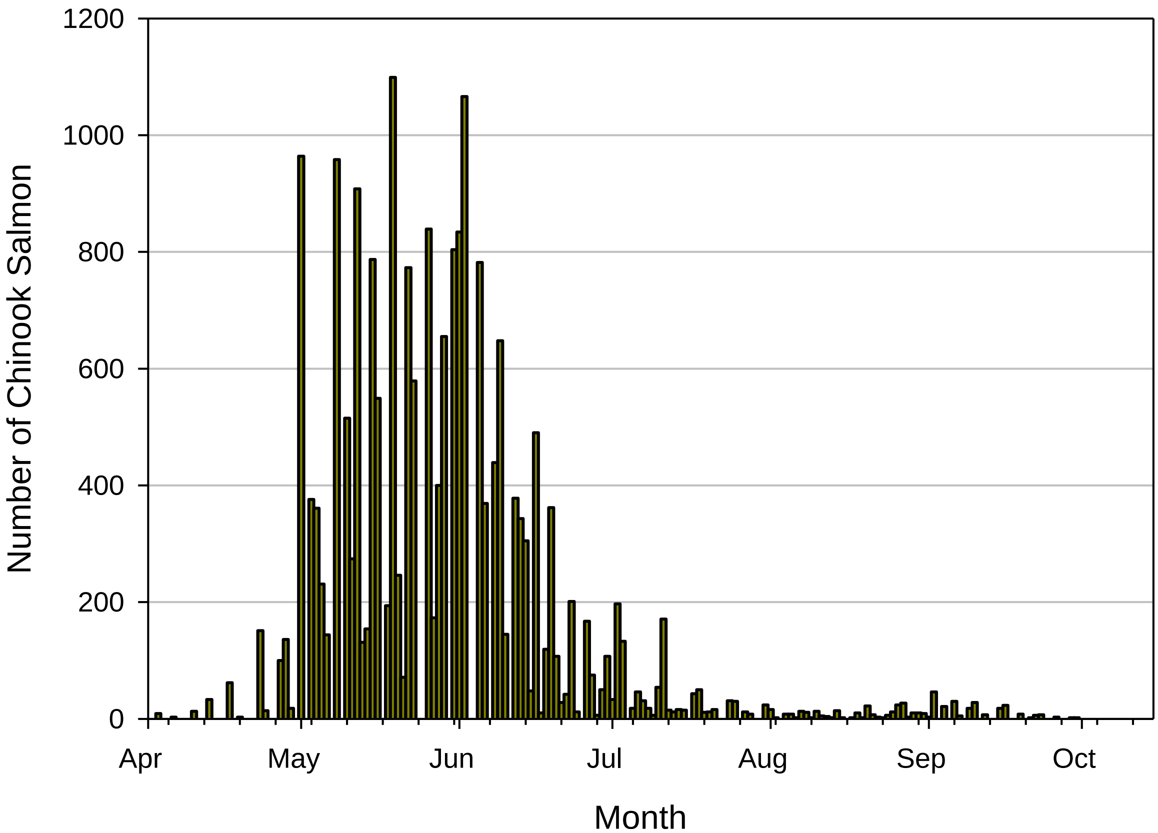

Figure B2. Illustration of weekly trap capture (timing) for spring Chinook at the base of Merwin Dam during the period 2003 through 2009

Table B1. Spring Chinook generalized collection curve for each program allocation in 2018

Week Ending (2018)	Hatchery Brood Stock	Adult Supplementation (Upstream)	Juvenile Supplementation (Acclimation Program Brood)	June Release	TOTAL
7-Apr	21	32	2	0	55
14-Apr	6	10	0	0	16
21-Apr	13	19	1	0	33
28-Apr	61	94	4	10	169
5-May	69	106	5	10	190
12-May	153	234	11	10	408
19-May	169	259	13	10	451
26-May	226	344	17	10	597
2-Jun	243	372	18	0	633
9-Jun	155	236	11	0	402
16-Jun	92	141	7	0	240
23-Jun	29	45	2	0	76
30-Jun	26	39	2	0	67
7-Jul	16	25	1	0	42
14-Jul	6	10	0	0	16
21-Jul	11	17	0	0	28
28-Jul	7	11	1	0	19
4-Aug	4	6	0	0	10
TOTAL	1,307	2,000	95	50	3,452

Note:
In 2018, fish arriving before the week ending 7-Apr were collected and held at Speelyai Hatchery as potential broodstock rather than transported upstream.

2.4 Broodstock Holding Protocols

Broodstock are collected daily from April 1 through as late as August 4 at the MCF or Lewis River ladder and transported to Speelyai Hatchery and held until spawning begins in mid-August. Broodstock that receive antibiotic injections are not released, used for nutrient enhancement, or donated to any food banks or tribes because of mandatory injection withdrawal periods.

2.5 Spawning Protocols

All collected fully mature broodstock will be spawned using a pairwise (1x1) mating cross with a backup male. No fish shall be excluded except for those with overt disease symptoms or physical injuries that may compromise gamete fertility or viability. All fish are kill spawned, and disposition of carcasses is directed by the WDFW.

2.6 Egg Take Goals

Total spring Chinook eggs needed to meet hatchery production is 1,875,000 to produce and release 1,350,000 smolts for the juvenile supplementation program.

2.7 Egg Incubation and Juvenile Rearing

Eggs are incubated in vertical stack incubators. Each female is assigned a number and only one female per tray, unless there are not enough trays towards the last egg take, then two or three fish will be pooled together until results are in from the enzyme-linked immunosorbent assay (ELISA) testing, if testing is performed. Once ELISA results are in staff will only combine females with the same level of results together for hatching. If determined on the last egg take that there is a surplus of eggs, then staff will have the option to cull any eggs with low, moderate, or high levels of Bacterial Kidney Disease (BKD) with confirmation from pathology. Culling has not occurred in recent years due to low numbers of returning adults available for broodstock. All adult females from the February release groups will be ELISA sampled and their eggs will be incubated as stated above. Females allocated to the October release group will not be ELISA sampled, and therefore, their eggs will be incubated in deep troughs (bulk eyed).

All spring Chinook from fry to smolt are fed the highest quality feed available from WDFW contracted vendors. Fry will start out being fed 7 days per week. As they grow, the number of days fed per week will be reduced, but will not be less than 3 days per week.

Hatchery staff will implement monthly performance sampling and a QA/QC sampling prior to release. These methods are described in detail in Appendix D.

2.8 Pathology Screening and Protocols

Kidney, spleen, and ovarian samples of at least 60 randomly selected adult females are to be inspected and sampled by a pathologist for reportable pathogens during spawning. The reportable pathogens, as defined in U.S. Fish and Wildlife Service policy 713 FW, are infectious hematopoietic necrosis virus (IHNV), IPNV, viral hemorrhagic septicemia virus (VHSV), infectious salmon anemia virus, *Oncorhynchus masou* virus, *Renibacterium salmoninarum* (causative bacteria of BKD), *Aeromonas salmonicida*, *Yersinia ruckeri*, and, if needed, *Myxobolus cerebralis*.

Only females allocated to the February release group will be ELISA tested. This test detects antigens of the causative agent of BKD and assigns a low, moderate, or high level based on the relative concentration of antigen detected. Females from the October group will not be sampled due to the lower risk of BKD expression and logistical considerations. In addition to ELISA sampling, 75 randomly selected females from the February group will be concurrently sampled for quantitative polymerase chain reaction (qPCR) assay. This molecular test detects relative concentrations of bacteria DNA present in the tissues sampled and is generally a more sensitive test compared to ELISA. This sampling will continue previous work completed in the past 2 years assessing and optimizing use of this diagnostic test in comparison to ELISA sampling.

2.9 Rearing and Release Program Schedule

Table B2. Hatchery production and collection timeline for North Fork Lewis River spring Chinook

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Adult Collection												
Spawning												
Incubation												
Rearing												
Tagging												
Volitional Release												

2.10 Juvenile Marking and Tagging

Juvenile tagging type and location for hatchery-produced spring Chinook are presented in Table 6-1 of the H&S Plan (PacifiCorp and Cowlitz County PUD 2014).

A subset of juvenile spring Chinook that are collected at the FSC will be PIT tagged to provide additional information on juvenile transport survival at the release ponds and preliminary information on smolt out-migration timing (based on lower Col. River detections) and out-of-basin avian predation (based on detections at bird colonies such as East Sand Island). The target is to tag approximately 10-15% of the parr or smolts (> 90mm) that are passed downstream from the Swift FSC. Juveniles captured at the FSC may be fish that were hatchery-reared and released from the juvenile supplementation program in previous years and overwintered upstream of Swift Dam or may be offspring of supplementation program adults.

The hatchery production goal is 1,350,000 smolts. Most smolts released from the hatchery (950,000) will be adipose clipped only. An additional 150,000 will be adipose clipped and tagged with snout CWTs. 150,000 will be tagged with snout CWTs with no adipose clip (double-index tag group). The remaining 100,000 smolts to be released are part of an integrated (50% natural-origin broodstock) hatchery group that in past years was designated for acclimation upstream of Swift Reservoir.

Prior to 2018, approximately 100,000 smolts were released as part of an integrated (50% natural-origin broodstock) hatchery group that was designated for acclimation upstream of Swift Reservoir. The ACC decided in 2018 the BY2017 acclimation group should be marked with a ventral fin clip and released downstream of Merwin Dam due to low rates of juvenile survival and passage through Swift Reservoir in recent years. The ventral fin clip will allow managers to differentiate returning adults of this group from segregated hatchery program fish and NOR adults. Ventral fin clips will also differentiate this group in fisheries. The ACC agreed in June 2018 that acclimation fish plants into the upper basin will be suspended until collection efficiency at the Swift FSC improves to warrant restarting the juvenile acclimation program upstream of Swift Dam. This decision will be reviewed on an annual basis by the H&S subgroup. BY2018 will be composed entirely of segregated hatchery release groups.

2.11 Juvenile Release Protocols

As described in objective 6, objective 8, and Appendix D of this plan, most spring Chinook (1,350,000) are volitionally released as yearlings in October or February from Lewis River Hatchery directly into the Lewis River. The volitional release includes pulling the screens, lowering the water level slowly over a 2-week period or until 90% or more of the smolts have left on their own. The remaining fish left are then flushed out.

<u>Target Release Size:</u>

- *Hatchery Program*: 8, 12, or 80 fpp depending on release group (see Table B2)

<u>Release Timing:</u>

All hatchery reared spring Chinook destined for the Lewis River below Merwin Dam prior to 2014, were volitionally released as one group between February and March. BY 2012 was split into three groups, one released in February 2014 at the same size as past years (~8 fpp), one released in February 2014 at ~11 fpp, and one released in March at ~11 fpp. For BY 2013, release timing was separated into fall and spring release groups, for experimental purposes, in an effort to improve survival and reduce stress (see Appendix D). Different release strategies were used for BY 2014 through 2016 (see Appendix D).

A new study designed to test release strategies and survival between up to five release groups is beginning with BY 2017, described in detail in Appendix D. Table B3 shows the different release groups planned as part of this study, which were designed to test the following variables: release month, date transferred to Lewis River Hatchery, rearing environment, and size at release. This study will continue for at least 3 BYs (through BY 2019) and strategies will be evaluated each year and changes made if substantial problems are discovered. After 3 years of implementation, in-hatchery survival rates, size-at-release, condition factor at release, fish health (frequency or rates of disease), and physiological status at the time of release will be compared between treatment groups as described in Appendix D.

No surplus juvenile Chinook salmon were available from BY 2017 to support a June release in 2018.

In 2018 only, the integrated acclimation program smolts formerly released upstream of Swift Dam will be released from the Woodland Release Ponds beginning in November. The integration of these fish among rearing and release groups will be revisited in the 2019 AOP.

Table B3. Release groups planned for release in 2018 (BY 2017)

Release Group	Release Month	Transfer Month to Lewis River Hatchery	Rearing Environment at Speelyai Hatchery	Size (fpp)	Total Number at Ponding	Losses Pre-Marking[1]	Number Tagged	Post-Tagging Mortality Rate[2]	Expected Tag Release	Expected Total Release	Mitigation Goal
1	February	June 2018	Raceway	8	200,000	6,000	75,000	24.0%	57,000	147,440	150,000
2	February	Dec 2018	Asphalt pond	12	200,000	6,000	75,000	9.0%	68,250	176,540	150,000
3	February	Dec 2018	Raceway	8	170,000	5,100	75,000	9.0%	68,250	150,059,	150,000
4	October	June 2018	Raceway	12	950,000	28,500	75,000	10.0%	67,500	829,350	800,000
Integrated Acclimation [4]	November	NA	Raceway	25	NA	NA	100,000	NA	100,000	100,000	100,000
	TOTAL				1,572,000	47,160	350,440		311,137	1,353,526	1,350,000

Notes:

[1]A pre-marking mortality rate of 3% applied to all groups

[2]Mortality rates averaged for BY 2011 through 2015 wherever release size and timing were similar. Mortality rates for potential June releases were derived from hatchery records. Mortality rates for October and February releases were derived by subtracting the RMIS release numbers from the original number tagged for each group. Mortality rate for release groups 2 and 3 was assumed to be the same as the 12 fpp release group from BY 2013

[3]Implementation of Group 5 is contingent on available broodstock and approval of the H&S subgroup. Assumes a minimum of 50,000 fish will be planted. See Appendix D for future target release goals. No surplus juvenile Chinook salmon were available from BY 2017 to support a June release in 2018.

[4] Chinook salmon smolts formerly released upstream of Swift Reservoir to be differentially marked (LV clip) and released downstream of Merwin dam in 2018 only. The allocation of this group among rearing and release groups and the maximum number of surplus or program smolts released in June will be updated in the 2019 AOP.

2.12 Adult Supplementation Protocol

Up to 2,000 spring Chinook (when available) will be transported from the MCF and Lewis River traps (or acceptable alternative stock) to Eagle Cliff or designated areas upstream of Swift Dam. It is preferable to have these adults be NORs; however, given the low number of returning NORs collected (Table B1), this is not presently possible. A minimum of two tanker fish trucks will be used weekly to move captured spring Chinook upstream. Each tanker truck can transport about 100 adult Chinook salmon. Figure B3 provides a proposed transportation schedule indicating weekly numbers to achieve the transport goal of 2,000 over the run period.

Prior to 2017, transported spring Chinook were released at different locations upstream of Swift Dam to enhance their distribution into streams (seed planting). Eagle Cliff, Muddy River Bridge, Clear Creek Bridge, and Curly Creek Bridge were used to release an approximately equal portion of the transported spring Chinook. To simplify the logistics, fish trucks rotated the release location of each haul. For example, the first load will be released at Eagle Cliff, the second at Muddy River Bridge, and so on, resulting in nearly equal portions released at each site. In 2017 the majority of spring Chinook were released at Eagle Cliff with small numbers released at other sites and spawning distribution in the upper watershed appeared to be adequate. In 2018, all fish will be released at Eagle Cliff. Eagle Cliff was chosen as a preferred site for release as it is not affected by reservoir fluctuations and provides the opportunity for released fish to migrate upstream immediately without having to migrate through reservoir waters which can exceed optimal water temperatures. Distribution of spawning will be monitored annually to determine if spawning distribution is adequate and protocols will be adapted as needed.

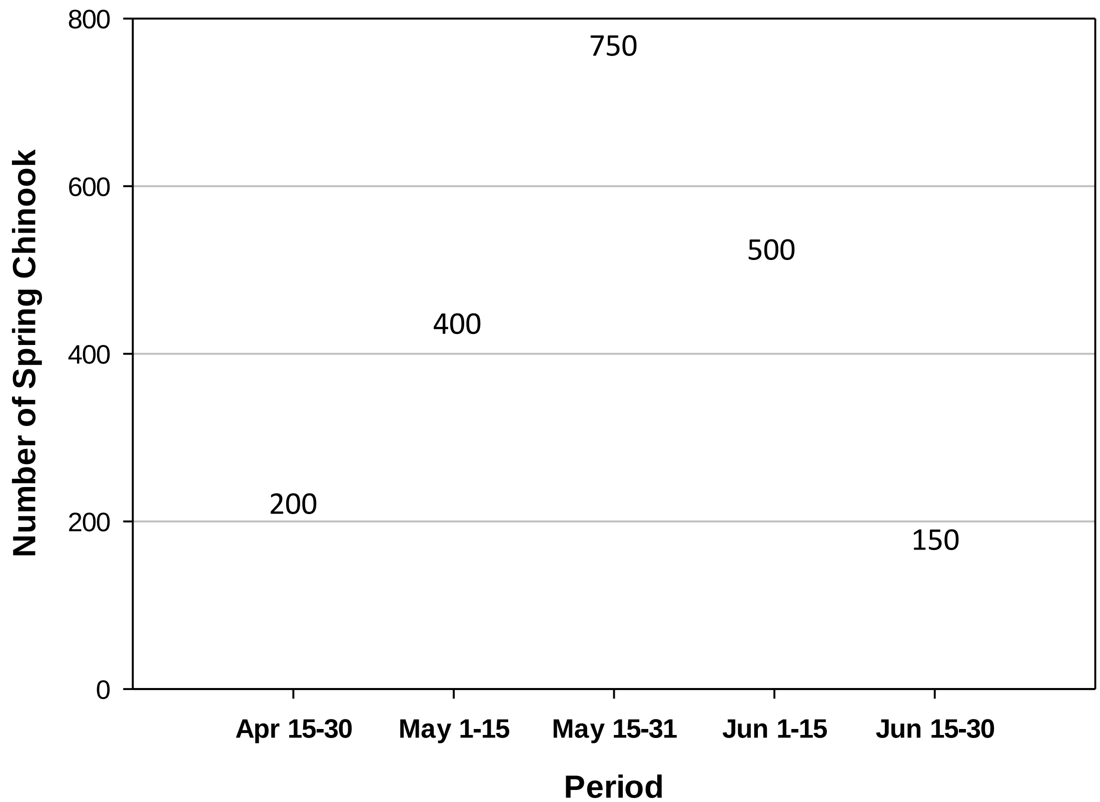

Figure B3. Recommended transportation timing of adult spring Chinook (n=2,000) for supplementation upstream of Swift Dam.

*Note: *Values based on actual MCF data between 2003 and 2009*

SECTION C. COHO SALMON

1.0 INTRODUCTION

The Lewis River coho salmon program has two components, upstream adult supplementation and downstream hatchery production. The goal of the adult supplementation program is to transport up to 7,500 early and late adult coho (both NOR and HOR) to the upstream end of Swift Reservoir. This target number of adults was selected through the Ecosystem Diagnostic and Treatment (EDT) process to define the spawning capacity upstream of Swift Dam. The supplementation program will increase the number of NOR coho salmon as the program continues to develop with a long-term goal of using only NOR coho salmon. The hatchery production goal is to release 1,100,000 HOR early coho smolts and 900,000 integrated late coho smolts annually. The minimum target for NOR integration into late coho hatchery production is 30% per HSRG guidance.

2.0 PROGRAM IMPLEMENTATION

The following section describes the protocols for implementing the coho program of the H&S Plan.

2.1 Broodstock Source

Broodstock source for the supplementation program shall be composed exclusively of both early (Type S) and late coho (Type N) returning either to the MCF or Lewis River Hatchery ladder on the Lewis River.[6] For adult supplementation, the MCF is preferred as these fish are assumed to be upstream migrants attempting to reach areas above Merwin Dam. The Lewis River Hatchery ladder will be used primarily for hatchery broodstock collection. However, any NOR fish trapped should also be used as part of supplementation efforts and integration of the late coho broodstock.

2.2 Broodstock Collection Goal

In most years, the number of coho salmon returning to traps has been adequate to achieve both hatchery and upstream supplementation targets of about 10,000 adults (Figure C1). Broodstock are comprised of both returning adult and precocious males (jacks). The proportion of jacks integrated into the hatchery broodstock may include up to 10% jacks.

Upstream Supplementation: Up to 7,500 early and late adult coho (both NOR and HOR in 2018) will be collected and transported to the upstream end of Swift Reservoir. The number of NOR coho available for upstream supplementation depends on the run size and proportion, and NOR needs for the integrated late coho hatchery program.

Hatchery Broodstock: Up to 1,400 HOR early adults, depending on fecundity, will be used as broodstock to support the hatchery production goal of 1,100,000 smolts (released annually).

[6] On July 21, 2015, the H&S Subgroup agreed to incorporate late coho as a supplementation stock. This decision was affirmed by the ACC on August 13, 2015.

An additional 1,000 late returning adults will be used to support hatchery production of about 900,000 smolts (released annually). The minimum target for NOR integration is 30% for late coho per HSRG guidance.

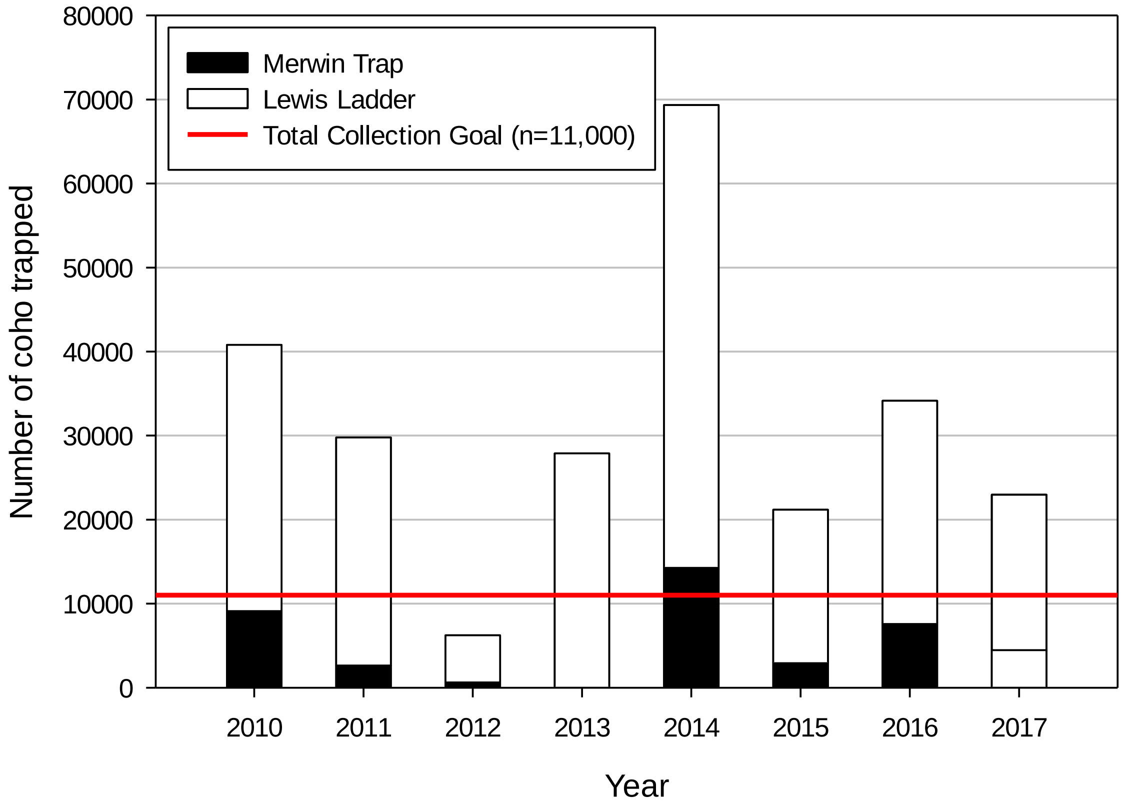

Figure C1. Total number of coho trapped annually between 2010 and 2017 at both the Merwin Collection Facility and Lewis Hatchery ladder

*Note: *Collection target line represents number of early and late coho needed to meet hatchery and adult supplementation goals. Broodstock target represents number required to meet hatchery production as specified in the Lewis River Settlement Agreement. Source: PacifiCorp and Cowlitz County PUD, 2004.*

2.3 Broodstock Collection Timing

Because the coho program relies on trapping, broodstock collection should occur proportionately over the trap collection curve. Early coho begin entering trapping facilities in early September and peak capture rates are observed in mid to late October. Late coho begin entering trapping facilities in late October and continue through December (Figure C2).

2.4 Broodstock Holding Protocols

Coho broodstock are collected at Lewis River Hatchery trap and the MCF. Early coho broodstock are transported to Speelyai Hatchery for spawning; late coho are held and spawned at Lewis River Hatchery. WDFW has initiated an integrated late coho program on the Lewis River and therefore a portion of late NOR coho are spawned at Lewis River Hatchery.

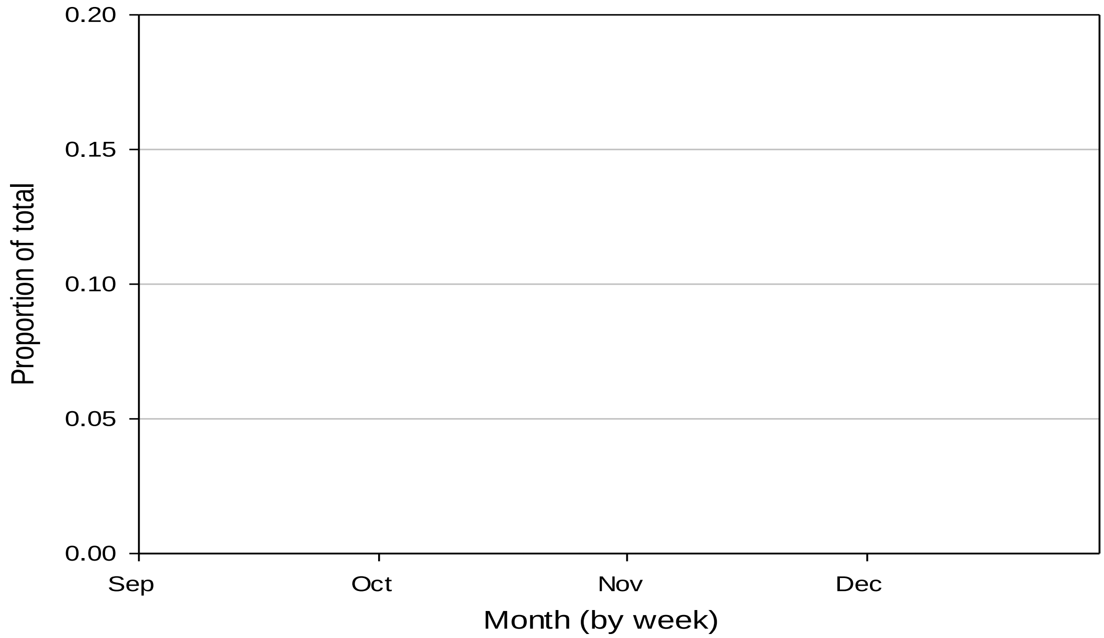

Figure C2. Proportion of natural origin early and late coho captured by week at the base of Merwin Dam (2010 – 2014) and Lewis River Hatchery ladder (2004 – 2010)

2.5 Egg Take Goals

Egg take required to meet hatchery production goals as set forth in the Lewis River Settlement Agreement (Settlement Agreement) include the following:

- Early Coho: 1,800,500 (to produce 1,100,000 smolts)
- Late Coho: 1,400,000 (to produce 900,000 smolts)

2.6 Egg Incubation and Juvenile Rearing

Early Lewis River coho are spawned at Speelyai Hatchery and the resulting eyed eggs are shipped to the Lewis River Hatchery in November for incubation in vertical stack incubators. Late Lewis River coho are spawned and reared at Lewis River Hatchery.

According to WDFW, incubation conditions are consistent with loading densities recommended by Piper et al. (1982). Water quality and temperatures are generally very good. Stack flows during incubation are 3.6 gallons per minute and all eggs are treated with Formalin to keep them free of fungus (WDFW and PacifiCorp 2014).

Hatchery staff will implement performance sampling prior to first feeding and a QA/QC sampling prior to release. These methods are the same as described above in late winter steelhead Section 2.16.

2.7 Pathology Screening and Protocols

Sampling of all adult brood stocks according to recognized national standards and the Salmonid Disease Control Policy of the Fisheries Co-Managers of Washington State (WDFW 2006) for regulated viral pathogens is carried out annually at a minimum of the low testing regime (5% assumed pathogen prevalence level. Samples are delivered to the U.S. Fish and Wildlife Fish Health lab in Olympia and results are sent back to the hatchery and fish health personnel. A minimum of 60 fish are sampled.

2.8 Rearing and Release Program Schedule

Table C1. Hatchery production and collection timeline for North Fork Lewis River coho salmon

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Adult Collection												
Spawning												
Incubation												
Rearing												
Tagging												
Volitional Release												

2.9 Juvenile Marking and Tagging

Juvenile tagging type and location for coho salmon are presented in Table 5-1 of the H&S Plan (PacifiCorp and Cowlitz County PUD, 2014). Fish are mass-marked in June when they are about 120 fpp.

Total production of juveniles is 2,000,000. Most smolts (1,700,000) will be adipose clipped only. An additional 150,000 will be adipose clipped and tagged with snout CWTs. The remaining 150,000 will be tagged with snout CWTs with no adipose clip (double-index tag group).

A subset of juvenile coho that are collected at the FSC will be PIT tagged to provide additional information on juvenile transport survival at the release ponds and preliminary information on smolt out-migration timing (based on lower Col. River detections) and out-of-basin avian predation (based on detections at bird colonies such as East Sand Island). The target is to tag approximately 10-15% of the parr or smolts (> 90mm) that are passed downstream from the Swift FSC. Juveniles captured at the FSC may be offspring of supplementation program adults.

2.10 Juvenile Release Protocols

Coho are volitionally released at Lewis River Hatchery beginning in April by pulling the screens, lowering the water level slowly over an approximately 2-week period (up to 6 weeks) or until 90% or more of the smolts have left on their own. Remaining fish are flushed directly to the river prior to May 20. Prior to release, an area Fish Health Specialist will evaluate the coho population's health and condition.

2.11 Adult Supplementation Protocol

The supplementation program relies exclusively on transporting adults upstream of Swift Dam, which began in 2012. Supplementation adults are able to spawn naturally using all available habitats upstream of Swift Dam. Progeny from these transported adults will be collected at the FSC and transported downstream of Merwin Dam to begin their migration to the sea. The program targets up to 7,500 early or late adult coho to be transported over the duration of the run timing. This target was selected through the EDT process to define the spawning capacity upstream of Merwin Dam. EDT estimates have been updated for habitat upstream of Swift Dam and are reported in the H&S Plan.

The H&S Plan and Settlement Agreement identify only early coho as the reintroduction species (as opposed to late coho). However, the H&S Subgroup agreed that early and late coho be managed as one group for supplementation purposes. Early and late coho differ in their spawn timing. Peak spawning for early coho is September while late coho peak in November. The inclusion of both early and late coho aligns the coho supplementation program with regional recovery planning efforts that do not differentiate between early and late coho (e.g., LCR ESA Recovery Plan). By incorporating late coho into the supplementation program, the supplementation period expands from 2 months (September to October) to 4 months (September to December) due to the later return timing of late coho. Natural factors such as water temperature, water flow, and turbidity will influence spawning success, and therefore (over time), naturally influence future run timing for natural origin coho. Other benefits include: 1) a more flexible transportation schedule that can adapt better to actual run sizes; and 2) more potential for coho to distribute into the upper basin due to the extended transportation window and variable flow conditions in the fall.

Previous trapping data for natural origin coho[7] (Figure C2) is used to create a collection schedule to meet the target goal of 7,500 coho (Table C2) for transport in 2018. Ideally, all transported coho would be NORs. However, there are not enough NOR coho to meet the supplementation goal. In addition, Lewis River Hatchery is currently implementing an integrated late coho program on the Lewis River that will use a portion of NOR late coho as broodstock. The supplementation program will use all NORs available that are not used for the integrated late coho hatchery production program.

Transported coho will be released at different locations upstream of Swift Dam to enhance distribution into streams and tributaries. Eagle Cliff, Muddy River Bridge, Clear Creek Bridge, and Curly Creek Bridge will be used to release an equal portion of the transported coho. To simplify the logistics, fish trucks will work on a rotating basis for each haul. For example, the first load will be released at Eagle Cliff, the second at Muddy River Bridge, and so on. This may not equate to equal portions for each site, but it should be reasonably close.

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[7] NOR coho returns may be progeny from upper river (supplementation program) or lower river spawners. There is no way to differentiate the two groups; However, this is not required because both groups are treated as the same population in this plan.

Table C2. Proposed collection rate of coho indicating relative and cumulative proportion by two-week period over the collection window

Period	Number of Coho*	Relative Proportion	Cumulative Proportion
Sep 1-15	300	0.04	
Sep 16-30	1,200	0.16	0.20
Oct 1-15	1,300	0.17	0.37
Oct 16-31	2,000	0.27	0.64
Nov 1-15	600	0.08	0.72
Nov 16-30	800	0.11	0.83
Dec 1-15	700	0.09	0.92
Dec 16-31	600	0.08	1.00

Note:
** Values based on supplementation goal of 7,500 adults*

SECTION D. MONITORING AND EVALUATION

1.0 INTRODUCTION

Monitoring activities described in this section are intended to meet monitoring objectives contained in the H&S Plan. Objectives were established to monitor population metrics and characteristics such as abundance, distribution, composition, and behavior or interactions of hatchery released smolts. An evaluation of these objectives and how they change over time is critical for assessing population viability (extinction risk) of target populations.

Generally, study methods proposed in this plan follow protocols widely used and established in the Pacific Northwest. This allows methods to be standardized or improved based on information collected at other locations. An important component of some objectives is the precision in which specific objectives are measured or quantified. NOAA Fisheries has provided guidance with respect to variation, and the intent of this plan is to strive to meet these precision guidelines when practical.

Methods to meet the following hatchery and supplementation objectives include the use of screw traps, carcass and redd surveys, genetic sampling, and hatchery monitoring. Monitoring areas are focused on the Lewis River downstream of Merwin Dam including tributaries. Monitoring activities upstream of Merwin Dam are included in the Aquatic Monitoring and Evaluation Plan (AMEP). Results from hatchery and supplementation monitoring are provided annually in the Lewis River Annual Operations Report.

2.0 OBJECTIVES

The following objectives directly reference the current H&S Plan. Since completion of the H&S Plan in 2014, several changes have occurred and some of the original objectives were moved to the AMEP in 2016. To remain consistent with the H&S Plan, the objective numbers are identical, and some objectives are noted as placeholders where appropriate. Appendix C summarizes the frequency, timing, study area, and status for each of the objectives.

OBJECTIVE 1: EVALUATE THE EFFECTS OF HATCHERY PLANTS ON REINTRODUCED SPECIES.

This objective was removed from hatchery and supplementation activities and moved to the AMEP during the revisions of that plan in 2016. This objective appears in this AOP only as a placeholder to maintain consistency with the H&S Plan objective number and order.

OBJECTIVE 2: DETERMINE PROPORTION OF HATCHERY ORIGIN WINTER STEELHEAD, SPRING CHINOOK SALMON, AND COHO SALMON ON SPAWNING GROUNDS DOWNSTREAM OF MERWIN DAM. EVALUATE PRECISION OF PROPORTION OF HATCHERY ORIGIN SPAWNER ESTIMATES AND ABILITY TO DETERMINE THE TREND TOWARD HATCHERY AND GENETIC MANAGEMENT PLAN TARGETS OVER TIME.

To assess potential risk posed by hatchery programs on the Lewis River to naturally spawning winter steelhead, coho salmon, and spring Chinook salmon, an estimate of pHOS will be calculated annually. In line with regional salmon and steelhead recovery guidance (Crawford and Rumsey 2011), the precision of annual pHOS estimates will also be evaluated and reported. In addition, trends in pHOS will be reported with estimates of certainty in the ability to detect changes over time. Though a reliable pHOS estimate is critical in assessing risk posed by hatchery programs, it does not quantify or monitor changes to the N_e or genetic variation (introgression) within the NOR population. Methods to evaluate N_e and other genetic diversity metrics are described in objective 11 of this AOP.

WINTER STEELHEAD

Introduction

Winter steelhead in the Lewis River include three main stocks:

1. A segregated early winter hatchery stock derived from Chambers Creek (HOR-Chambers Creek)
2. A native late winter steelhead stock (NOR)
3. An integrated supplementation stock derived from native late winter broodstock but spawned and reared to yearling stage in the hatchery (HOR)[8]

Over previous decades, hatchery practices in Washington State have created a significant separation in spawn timing between Chambers Creek winter stock (peak spawn in December) and native Lewis River winter steelhead (peak spawn in April). This separation limits the presence of Chambers Creek winter steelhead in the river after March 1 and if present, they are often kelts (as reported in annual reports). Adult returns from the supplementation program, however, do share the same spawn timing as the native stock. N_e may decrease if family representation among the supplementation program returns is disproportionately low (Christie, et al., 2012).

General Approach

Because steelhead may spawn over multiple years and do not die after spawning, estimating pHOS is particularly challenging. Determining origin of steelhead requires collecting and examining live steelhead.

Tangle nets (and traps) are used to capture a portion of the broodstock needed for the supplementation program. Data collected during tangle netting can be used to inform pHOS estimates. Specifically, tangle netting live steelhead on or near the spawning grounds during peak spawning months provides an opportunity to collect representative samples of the spawning population. An example of these data is summarized in Table D1, which can be used to calculate pHOS at the time of capture, at a specific netting site.

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[8] All supplementation program smolts receive a BWTs in their snout prior to release. This mark differentiates supplementation program fish from native NOR stock. HOR supplementation program stock are commonly referred to as BWT to clarify their separation from HOR-Chambers Creek.

Table D1. Example of initial proportion of hatchery origin spawner estimates by site and month from tangle netting

Netting Site Name	River Mile	Total Captured and Initial pHOS							
		FEB		MAR		APR		MAY	
		Total Netted	pHOS	Total Netted	pHOS	Total Netted	pHOS	Total Netted	pHOS
Honey	11.4	--	--	2	0%	6	17%	1	0%
Channel Break	11.9	1	0%	--	--	--	--	--	--
Golf Course BR	12.4	--	--	--	--	2	0%	--	--
Golf Course	13.0	--	--	1	0%	--	--	--	--
Kyser	13.6	3	100%	3	0%	5	40%	--	--
Happa	14.4	3	66%	6	0%	4	0%	1	0%
24K	15.8	3	100%	5	40%	14	14%	11	27%
Erik's	16.3	1	100%	6	67%	20	15%	--	--
Deck Run	17.0	5	60%	17	47%	21	52%	5	20%
2/3 Break	17.6	7	57%	12	50%	20	15%	2	50%
Haggies	18.0	15	66%	35	49%	49	35%	22	55%
Monthly Total Netted		**38**		**87**		**141**		**42**	
Monthly Average pHOS			**68.4%**		**42.5%**		**27.7%**		**40.5%**

However, this method does not account for the proportion of the steelhead captured in tangle nets that may spawn naturally or the proportion that may migrate to the MCF.

The BWT supplementation program steelhead continue to migrate into the MCF through mid- to late May, with approximately 90% of the total captures occurring by May 1 (Figure D1). Mark recapture techniques may be used to estimate the proportion of tangle netted steelhead migrating to the MCF, and thus, not contributing to pHOS.

Field Methods

Initial Capture

Tangle netting will be used to capture and mark steelhead for evaluation of pHOS. Tangle netting occurs at designated sites once per week. Sites are distributed from Merwin Dam to the upstream end of Eagle Island (Figure D2). In this portion of the Lewis River nearly all of the available steelhead spawning is gravel as it is not affected by tidal influences.

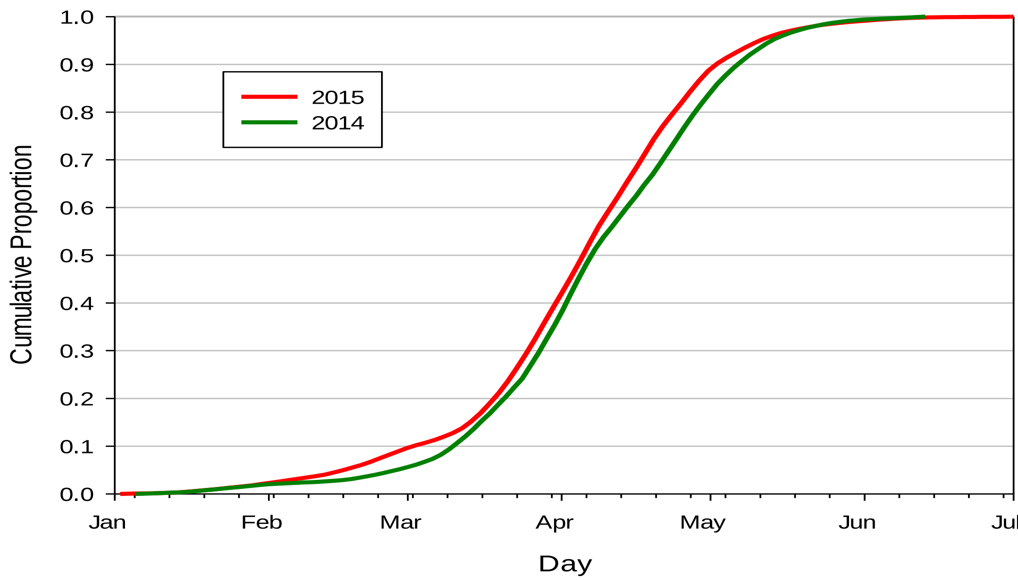


Figure D1. Cumulative daily trap counts of hatchery origin winter steelhead at the Merwin Collection Facility in 2014 and 2015

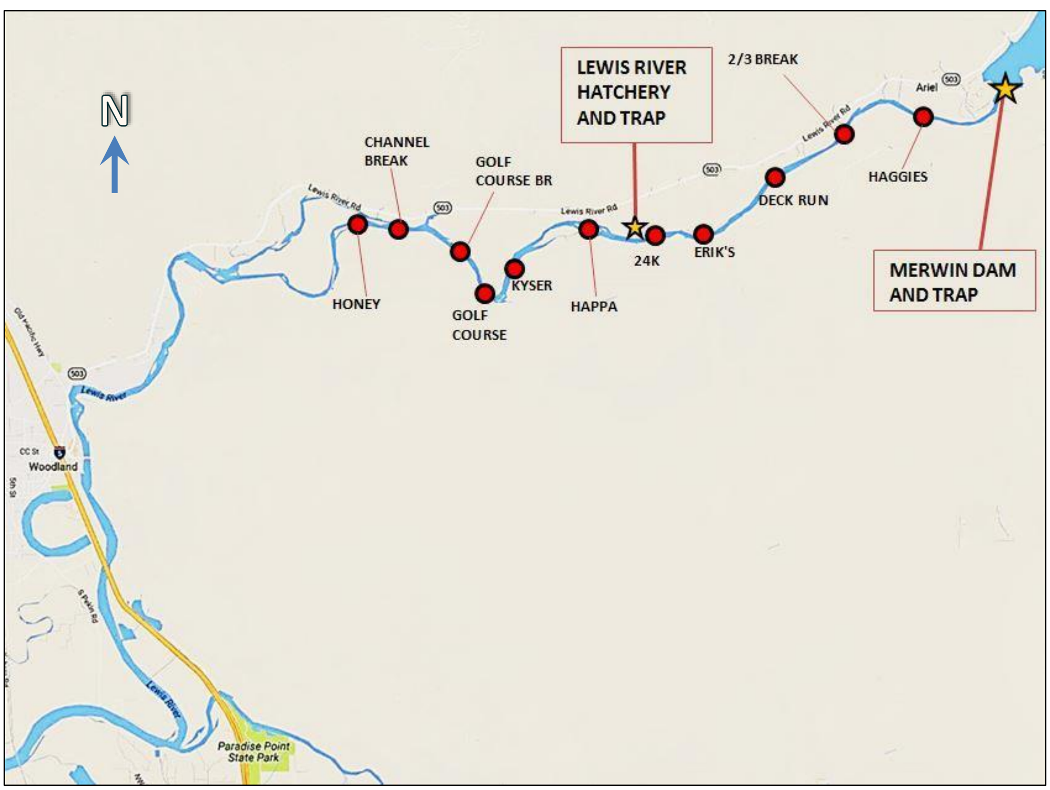


Figure D2. Location and names of established tangle netting sites between Merwin Dam and Eagle Island, North Fork Lewis River

Upon capture, steelhead are identified as HOR or NOR. HOR Lewis River supplementation program fish are identified by a BWT. There is known BWT loss in program returns; therefore, all BWT negative steelhead will be observed for stubby dorsal fins (see Figure A1). BWT negative steelhead with a stubby dorsal fin, will be assigned as HOR. All BWT negative steelhead with intact and non-stubby adipose fins will be assigned as NOR. Additional information collected will include fork length, gender, time, anadromy (anadromous or residual), reproductive status of residuals (mature or immature), and capture location. Scale samples will be obtained from each fish.

Marking and Re-Release

A maximum of 100 HOR steelhead captured in tangle netting events will be tagged with PIT tags (including those identified as broodstock or kelts) to identify recaptures and estimate upstream migrants. All PIT-tagged fish records are uploaded to PTAGIS after each tangle netting event. Steelhead will be PIT-tagged in the dorsal sinus and released to the river over the course of in-river netting. This group may include BWT-negative steelhead with stubby dorsal fins. NOR steelhead used for broodstock are transported to Merwin Hatchery, but may also be tagged and released on site if broodstock needs are met at the hatchery. Residuals that are sexually mature will be included in the evaluation. Residuals will be identified as HOR or NOR. HOR and NOR residuals will be PIT-tagged and returned to the river. Data from fish that are removed from the river will be recorded, as these fish will not be included in estimates of actual pHOS nor will they be available for recapture. All kelts (not identified as hatchery broodstock spawners) will be assumed to have spawned naturally in the river. Kelts will be identified as HOR or NOR, identified for gender, measured for fork length, and will receive a PIT tag prior to release.

Recaptures

Trap recaptures will be recorded each day at the MCF. An automated PIT tag detector scans every trapped fish. In addition to being scanned for a PIT tag, each fish captured at the trap will be recorded including details on sex, origin, and anadromy. The PIT tag detector logs and time stamps each code. All PIT tag data are uploaded to PTAGIS daily. All BWT steelhead are transported upstream of Swift Dam as part of the adult supplementation program. All residuals (NOR and HOR) are similarly transported upstream of Swift Dam.

In addition, redd surveys are conducted once per week to estimate the abundance of spawners (for methods please see objective 13). The pHOS estimates will be applied to spawner abundance estimates to calculate the ratio of HOR spawners within the population of naturally spawning winter steelhead.

Frequency and Duration

Due to the invasive nature of tangle nets, great care must be used to prevent mortalities. This is especially true late in the spawning season when steelhead are actively spawning and already in poor physical condition (especially males). Typically, broodstock collection ends the first week of May, and based on previous experience, tangle netting past this date increases the potential for mortalities and reduced reproductive success. Therefore, all tangle netting will cease in early May.

Table D2. Duration and frequency of tangle net collection

Duration	Frequency
March 1 to early May	one day per week

Analytical Methods

Conceptual Framework

A multi-state mark-recapture model will be used to calculate steelhead pHOS (Lebreton, et al. 2009, Lebreton and Pradel 2002). Fish assume one of four ecological states: 1) initial potential population (necessary for the modelling process, but without ecological meaning); 2) returning; 3) lower-river spawners; and 4) up-river migrants. The proposed model allows for steelhead in the Lewis River to transition from the returning state to one of two states, either a spawner or an up-river migrant, in the interval between tangle netting events. Fish that remain on the spawning grounds in the returning state or as kelts are available for capture on subsequent tangle netting events. Each tangle netting event is indexed as a time period, with the first tangle net event indexed as time, $t = 1$. Any non-broodstock kelts will be identified as spawners at the time of their capture. After the final tangle netting event, all returning steelhead and sexually mature residuals that were not captured at the MCF will be identified as spawners in the final timestep. The pHOS is then calculated based on the subset of fish identified as spawners, thus removing up-river migrants from the equation. A conceptual representation of the mark-recapture model framework that will be used to calculate pHOS is presented in Figure D3.

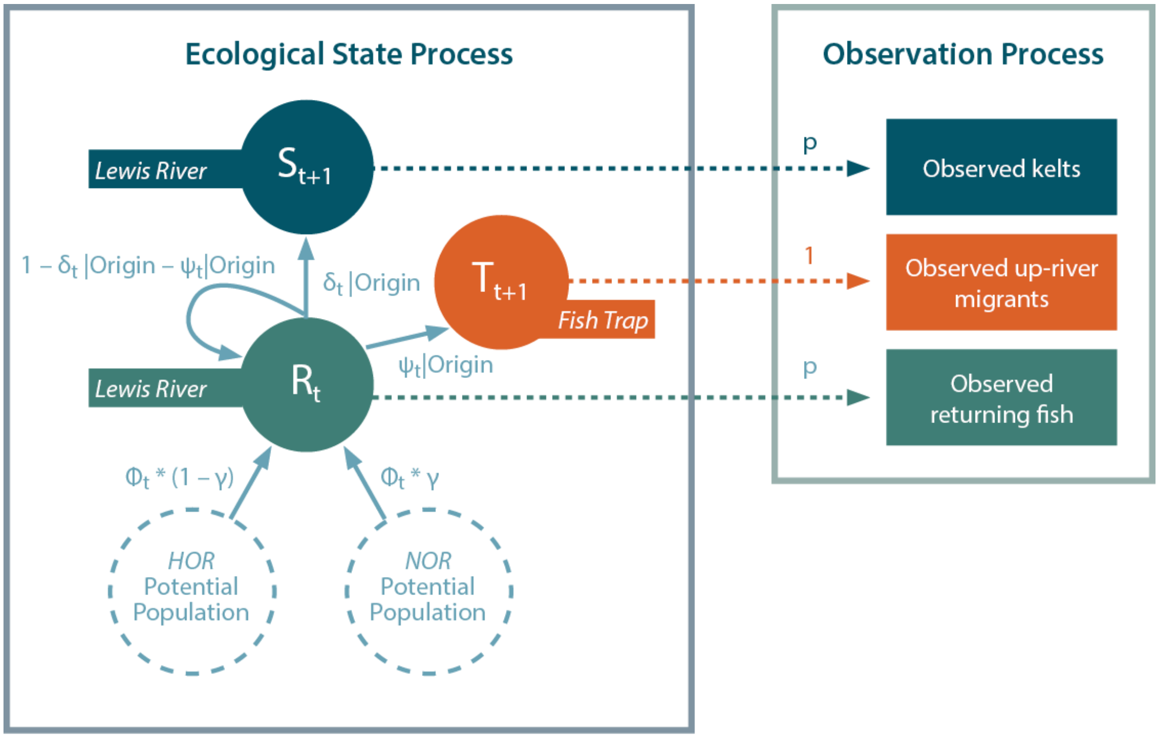


Figure D3. Conceptual model for estimating proportion of hatchery origin spawners while accounting for up-river migrants

The model is initialized with a potential population of Lewis River HOR and NOR winter steelhead that have not yet returned to the Lewis River. This data augmentation step is a common feature of mark-recapture models for estimating abundance and involves providing the statistical model with a large number of dummy records of fish virtually released that were never captured (Royle and Dorazio, 2008). Each fish in the observed and augmented dataset is associated with three variables: sex, origin, and anadromy. Because these characteristics cannot be determined until a fish has been physically captured and because we assume that some portion of the population will never be captured, each of these characteristics must be associated with a parameter in the model. The ratio of males to females is determined by a probability parameter, α, and is assumed to be independent of other characteristics (i.e., HOR-BWT and NOR fish have the same ratio of males to females). The ratio of HOR to NOR fish in this potential population is described by a probability parameter, γ, and is also assumed to be independent of other characteristics. Because males are considered more likely to residualize than females, the percentage of residuals in the total population is described by a conditional probability parameter, $\rho|Sex$.

Fish are allowed to transition between states in the interval between tangle net events. At each time index until the final capture event, some proportion of this potential population transitions to the state of returning, R with inclusion probability, ϕ_t. Because residual fish by definition do not migrate, the inclusion probabilities for these fish will be treated differently than the inclusion probabilities for anadromous fish. Residual fish are assumed to only transition to returning at the first time index. Thus, an inclusion probability will be estimated for residual fish during the first time index and inclusion probabilities for all other timesteps will be set to zero.

Fish in the returning state are subject to capture by tangle netting, but their ultimate status as up-river migrants or spawners is not known. Returning fish that are captured are either marked and released or simply released if already marked or removed from the modeled system because they are selected for broodstock or euthanized. To account for fish being removed from the modeled system, each fish will be associated with an indicator vector of denoting availability status, $\boldsymbol{A}$. For fish that are removed at time, t, the availability vector will contain zeros for all events from time, $t+1$ through the last event. Otherwise the availability vector will consist of a one if a fish might be available for capture. Fish that remain available for capture, may transition to an up-river migrant, T with probability, $\psi_t|Origin, Anadromy?$ in the interval between each subsequent capture events. Here, $\psi_t|(Origin, Anadromy)$ is a conversion rate dependent on whether a fish is HOR or NOR and whether a fish is a residual or anadromous. Returning fish may also transition to a spawner, S with probability, $\delta_t|(Origin, Anadromy)$, or they may remain in the returning state with a probability

$$1-\psi_t|Origin, Anadromy? -\delta_t|Origin, Anadromy?.$$

In the interval after the last tangle netting event and the final day of fish trapping efforts, the model assumes that all fish remaining in the state of returning have transitioned to spawners.

To complete specification of model parameters, capture efficiency of the various modes of capture must be defined. The model assumes: 1) perfect detection of PIT tags in the Merwin or Lewis River traps; and 2) fish in the spawner state or remaining in the returning state are captured (or recaptured if marked) with the tangle net capture efficiency, p, estimated by the model based on marked and unmarked fish observed at the traps and recaptured in tangle netting. Finally, the model assumes that all fish survive the tangle netting events to spawn or migrate and therefore no survival parameter enters into the model.

The proposed model is typical of ecological multistate mark-recapture model in that it can be described using the conditional data likelihood and in that it consists of highly constrained parameter matrices. The model can be described in two parts, one latent and one observed. The latent state is described by:

$$z_{i,t+1}|z_{i,t} \sim \text{categorical}(\boldsymbol{\Omega}_{z_{i,t},1\ldots4,i,t})$$

where $\boldsymbol{\Omega_t}$ is the state transition matrix at time t. For example, the initial state matrix allows fish in the potential population (state 1) to transition to the returning state (state 2). That is:

$$\boldsymbol{\Omega_0} = \begin{bmatrix} 1-\phi_0 & \phi_0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{bmatrix}$$

Subsequent transition matrices additionally allow fish to transition to spawners (state 3) or up-river migrant (state 4):

$$\mathbf{\Omega_t} = \begin{bmatrix} 1-\phi_t & \phi_t & 0 & 0 \\ 0 & 1-\psi_t-\delta_t & \delta_t & \psi_t \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

Similarly, the observed state can be described by an observation matrix and the availability indicator:

$$y_{i,t}|z_{i,t} \sim \text{categorical}\left(\mathbf{\Theta}_{z_{i,t},1\ldots4,i,t}\right) * A_t + 1 * (1 - A_t)$$

Where $\mathbf{\Theta_t}$ is the observation matrix at time t. In this case state 1 takes the meaning "unobserved" while the remaining states retain their meaning as defined above. Note that when the availability status is set to zero, the observed state takes the value of 1. We then let:

$$\mathbf{\Theta_t} = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 1-p_t & p_t & 0 & 0 \\ 1-p_t & 0 & p_t & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

This matrix indicates that fish remaining in the potential population at time t will always be unobserved, fish in either the returning state or the spawner state will observed during tangle netting with probability p_t and fish will be observed as up-river migrants at the trap with probability one.

The number of HOR spawners (S_H) and NOR spawners (S_N) can then be calculated after the final day of fish trapping efforts based on the number of fish in the model that are in state 3 after the last tangle net event. The pHOS is defined as the ratio of HOR remaining in the spawning population after accounting for emigration of up-river migrants from the spawning grounds, as in the following:

$$pHOS = \frac{S_H}{S_H + S_N}$$

The final status of fish in the returning state will be unknown until after tangle netting and trapping efforts have ceased, therefore pHOS can only be estimated at the end of the season after all data have been collected.

The point estimates of pHOS will be based on the median of the posterior distribution and uncertainty will be quantified with a 90% credible interval (the probability that pHOS lies within the reported interval is 90%).

Note: The pHOS model will estimate steelhead spawner abundance and thus can be compared to estimates of steelhead spawner abundance based on other methods (e.g., redd-based methodologies; see objective 14).

Model fit will be assessed using a posterior predictive check (Gelman, et al. 2014), which compares a summary statistic of observed data to expected data and can be used to produce a Bayesian P-value. The summary statistics which will be used will be the number of fish observed at the trap and in tangle nets during each event.

Assumptions

- Fish assume one of four ecological states: 1) initial potential population (necessary for the modelling process, but without ecological meaning); 2) returning; 3) lower-river spawners; and 4) up-river migrants.
- In the interval between any given tangle netting event, fish can transition from the potential population to returning, and from returning to spawner or up-river migrant.
- Netting sites are representative of the available spawning area from Eagle Island upstream to Merwin Dam.
- Tangle net capture efficiency is constant with respect to the origin of captured steelhead, fish gender, and potential to transition to spawner or up-river migrant.
- Tangle netting and marking does not affect survival or migration probability of steelhead released back to the Lewis River.
- Marked fish that do not enter the traps spawn in the Lewis River.
- No PIT tags are lost or unreadable.
- The probability of detection of marked fish at the Merwin and Lewis River traps is equal to one, and all unmarked fish will be enumerated accurately.
- Kelts captured have spawned in the Lewis River, unless identified as those used in the hatchery in for broodstock and released back to the river.
- The pHOS for the portion of the population that spawns in late May and June is the same as the pHOS observed during the sampling period up to early May.

Deliverables

Mark-recapture data and pHOS estimates will be reported as:

- Daily number of HOR and NOR steelhead collected from each tangle netting event and for each site including biological data, marking codes, and disposition for each steelhead captured (including recaptures)
- Daily number of recaptures at the Merwin and Lewis River traps
- Estimates of *actual* pHOS for late winter steelhead spawners in the Lewis River downstream of Merwin Dam applied to spawner abundance calculations from redd surveys. This estimate is the actual pHOS given removal of all steelhead from traps and removal of NOR steelhead during tangle netting for broodstock.
- Estimates of *potential* pHOS for late winter steelhead spawners in the Lewis River downstream of Merwin Dam by including all removed trapped and tangle netted fish in

the estimate of pHOS. This estimate is the potential pHOS in the absence of any tangle netting or trapping facilities. Fish currently removed from the system will be included to provide an understanding of actual returns and potential pHOS resulting from the supplementation program.

Limitations and Specific Concerns

The program is starting its seventh year of supplementation. An unknown portion of returns may be the offspring of HOR supplementation program fish that spawned naturally. There is no cost-effective method to differentiate endemic NOR from the offspring of HOR supplementation program fish (F2 generation). Though the pHOS estimate does not require this differentiation, it should be noted that the impact of supplementation is likely higher on the native population and the pHOS estimate should be interpreted as a minimum estimate.

The Lewis River winter steelhead population includes fish that spawn in Cedar Creek. Lewis River winter steelhead may stray into Cedar Creek to spawn. The pHOS estimate may not accurately reflect interactions between HOR and NOR in Cedar Creek. Lewis River winter steelhead may also stray into other rivers to spawn. The model may overestimate pHOS for the Lewis River if HOR spawners are marked in tangle net events, but later stray into other rivers.

Tangle-netting and broodstock collection ceases in early May. It is unlikely that mature steelhead continue to migrate into the Lewis River after this date; however, it is possible that pHOS among late spawners may differ from the estimated pHOS. The NOR population may tend to spawn slightly later than the HOR population as a result of selection for broodstock that are mature prior to early May. The estimated pHOS would be a conservative estimate of hatchery influence on the native population if pHOS is lower in the portion of the population that spawns in late May and June.

Tangle-net capture efficiency may vary considerably between capture events due to differences in accessibility between sites and changes in flow across the sampling period. This uncertainty will be accounted for in credible intervals provided for the pHOS estimate. Tangle-net capture efficiency may also differ between different groups of fish. Males are typically more likely to become entangled due to their larger heads and kype. Up-river migrants transitioning to the trap may have shorter residence times in the lower river than spawners, reducing their probability of capture in a series of tangle net events. Potential differences in tangle net capture efficiency among different groups of steelhead will not be quantified in the initial runs of the pHOS model and it is unknown how these differences could bias the pHOS estimate. These sources of uncertainty will be reported with the pHOS estimate.

SPRING CHINOOK AND COHO SALMON

Introduction

Spring Chinook and coho salmon that spawn downstream of Merwin Dam may be HOR or NOR. A significant portion of adult returns are collected at the MCF and Lewis Hatchery ladder and thus do not contribute to the number of actual spawners downstream of Merwin Dam. Both species are propagated in the Lewis River Hatchery complex to support both harvest and reintroduction efforts upstream of Swift Dam in accordance with the Lewis River H&S Plan (PacifiCorp and Cowlitz County PUD 2014).

NOR spring Chinook salmon that spawn downstream of Merwin Dam originate from a non-native but self-sustaining stock that has returned to the Lewis River Hatchery complex for several generations. Few spring Chinook salmon spawn below Merwin Dam compared to the number returning to the hatchery complex. Spring Chinook salmon spawn mainly in the lower mainstem Lewis River, with some spawning observed in Cedar Creek.

Coho salmon spawning downstream of Merwin Dam and in tributaries include both early (Type S) and late (Type N) stocks. Because both stocks are treated as one population for recovery planning purposes, estimates of pHOS will not differentiate between early and late coho.

In the mainstem Lewis River, seasonal surveys of spring Chinook and coho salmon carcasses are performed from Merwin Dam downstream to the lower end of Eagle Island (details provided in objective 14 for coho and objective 16 for Chinook). Tributary surveys for coho use a Generalized Random Tessellation Stratified (GRTS) method to define survey reaches (panels) each year. GRTS survey reaches identified each year in the Lewis River tributaries are developed as part of the overall LCR DPS sampling and thus not specific to the Lewis River coho population.

The origin (NOR or HOR) of each carcass recovered is documented.

General Approach

The ratio of HOR spawners observed in sampled carcasses will be used as an estimate of the pHOS in the total population. Data from weekly abundance surveys throughout the spawning period of spring Chinook and coho salmon (objectives 14, 16) will be scaled by weekly abundance estimates and pooled to calculate a seasonal pHOS for each species. During weekly surveys, carcasses are recovered and sampled by either walking along the stream margins or by boat. As part of abundance surveys, all carcasses that are directly handled are marked with either a plastic opercle disc (coho) or by removal of the caudal fin (spring Chinook) to prevent double counting.

Field Methods

All carcasses recovered during surveys will be identified as HOR or NOR (when possible). HOR fish are identified by the combination of a missing adipose fin and/or CWT snout tag, while NOR fish are identified by intact adipose fin and no CWT snout tag. Both spring Chinook and coho salmon releases from the hatchery include double index tag groups that have adipose fins and a CWT. All salmon are wanded to ensure that hatchery double-index tag groups are accurately identified. If a carcass is too far deteriorated to clearly identify the presence or absence of an adipose fin the fish will not be included in the data used to estimate pHOS. Because surveys are conducted every week, the number of carcasses with unknown origin is expected to be small.

The survey area includes the mainstem Lewis River from Merwin Dam (RM 19.4) downstream to the downstream end of Eagle Island (RM 10).

Frequency and Duration

Table D3. Frequency and duration of carcass surveys

Species	Duration	Frequency
Spring Chinook	Aug 15 – Oct 30	1 day per week
Coho	Oct 15 – Jan 31	4 days per week

Analytical Methods

For both coho and spring Chinook salmon, the observed ratio of hatchery origin carcasses to total carcasses will be treated as a binomial proportion and corrected for mis-clip rates.

The observed number of HOR carcasses (S_H) and NOR carcasses (S_N) can be summed after the completion of each week of carcass surveys for each species.

Weekly pHOS estimates will be scaled by time-stratified (e.g., weekly) spawner abundance estimates ($B*$), determined by methods described in objectives 14 and 16, to account for differences in carcass capture probability that occur with the change in abundance and distribution of the population across the sampling period, as in the following:

$$pHOS = \frac{\sum_{i=1}^{n} B^* \times S_H}{\sum_{i=1}^{n} B^* \times (S_H + S_N)}$$

The pHOS of a given species is defined as the ratio of HOR carcasses to the total number of carcasses, adjusted by the proportion marked (pMark) as in the following:

$$S_H = \frac{S_H^{"marked"}}{pMark}$$

Weekly adjusted pHOS ($pHOS_{adj}$) estimates will be pooled to calculate a seasonal estimate of pHOS by summing numerators and denominators of all weekly estimates for each species.

Increasing or decreasing trends in the pHOS over time will be investigated using a hierarchical logistic regression model with a fixed effect for a yearly trend and a random effect for each year to account for potential over-dispersion commonly observed in natural systems (Zuur et al., 2009)

The bounds of uncertainty will be estimated with 90% credible intervals (the probability that the estimate lies within the reported interval is 90%) for both the annual estimates of pHOS and for the trend in pHOS over time.

Assumptions

- Detection probability for hatchery and natural origin carcasses is identical unless directly or indirectly accounted for in the abundance estimator.
- Fish First coho salmon reared for the Remote Site Incubator Program are unmarked and if recovered would be erroneously counted as NOR.

Deliverables

- Weekly and seasonal (pooled) estimate of mainstem pHOS by species
- Estimate of change in pHOS over time
- For coho salmon, tributary pHOS will also be reported from GRTS reaches surveyed

Limitations and Specific Concerns

- Not all carcasses are available for sample because they are either too deep to be seen, have been removed by predators, or have deteriorated and the presence of an adipose clip cannot be confirmed. Carcass capture efficiency is low in the mainstem Lewis River and sampling effort is lower in tributaries compared to the mainstem. Methods described in objectives 14 and 16 estimate abundance while accounting for unobserved fish, providing a higher level of confidence in the measure of abundance of both HOR and NOR fish compared to relying on direct observations.
- If a relatively large portion of carcasses in the population are sampled in a given year (greater than 20%), then the error associated with the estimate of pHOS described above can be described as overly conservative.
- As noted in objective 14, currently the overall Lewis River coho estimate only contains tributary subunits 3 and 4, which WDFW is responsible for analyzing. However, in the future when robust estimates of abundance and pHOS are available for subunits 1 and 2, these should also be incorporated to estimate overall pHOS for Lewis River coho salmon.

OBJECTIVE 3: DEVELOP AND MONITOR HATCHERY PROTOCOLS TO REDUCE HATCHERY EFFECTS ON JUVENILE NATIVE AND ENDANGERED SPECIES ACT-LISTED SPECIES PRESENT DOWNSTREAM OF MERWIN DAM.

Introduction

The purpose of this objective is to monitor hatchery practices or protocols that may increase the potential for adverse interactions between hatchery- and naturally-produced smolts.

Adverse interactions identified by the HSRG (2014) include the following:

- Inter- and intra-specific competition for space and food
- Increased predation
- Increased disease transmission

To avoid these potential interactions, the HSRG recommends reducing (to the extent possible) the spatial and temporal overlap between hatchery smolts and their natural counterparts. The most effective means to minimize this overlap is to adopt hatchery practices that produce smolts that emigrate quickly. In addition, hatchery practices should minimize the portion of the population that are prone to precocity or residualism.

General Approach

This evaluation will subsample a portion of the smolts available at the time of release to: 1) establish a baseline for each species; and 2) compare this baseline to existing literature or similar observations in other programs. This comparison will be done to determine whether sampled juveniles express characteristics consistent with peak smolt development, early maturation, or residualism.

Field Methods

Up to 100 juveniles will be subsampled from each release group of winter steelhead, coho salmon, and Chinook salmon to evaluate size and indices of smolt development at the time of release. Subsamples that are representative of the entire release group will be collected by dipnet, seining, or cast net depending on the rearing vessel. For spring Chinook, samples will be obtained from each of the five treatment groups. All sampled juveniles will be measured to fork length, weighed, and through visual observation categorized as: 1) parr; 2) transitional; or 3) smolts (see definitions). Condition factor (K) will be calculated as an index of smolt development. Presence of milting fish will also be noted and photographs will be taken to illustrate differences between index groups as well as between volitional and forced release groups. After the volitional release period ends, if any juveniles did not leave the hatchery volitionally, up to an additional 100 juveniles will be subsampled for size and indices of smolt development before all remaining fish are forced-released. Note that spring Chinook length, weight, and K will additionally be monitored monthly, as detailed in Appendix D.

If precocious males are identified by external coloring or milting in the subsample, they will be culled. Testes of up to 100 males will be weighed and testes of at least 10 immature males will be weighed to establish a baseline for early testis development.

Analytical Methods

Results from the morphological sampling will be compared to determine what differences or correlations exist both between and within each release group and among volitional and forced releases.

Frequency and Duration

Species	Sampling Time	Sampling Frequency
Spring Chinook*	October, February	Once prior to volitional and once prior to forced release
Coho Salmon	April	Once prior to volitional and once prior to forced release
Winter Steelhead	April	Once prior to volitional and once prior to forced release
Late Winter Steelhead	April	Once prior to volitional and once prior to forced release

**Note: spring Chinook length, weight, and condition factor will additionally be monitored on a monthly basis as detailed in Appendix D.*

Assumptions

1. A representative subsample of each release or treatment group can be obtained including sampling of forced release groups.
2. The initial subsample of each release group will include a mixture of fish that will volitionally leave and those that must be forced released. It is assumed that sampling rates are high enough between both the mixed group and forced release group to detect morphological differences between groups if they exist.

Deliverables

1. An analysis of all release groups to observe distributions of size, smolt index, and testis development data and observe trends in morphological characteristics across years.
2. An analysis of volitional and forced release groups to test for significant differences in size and smolt development.
3. Discussion and recommendations for optimizing emigration rate and minimizing residualism or precocity among hatchery release groups for each species.

Limitations and Specific Concerns

1. The initial subsample of each release group will include a mixture of fish destined to become those that migrate during the volitional release period and those that do not migrate (part of the forced release group).
2. Fish that are destined to become smolts, residuals, or precocious males may not be easily identified at the times of release using the proposed non-lethal indices. Additional physiological evaluations may be necessary to confirm optimal smolt timing or rates of residualism or precocity.

OBJECTIVE 4: ESTIMATE JUVENILE RELEASE BEHAVIOR OR RESIDUALISM AFTER RELEASE FROM HATCHERIES DOWNSTREAM OF MERWIN DAM.

Introduction

The behavior and residency time of hatchery released smolts have been evaluated using different methods over the past 15 years. Methods have incorporated screw trapping (to observe migration rate and abundance), radio telemetry (to observe residence time), and seining (to observe predation rates on naturally-produced fry). The AOP proposes to use screw trapping in 2018 to estimate abundance and peak migration timing of hatchery juveniles passing the trap during the study period (which will be reported in smolt trap reports). Additionally, an analysis of the past 2 years (2016 and 2017) of existing screw trapping results will be completed to evaluate and compare annual trends in migration rates of HOR juveniles.

General Approach

Results obtained from screw trapping efforts described in objective 14 will be used to estimate the number and timing of HOR juveniles passing the trap. These data will be used to infer the duration and peak migration timing of HOR juveniles while the traps are operating.

Additionally, any HOR spring Chinook captured in 2018 are assumed to be from the October 2017 release and will be noted.

Field and Analytical Methods

Two (8-foot cone) screw traps equipped with dual pontoons and fished in tandem will be deployed near the Lewis River Golf Course (Figure D4). This site meets safety requirements for navigable rivers. Smolt traps will be checked daily and all hatchery captures will be enumerated and identified to species. Hatchery fish will be sampled according to protocols described in objective 14, Smolt Trapping and Sampling.

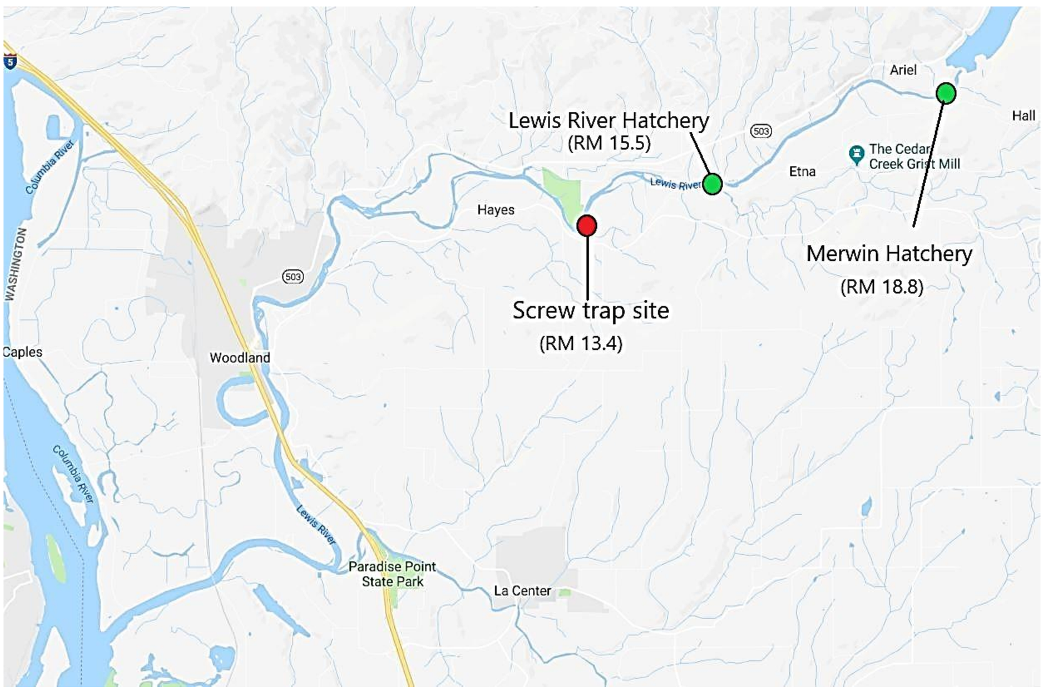


Figure D4. Location of screw trap in relation to hatchery release sites, North Fork Lewis River

Estimates of trapping efficiency will be used to derive an estimate of the total number of fish passing the trap on a weekly basis. Total estimates of hatchery fish passing the trap during the trapping period and 95% confidence intervals will be generated using the Bootstrap Method (Thedinga, et al. 1994). The sum of discrete interval method of calculating total outmigration will be used to make a secondary estimate for coho juveniles (Volkhardt 2007). Total estimates should only be viewed as the total fish that passed the trap during the study period and not total species outmigration abundance. Estimates of the number of HOR juveniles passing the trap will be plotted by species weekly to determine the distribution and peak migration timing of juveniles.

Frequency and Timing

The smolt traps will be operated daily from February through June 30. An additional trapping period for the month of October is planned for 2018 to collect data on the fall release planned for spring Chinook. Installation and removal dates are dependent on river flows. A request for reducing outflow from Merwin Dam is typically required for installation of the traps.

Assumptions

Weekly screw trap efficiency (and abundance) will rely on methods described in objective 14

Deliverables

All deliverables are consistent with those stated for objective 14.

Limitations and Specific Concerns

1. Low numbers of captures, and especially recaptures, limit the ability to accurately estimate screw trap capture efficiency and therefore abundance and non-migrants.
2. Daily operation of the trap may not be possible if river conditions are unsafe (i.e., spill operations) or equipment is damaged or lost.
3. Post-release mortality rates from the hatchery are unknown and cannot be separated from estimated proportion of non-migrants.
4. A large portion of the Lewis River spring Chinook salmon will be released in October 2018, approximately 750,000 or 60% of the total BY 2017 release (Table B3). The emigration patterns of fish released in October into the lower Lewis River are currently unknown. One screw trap in the lower Lewis River will be operational in October 2018 allowing for emigration to be monitored.
5. No spring Chinook were available for release in February 2018; therefore, no estimate of abundance or non-migrants will be made in 2018 for this species. All spring Chinook captured, however, during the sampling period will be noted and measured.
6. Behavior of hatchery releases (e.g., residualism) between the trap and the mouth of the Lewis River cannot be described by the screw trap catches.

OBJECTIVE 5: PRODUCE AN ANNUAL HATCHERY OPERATIONS REPORT.

Hatchery operations include many activities including spawning, rearing, feeding, pathogen testing, permit compliance, fish marking, and trapping counts. Each year the WDFW produces an annual report that includes a number of metrics. At a minimum, this report should include the following metrics to monitor and ensure that fish health is not compromised:

- Rearing conditions by life stage (e.g., flow indexes, densities)
- Disease presence, prevention (treatments), and loss by life stage
- Growth rate by month from fry ponding to release as smolts
- Length, weight, and condition factors (subsample) for each species at release
- Number of fish tagged, tag type, and purpose (experimental, production)
- Number of adults (including jacks) collected, spawned, recycled, and sent to food banks or other disposition options.
- All fish transfers in or out of the basin including species, number, marks, and life stage
- Number of NOR fish collected, origin (if possible), and disposition

- Number of HOR fish collected that originated from outside of the Lewis River Basin (based on CWT tag data)
- Volitional release data including volitional release periods for all species and estimated number of non-migrants.

OBJECTIVE 6: MONITOR REARING CONDITIONS TO BE CONSISTENT WITH PRODUCING A HIGH QUALITY SMOLT THAT EMIGRATES QUICKLY WITH A RELATIVELY HIGH RATE OF SURVIVAL.

For 2018, objectives 6 and 8 will be combined to develop a comprehensive evaluation of spring Chinook rearing and release practices. The focus on spring Chinook is necessary to address several years of below average adult return rates. Monitoring of rearing conditions for other species aside from spring Chinook salmon will remain the same as described in past AOPs, including measures described in objective 3 as no major issues have been noted.

The spring Chinook rearing and release monitoring plan proposed for 2018 is provided as Appendix D and concentrates on three specific areas:

- Defining five planned release groups, each with a different rearing and release strategy (current protocols include only two yearling release groups in October and February)
- Describing methods for evaluating the survival of these release groups
- Describing monthly monitoring of juveniles during rearing at the hatchery and sampling methods prior to release

In addition to the rearing and release plan, a water quality evaluation plan was proposed and completed in 2017 (Appendix E) to monitor total dissolved gas and temperature fluctuations at Lewis River Hatchery. Data from this evaluation will be analyzed in 2018 and presented to the H&S Subgroup. The H&S Subgroup may recommend changes at Lewis River Hatchery based on these results to improve rearing conditions at the hatchery.

OBJECTIVE 7: MONITOR HATCHERY UPGRADES.

Schedule 8.7 of the Agreement includes a number of upgrades for Lewis River, Merwin and Speelyai hatcheries. These upgrades include pond reconstruction, modification to intakes and sorting facilities and controls upgrades. Upgrades should continue to be monitored to ensure that the objectives of hatchery production are being met (e.g., rearing conditions, density, and production) and ESA protections continue to be in place (e.g., intake modifications continue to meet NOAA-NMFS criteria).

OBJECTIVE 8: ADOPT RELEASE STRATEGIES THAT ARE CONSISTENT WITH HATCHERY SCIENTIFIC REVIEW GROUP AND HATCHERY AND GENETIC MANAGEMENT PLAN RECOMMENDATIONS.

For 2018, objectives 6 and 8 were combined to develop a comprehensive evaluation of spring Chinook rearing and release practices. See objective 6 and Appendix D for details on this evaluation. The study plan (Appendix D) is consistent with HSRG and Hatchery and Genetic

Management Plan (HGMP) recommendations. Additionally, release strategies for other species (detailed in Section A. Late Winter Steelhead and Section C. Coho salmon) will be evaluated further for consistency with HSRG and HGMP recommendations in 2019.

OBJECTIVE 9: MONITOR PRODUCTION LEVELS AND PROGRAM RELEASE NUMBERS.

Hatchery production and final release numbers are affected by a number of factors including achieving broodstock targets, disease outbreaks, and operational or mechanical failures at the facilities. Hatchery managers along with the hatchery pathologist routinely monitor fish health at the facilities as directed by state protocol. Mechanical failures at the facilities may occur; however, mechanisms that support fish health and life are given high priority with respect to maintenance. Production levels and final release numbers are provided each year for each species in the annual hatchery operations report.

Production levels may change during the implementation of this plan as stipulated in Section 8.3.2 "Modification to Hatchery Production" of the Settlement Agreement. Hatchery production may be reduced (subject to a minimum production number) when natural production levels upstream of Merwin Dam increase to a specified threshold level. Ocean Recruit estimates (as provided in the AMEP) will provide the metric to make this determination every year after the initial 5-year period.

Hatchery production levels may also change due to modifications of the HGMP required for production of ESA-listed species and their impact to other listed species in the basin. Hatchery production changes related to ESA compliance would require changes to the Federal Energy Regulatory Commission operating licenses and the Settlement Agreement.

OBJECTIVE 10: SUBMIT AND GAIN HATCHERY AND GENETIC MANAGEMENT PLAN APPROVAL FOR ALL HATCHERY PROGRAMS ON THE LEWIS RIVER.

The H&S Plan must be consistent with HGMP provisions once approved by NOAA Fisheries. A revised HGMP will be submitted to NOAA Fisheries in late 2018, with approval from NOAA Fisheries expected in 2019. An approved HGMP is required to maintain hatchery programs on the Lewis River. Hatchery and supplementation programs are necessary to initiate the H&S Plan. Thus, HGMP approval is a key component to maintaining the hatchery and supplementation programs necessary to meet reintroduction objectives.

OBJECTIVE 11: DETERMINE THE GENETIC EFFECTIVE POPULATION SIZE OF LATE WINTER ANADROMOUS RAINBOW TROUT (STEELHEAD) DOWNSTREAM OF MERWIN DAM.

Introduction

In the Lewis River (Columbia Basin), three stocks of anadromous Rainbow Trout (steelhead) categorized as winter-running are managed. Washington State hatchery practices have created a winter steelhead stock derived from Chambers Creek (Puget Sound) that spawns earlier (peak spawn in December) then the endemic Lewis River steelhead (peak spawn in April), and is therefore considered a “segregated” stock. The endemic (late winter) steelhead spawning in the lower Lewis River are considered a stock, with NORs from this stock used as broodstock for an associated supplementation program. Recruiting HORs from the supplementation program returning to spawn in the Lewis River are considered a separate but integrated stock to the late winter endemic steelhead.

HOR adults from the supplementation program that are not transported off spawning grounds for operational reasons have the opportunity to spawn with NOR adults in the lower Lewis River. Uncertainties exist regarding the fitness (reproductive success) of artificially propagated Rainbow Trout (*Oncorhynchus mykiss*) (Christie et al., 2012; Christie et al., 2014). A reduction in population genetic diversity is also a known potential outcome of hatchery stocking (Ryman and Laikre, 1991). As such, questions have been raised about the potential for the supplementation program to have adverse effects on endemic NOR steelhead populations.

From a conservation and population recovery stand point, the N_e is a critical metric to gauge population status and long-term viability. The size at which a population functions genetically is the N_e. For example, in general terms the standing diversity of character traits (i.e., genetic variance) is a function of the N_e, which results in evolutionary potential being synonymous with N_e. The loss rate of each generation's genetic diversity is also a function of N. Conventions for population size thresholds at which genetic impact would be minimized have been derived from such concepts as mentioned above, the so called 50/500 rule (Franklin 1980; Franklin and Frankham 1998; Frankham et al. 2014). More specifically, an N_e greater than or equal to 50 would prevent an unacceptable rate of inbreeding for a short time, while N_e greater than or equal to 500 is required to maintain long term genetic variability. Therefore, estimating N_e can be an important tool for assessing the genetic vulnerability of an endangered species. Further, any hatchery supplementation program should not reduce the overall N_e. Trends in N_e would provide an early warning capability for observing threats to viability (i.e., loss of genetic diversity through inbreeding) or genetic stochasticity prior to any indication apparent from census estimates. To assess the potential risk to naturally spawning steelhead posed by the hatchery supplementation program on the Lewis River, an estimate of the late winter NOR steelhead N_e will be calculated annually.

Interpretation of the results from this analysis will involve collaboration between PacifiCorp's contractor(s) and geneticists from WDFW. Collaboration will improve WDFW's ability to justify and initiate program changes should they be deemed necessary. Additionally, the sharing and collaboration of information will improve our ability to meet program goals, ensure consistency with HSRG recommendations and pending HGMP objectives.

General Approach

For an "ideal" population, N_e equals the census size (N). Yet, populations typically do not meet the criteria that defines "ideal" due to factors such as different numbers of males and females reproducing or variance in reproductive success among parents (i.e., some parents producing more offspring than others). Therefore, N_e is generally reduced below the quantity estimated for N.

Genetic methods can be used to estimate N_e by measuring genetic indices affected by the magnitude of N_e. Populations with smaller N_e lose genetic diversity faster over time than populations with larger N_e, which bears directly on the means by which N_e is estimated.

The fundamental concept is that genetic diversity will be more stable over time in a population with a large N_e than a population with small N_e, with the mathematical relationship defined between the estimated genetic diversity measures and underlying N_e. Jargon surrounds the descriptions of genetic estimators, but the most common categories are inbreeding effective size ($N_{e\ (I)}$) and variance effective size ($N_{e\ (v)}$) (reviewed by Wang, 2005). The salient differences between the two categories are that $N_{e\ (I)}$ deals with loss of diversity and inbreeding *prior to reproduction* and variance effective size ($N_{e\ (v)}$) deals with the random loss of alleles *following reproduction*. In fish, the most common methods are $N_{e\ (v)}$ in form. The plan presented here would use a variance estimator, sampling post-reproduction. Note that it is not necessary to solely target juveniles in order to sample post-reproduction. In this case, returning mature adults would be classified by age and analyzed as progeny of their respective BY.

Common genetic methods used to estimate N_e are based on the observed: 1) change in allele frequencies between two time points (temporal methods; Nei and Tajima, 1981; Waples, 1989); 2) magnitude of chance associations of alleles between loci within a single cohort (linkage disequilibrium; Hill, 1981; Waples, 2006); and 3) sibship frequencies (i.e., distribution of relatedness) within a single cohort (Wang, 2009). It is recommended that the Wang (2009) method be used for assessment as it has a lower root mean squared error then other common methods such as that based on non-random correlations between allele frequencies (linkage disequilibrium) (N_eLD; Waples, 2006). While the Wang (2009) algorithm appears to have superior performance, credible mathematical theory supports alternative methods. Given the same data are analyzed irrespective of method employed, we suggest a replicate analysis of existing annual datasets using both sibship and N_eLD, along with periodic application of the temporal method.

Hatchery supplementation may also affect N_e due to alteration of reproductive success for a subset of a population and subsequent contribution rate (stocking proportion) of the artificially propagated parents (Ryman and Laikre, 1991). The Ryman-Laikre effect quantifies potential change in N_e due to hatchery stocking. Obviously, if there is no hatchery stocking, the population N_e is that of the natural fish in-river. Conversely, if the natural population consists totally of stocked hatchery fish, then the in-river N_e is that of the source hatchery broodstock. For situations in between those two extremes, a relationship can be derived for an expected equilibrium value of N_e.

It has been shown empirically that hatchery supplementation may reduce overall N_e (Christie et al., 2012). Hatchery broodstocks consist of fewer individuals than the natural population in-river and are often inconsistent at returning offspring (i.e., high variance in reproductive success lowers N_e), so broodstock sources are expected to have lower genetic diversity (i.e., fewer alleles, higher relatedness) than associated natural stocks. An equilibrium ratio of N_e (natural) over total N_e may be below one, meaning that the presence of hatchery fish, with their lower genetic diversity, may reduce the N_e over time below what it would have been had the hatchery not been present. The salient point is that without knowing N_e for a hatchery, as estimated from returning HOR program fish present on spawning grounds, artificial propagation programs may reduce the genetic diversity of the associated natural population.

Field Methods

Tissue Collection

Tissue samples required for assessment of N_e will be obtained from monitoring activities associated with estimation of pHOS (objective 2). Both NOR and HOR late winter steelhead (i.e., BWT fish) are encountered on the spawning grounds during tangle net sampling and at the MCF. NOR steelhead both taken as broodstock and released on site (in-river) can be included in analysis as NOR. HOR steelhead tagged and released during tangle net sampling can be used for HOR collection as well as tagged fish captured at the MCF.

Frequency and Duration

Tissue sampling specifics in the field will be based on requirements for estimating pHOS. The plan is currently to conduct sampling weekly from March to May (annually). It is recommended that a minimum of N=50 tissue samples per stock be collected annually and over the run timing of returning mature adult steelhead.

Analytical Methods

Effective Population Size

Expected genetic diversity retained from hatchery mating regimen could be simulated prior to or calculated after mating using observed data following (Kimura and Crow, 1963):

$$N_e = \frac{4N_{ef}N_{em}}{N_{ef} + N_{em}}$$

Where, N_{ef} and N_{em} are the effective number of breeding females and males, respectively. The estimation of the values is based on actual numbers of breeders, the mean progeny produced, and the variance in progeny produced (by sex) (Kimura and Crow, 1963).

Alternatively, the N_e of the parental BY can be inferred from observed sibship frequencies (i.e., distribution of relatedness) within returning (mature) offspring using genotype data. Following Wang (2009), the N_e can be estimated by the probabilities of offspring pairs taken at random from the population being half-sibs (share one parent) and full-sibs (share both parents):

$$\frac{1}{N_e} = \frac{1+3\alpha}{4}(Q_1 + Q_2 + Q_3) - \frac{\alpha}{2}\left(\frac{1}{N_1} + \frac{1}{N_2}\right)$$

where Q_1, Q_2, and Q_3 are the probabilities an offspring pair taken at random being paternal, maternal half-sibs, and full-sibs, respectively. N_1 and N_2 are the number of males and females, respectively. A sibship assignment analysis from a sample of genotypes that is intrinsic to Wang

(2009) algorithm estimates Q_i and N_i. The measurement of deviation from expected Hardy-Weinberg proportions in genotype frequencies is α (equivalent to Wright's F_{IS}). A maximum likelihood estimate of α is obtained from allele frequencies estimated from sampled individuals. Other measures can be employed to estimate N_e from genotype data (Waples, 1989; Waples, 2006), which may be informative, as competing metrics may not be the same depending on the dynamics (or stability) of population size (Crow and Morton, 1955; Kimura and Crow, 1963).

The N_e will be estimated separately for NOR and HOR collections. As stated above, NOR and HOR collections will be defined based on marking and tagging criteria for Lewis River populations. Ideally, age would be available for each steelhead, as genetics models assume single cohorts are being analyzed, although the sibship method may be less sensitive to this assumption. All sampled steelhead will have an associated scale sample that could be used to determine age (i.e., BY).

There is a dominant year class for Lewis River late-winter steelhead, although NOR tend to be more diverse than HOR. Using the dominant annual cohort for trend analysis is the most convenient. To obtain overall population N_e, the annual N_e is multiplied by the mean generation length. As sampling is planned to occur consistently over time, all returns from a single BY can be combined and used to estimate total N_e periodically using appropriate method.

Ryman-Laikre Effect

Hatchery stocking proportion is known to directly influence N_e (Ryman and Laikre, 1991; Hedrick et al., 1995), with the relationship between total population N_e and stocking proportion being:

$$\frac{1}{N_e} = \frac{x^2}{N_c} + \frac{(1-x)^2}{N_w}$$

where, x is the stocking proportion, N_C is the effective size of the captive population, and N_W is the effective size of the wild population (Ryman and Laikre, 1991). Hatchery populations often contain fewer individuals than the population in-river, so N_C is typically smaller than N_W. Therefore, as the fraction of the population represented by hatchery fish increases, the total N_e decreases. A hypothetical example using an N_W=50 and N_C=5 is shown in Figure D5. The total N_e "begins" at 50 when there is no hatchery contribution. The total N_e increases up to a contribution rate of 18%, then decreases to the captive N_e when a contribution rate of 100% is attained.

The estimate would represent expectation for N_e of returning adult offspring produced from current class of spawners. The hatchery contribution rate used to model the Ryman-Laikre effect will be based on pHOS estimates that account for removal of steelhead for broodstock purposes and those transported upstream (i.e., trapped).

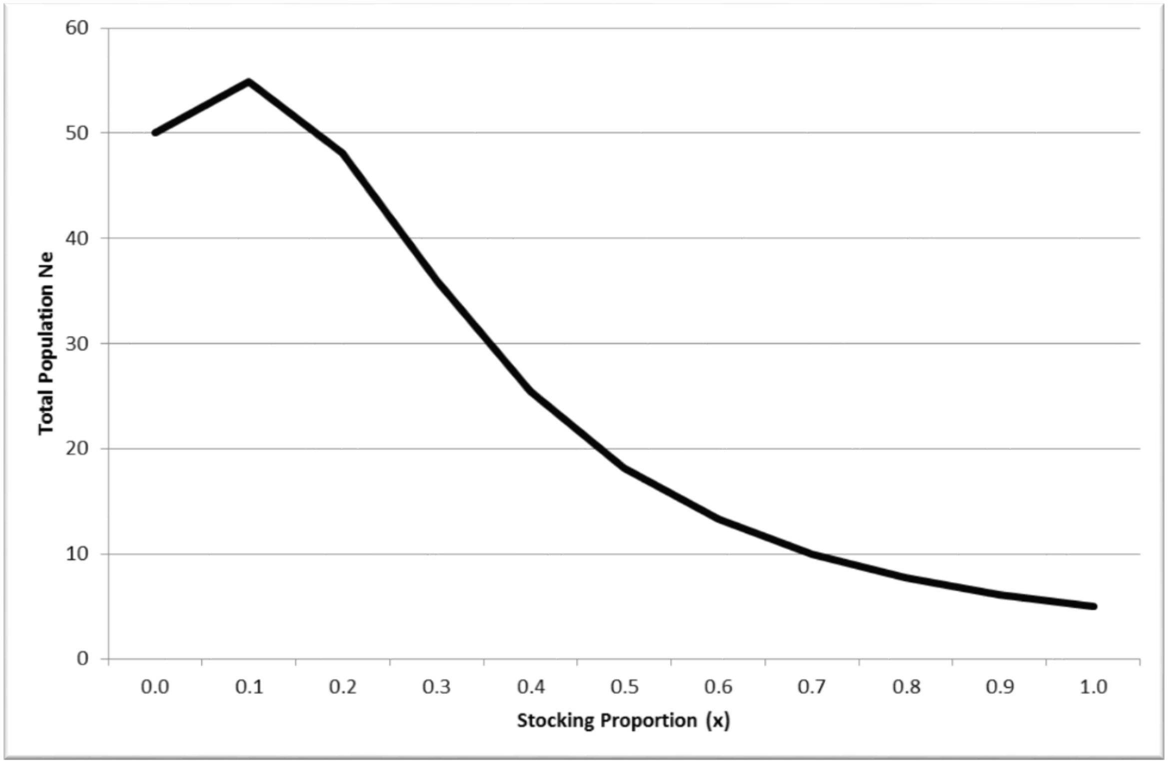


Figure D5. Ryman-Laikre relationship given an N*w* = 50 and N*c* = 5

Deliverables

NOR N_e – The annual effective population size estimated from late winter NOR tissues collected as part of tangle net sampling on spawning grounds or encountered at MCF.

HOR N_e – The annual effective population size estimated from late winter HOR collected as part of tangle net sampling and (re)captures at MCF.

Ryman-Laikre Effect – The estimated total N_e for late winter steelhead given the Ryman-Laikre model.

- pHOS estimate will be used as index for contribution rate. The estimate would require:
  - Abundance from weekly redd surveys
  - The proportion of HOR remaining in lower river based on mark-recapture estimates of HOR not collected at MCF (i.e., transported upstream)

Limitations and Specific Concerns

Many genetics models assume analyses are being conducted on single populations, which entails making assumptions about connectivity (straying, gene flow, migration). For example, when inferring N_e from correlations in allele frequencies, migration is assumed to be absent (i.e., only genetic drift is altering allele frequencies). If straying from another population is high, then an annual single cohort estimate of N_e may be biased low.

Age information is required for partitioning adult offspring into their appropriate BY cohorts. Combining individuals across multiple cohorts violates model assumptions regarding connectivity as mentioned above. An unknown level of estimation bias may occur if analysis combines multiple cohorts.

The Ryman-Laikre model assumes hatchery and natural population components are equivalent from a recruitment stand point. In other words, it is assumed that the proportion of hatchery and natural fish returning to spawn is predictive of the proportion occurring in subsequent progeny (smolts). Further, it is assumed that the pHOS estimate is informative regarding contribution rate.

The fish passage program reconnects the population between the hydroelectric projects by transporting adults upstream and juveniles downstream of Merwin Dam. Juveniles may be a product of hybrids between resident trout and transported steelhead. The existing baseline accounts for this and is the proportion of hybrids is estimated from a subsample of smolts collected in the FSC. However, the effect of these hybrids as returning adults on the population spawning downstream of Merwin is not clear.

OBJECTIVE 12: DEVELOP SAMPLING PROTOCOLS FOR SUPPLEMENTATION ADULTS RETURNING TO TRAPS OR IN-RIVER CAPTURE.

This objective deals with handling and distribution of captured adults that are the progeny from the adult supplementation program. Beginning in 2012, the supplementation program received its first return of Lewis River late winter steelhead hatchery program adults. Spring Chinook and coho salmon that are progeny from adult supplementation programs upstream of Swift Dam will have no tags and be considered NORs. A portion (10-15%) of downstream migrating juveniles sampled at the FSC will be PIT-tagged at the time of collection (detailed in Section 2.18). For late winter steelhead returning to the MCF, a genetic subsample (20% sample rate or 200 fish) of all returns over the run period will be taken to estimate the family representation in the run for each production cohort. For unmarked spring Chinook and coho, these fish will be transported upstream either as program returns or as NOR fish that volunteered into the trap. PIT tagging of transport species may be beneficial in providing additional information regarding distribution from PIT antenna arrays are already in position upstream of Swift Dam for bull trout monitoring purposes. PIT tagging all steelhead transported upstream will provide survival information for steelhead recovered either at the FSC or through bull trout netting. The number of fish PIT tagged will be decided in-season based on the projected (and realized) return rates for 2018 for all transport species.

OBJECTIVE 13: EFFECTS OF UPSTREAM ADULT AND JUVENILE SUPPLEMENTATION ON ENDANGERED SPECIES ACT-LISTED SPECIES.

This objective was removed from hatchery and supplementation activities and moved to the AMEP during the AMEP revisions in 2016. This objective appears in this AOP only as a placeholder to maintain consistency with the H&S Plan objective number and order.

OBJECTIVE 14: ESTIMATE ADULT AND JUVENILE ABUNDANCE OF WINTER STEELHEAD, COHO, AND SPRING CHINOOK DOWNSTREAM OF MERWIN DAM.

ADULT ABUNDANCE

Adult abundance estimates will be performed through redd surveys (steelhead), carcass counts (Chinook), and a combination of these techniques (coho).

Late Winter Steelhead

Redd surveys will be used to estimate the abundance of winter steelhead spawners in the mainstem Lewis River downstream of Merwin Dam. These same surveys will be used to describe distribution metrics for winter steelhead as part of objective 15. Surveys will not include tributaries, and therefore, are not a total spawning escapement estimate, but rather an estimate of the mainstem spawning population. Tributary surveys may be incorporated at some point; however, until a practical approach is agreed to, abundance estimates will continue to focus on the mainstem Lewis River.

Surveys will be conducted from the Merwin boat ramp to the downstream end of Eagle Island (Figure D6). On each survey, the coordinates of newly identified redds will be recorded using recreational grade GPS receivers. Each redd or redd cluster location will be marked with a GPS waypoint(s). Each waypoint will be time stamped and assigned a sequential number by the GPS receiver. Each new redd will also be flagged with high–visibility tape and appropriate weight (e.g., railroad spikes, washers, lead weights). Each flag marker will include the date and number assigned by the GPS receiver. Flagging will reduce error associated with double counting.

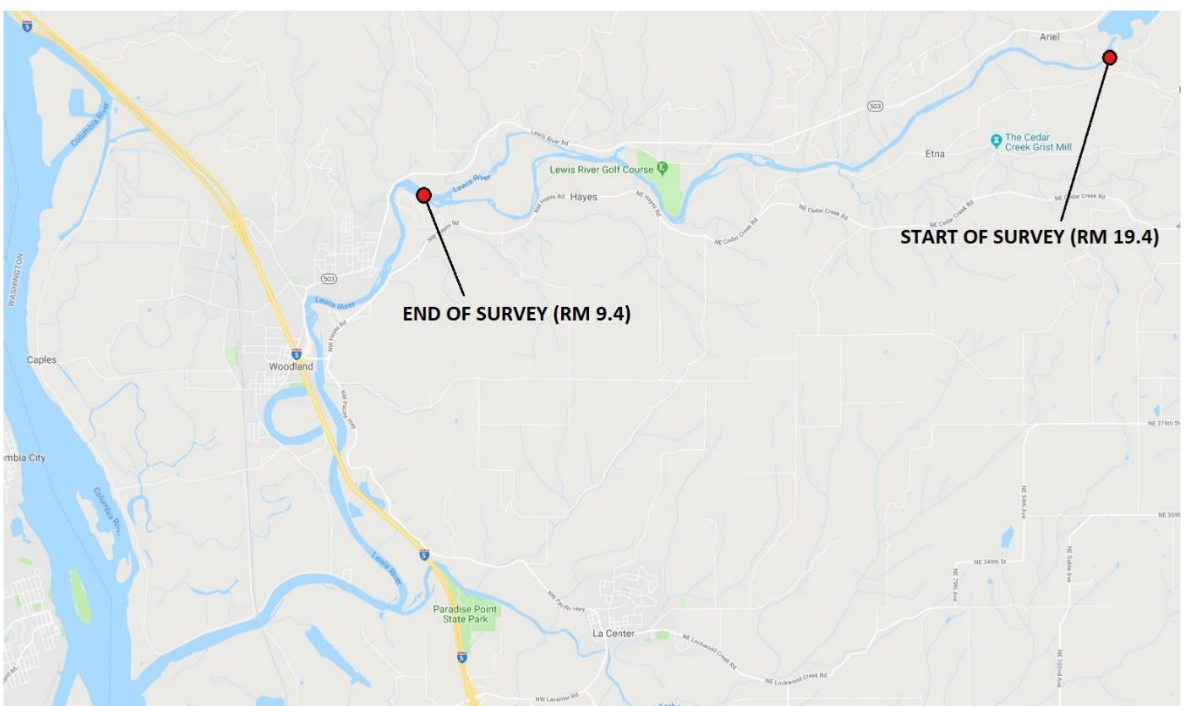


Figure D6. Winter steelhead redd survey study area

In subsequent surveys, previously flagged redds will be inspected to determine if they should be classified as “still visible” or “not visible.” A redd is classified as “still visible” if it would have been observed and identified as “new” without the use of GPS, notes or flagging, and is recorded as “not visible” if it does not meet this criteria. Once a previously flagged redd is determined to be "not visible," the flagging will be removed and the date will be recorded. This information will provide estimates of redd life and may be used if Area Under the Curve (AUC) methods are needed (from a lack of consistent redd surveys).

To estimate in-river escapement abundance, the number of redds will be multiplied by a 0.81 multiplier, used broadly for LCR steelhead stocks. This multiplier represents the apparent number of redds per female in Snow and Salmon Creeks between 1977 and 1980 (Freymond and Foley 1986). The estimate of females is then multiplied by two to derive an estimate of spawner abundance. This calculation assumes and average sex ratio of 1:1 (Freymond and Foley 1986).

The assumed sex ratio of 1:1 may be modified based on winter steelhead captured during the year in which the redd survey is performed. If the ratio observed in the MCF differs from the assumed 1:1 ratio, abundance estimates will be calculated both for an assumed ratio of 1:1 and using a corrected ratio based on actual sex ratio observed from the MCF using the following equation:

$$N = (r * 0.81)s$$

Where N = Estimate of Lewis River total spawner escapement
r = Total number of new redds observed
s = Sex ratio of 1:1 (s = 2) or corrected by observed ratio from the MCF

Ideally, redd surveys will be conducted every 7 to 10 days throughout the spawning season to provide a census count of all redds constructed. By marking redd locations via GPS, flagging and detailed notes, double counting of redds is minimized and a total count of unique redds can be developed. Conversion of redd counts to fish numbers as described above, yields an estimate of spawning escapement in the mainstem. Mainstem escapement estimates will be reported in the Lewis River Annual Operations Report. It is important to note that abundance estimates do not include late winter steelhead captured and retained for broodstock at the hatchery or transported upstream of Swift Reservoir for reintroduction.

Depending on the time of year, survey conditions on the Lewis River tend to be highly variable. Turbidity from runoff in the upper basin as well as flow regulation from Merwin Dam can negatively affect the ability of surveyors to identify redds. During periods of prolonged turbidity or high flows, AUC methods may be required to estimate redds from missed survey periods. However, AUC methods rely on a number of untested assumptions, including redd life, which can also be highly variable over the spawning season.

Spring Chinook

Carcass counts are used to estimate abundance of spring Chinook spawners in the mainstem Lewis River, following methods that have been used for fall Chinook on the Lewis River since the early 1980s (detailed in objective 16). Surveys for spring Chinook abundance use the same methodology as described in the AMEP for fall Chinook (Schedule 9.1). No tributary sampling occurs for spring Chinook. In recent years (prior to 2017), the numbers of spring Chinook returning to the Lewis River have been depressed and most of these fish that entered the Lewis River were trapped and used as broodstock for the hatchery production program. As a result, the number of spring Chinook remaining in the lower river to spawn naturally is relatively low compared to fall Chinook, and estimates of abundance through carcass recovery is challenging due to poor sample sizes of recovered carcasses. Spring Chinook abundance and spatial and temporal distribution data are collected in the same surveys and using the same methods as fall Chinook (see objective 16).

Coho Salmon

The geographic extent of the Lewis River coho salmon population, as defined by NMFS, includes the Lewis River mainstem and all tributaries above and below Merwin, Yale, and Swift dams, as well as several creeks that drain directly into the Columbia River in the vicinity of the Lewis River (e.g., Gee Creek). Due to differing management considerations associated with subcomponents of this overall population, monitoring and data analysis is further split into four subunits: 1) Lewis River mainstem below Merwin Dam; 2) Lewis River mainstem and tributaries above dams; 3) Cedar Creek Basin; 4) tributaries of the Lewis River mainstem below Merwin Dam, and creeks that drain directly into the Columbia River in the vicinity of the Lewis River (e.g., Gee Creek). Monitoring and estimation for each subunit is described below.

Subunit 1 – North Fork Lewis River Mainstem Below Merwin Dam

For the mainstem Lewis River, Jolly Seber (JS) mark-recapture via carcass tagging will be used to estimate coho abundance. This method requires surveying every 7 to 10 days of the mainstem Lewis River from Merwin Dam to the downstream end of Eagle Island. This section is divided into established reaches currently used for fall Chinook surveys. The timeframe for surveying begins October 15 and continues through January 31, as survey conditions allow. Mainstem carcass tagging and recoveries may occur on draw down days scheduled for fall Chinook surveys and will follow the schedule provided in Table D4.

Table D4. Proposed survey days for coho salmon surveys of mainstem and tributary areas

Activity	Day
Coho carcass tagging and recovery (Reach 5)	Monday and Tuesday
Coho tagging and recovery (Reaches 1-4)	Wednesday (Fall Chinook drawdown day)
Coho tributary sampling	Thursday
Coho tributary sampling	Friday (if necessary)

Recovered carcasses will be sampled for fork length, sex, and the presence/absence of an adipose fin and CWT to determine origin. CWT positive fish will have their snouts taken for CWT recovery. Additionally, up to 150 NOR coho (adipose intact, wand negative) should be scale sampled for age composition of NOR fish. Recovering CWTs provides the information necessary for determining origin and age structure of hatchery fish.

The carcass tagging method and accompanying analysis and assumptions used in the JS model are described in detail by Kinsel, et al., (2009) and are briefly summarized here. All carcasses that are intact (i.e., not completely decomposed) are tagged and biologically sampled as described above. Carcasses are tagged on both opercles with uniquely numbered plastic tags (McIssac 1977). Tags are placed on the inside of both opercles to limit bias from tag loss. Tagged carcasses are then placed into moving water to facilitate mixing with untagged carcasses (Sykes and Botsford 1986). On subsequent surveys and after drawdown days for fall Chinook surveys (mixing event), technicians perform recovery surveys and record the tag numbers of recovered carcasses. When tagged carcasses are recovered, the tags are removed and fish are marked by removing the tail, which is denoted as loss on capture in the JS model.

Tagging of all carcasses is preferable for the carcass tagging study. Depending on abundance, however, it may be necessary to subsample the number of coho tagged. If the number of coho carcasses precludes completing the survey for the day, field staff may elect to subsample. The selected sampling interval may be determined in the field to ensure completion of all survey reaches. Any subsampling will follow a systematic sampling approach whereby every third or fifth fish is tagged as opposed to every fish. Fish that are not tagged will be marked by removing the tail to prevent double-counting unmarked fish.

Data Analysis

Results from carcass surveys will be summarized as capture histories and analyzed using a multi-state model formulation of the JS model to account for loss on capture for fish marked by removing the tail (Kéry and Schaub, 2012). Uncertainty in mainstem spawner abundance will be reported as the range in potential abundance within associated confidence intervals

Subunit 2 – North Fork Lewis River Mainstem Above Merwin Dam

Methodology for this area is detailed in the AMEP for the Lewis River.

Subunits 3 and 4 – Cedar Creek, other North Fork Lewis River tributaries below Merwin Dam, and Creeks Draining to the Columbia River in the Vicinity of the North Fork Lewis River (e.g., Gee Creek)

Data Collection

WDFW established a sampling frame containing all coho salmon habitat in subunits 3 and 4. Within this frame, GRTS sampling was used to identify a spatially balanced set of 1-mile long spawning ground survey reaches for coho salmon. These reaches are split into three panels. All reaches in the first panel are surveyed annually, the second panel is split into three sets of reaches of which one set is surveyed each year on a rotating basis. The final panel is split into nine sets of reaches of which one set is surveyed each year on a rotating basis. The size of the panels is designed such that each year's set of survey reaches is comprised evenly of those visited annually, every third year, and every ninth year.

Spawning ground surveys are conducted according to WDFW's Region 5 spawning ground survey manual (WDFW, 2017a) and coho spawning ground survey manual (WDFW, 2017b). Briefly, each reach is surveyed once per week, environmental conditions permitting, from October 1 to January 31. On each survey, counts are made of: live adult coho, coho redds, and dead coho carcasses. Coho redds are individually identified by flagging, recorded on a GPS unit, and tracked to determine whether they are still visible in subsequent weeks following Gallagher et al. (2007). On each subsequent survey, the number of new redds (those not yet flagged) and old redds (those already flagged AND still visible) can be counted, providing a census in survey areas without double counting redds. Carcasses are sampled for fork length, sex, the presence or absence of an adipose fin and CWT to determine origin. Snouts are taken from CWT-positive fish for CWT recovery. Recovering CWTs provides the information necessary for determining origin and age structure. Finally, counts of live coho are made for each reach on each survey, and individual fish are classified as holders or spawners and the presence of an adipose fin is noted as present, absent, or unknown.

Data Analysis

Data are analyzed in conjunction with spawning ground survey data, mark-recapture data, dam census counts, and fishery harvest estimates for coho salmon from throughout the lower Columbia Evolutionarily Significant Unit (ESU) via a Bayesian multivariate state-space model (Buehrens et al., *in prep*). The primary outputs of this model are estimates of spawner abundance and pHOS. Briefly, for each subunit, counts of uniquely identified redds are summed together with an estimate of the number of redds constructed outside of the survey reaches. This total is expanded to a female coho salmon abundance estimate based on the number of "apparent redds per female" which is estimated in the model based on other subunits in the LCR where paired redd counts and either census or mark-recapture estimates of female abundance are available. The female abundance estimate is expanded to total abundance based on the sex ratio of recovered carcasses in the subunit. The pHOS is then estimated based on the proportion of HOR carcasses recovered in the subunit. Parameters are reported as posterior medians with associated 95% credible intervals. Parameters are reported for subunits as well as for the overall Lewis River coho salmon population. The overall estimate is achieved by summing the subunit abundance of hatchery and wild spawners within the Bayesian model, thereby intrinsically propagating uncertainty in subunit parameters and covariance among them.

Deliverables

The following annual estimates will be reported in the Lewis River Annual Operations Report:

1. Steelhead
    a. Direct counts of steelhead redds or estimate provided by AUC

    b. Estimated spawner abundance for the mainstem Lewis River population (mainstem escapement)
2. Spring Chinook
    a. Direct counts of spring Chinook carcass abundance
    b. Estimated spawner abundance for the mainstem Lewis River population (mainstem escapement)
    c. Fork length, sex, age, and origin (HOR or NOR), and tag presence of all carcasses
3. Coho
    a. Estimated mainstem spawner abundance based on carcass observations and recovery of tagged carcasses. (mainstem escapement)
    b. Direct counts of carcasses and redds per week in tributaries
    c. Estimated spawner abundance and pHOS for tributary units and mainstem Lewis River (estimated medians with 95% credible intervals)
    d. Fork lengths, sex, origin (HOR, NOR), and CWT presence for all carcasses directly sampled

Limitations and Specific Concerns

Estimates of spring Chinook and mainstem coho abundance through carcass recovery is challenging due to poor sample sizes of recovered carcasses. The ability to identify redds accurately to species is complicated by the relatively large number of fall Chinook that overlap with both species in terms of distribution and redd construction.

Currently, the overall Lewis River coho estimate only contains subunits 3 and 4, which WDFW is responsible for analyzing. However, in the future when robust estimates of abundance and pHOS are available for subunits 1 and 2, these should be incorporated into the model to estimate overall abundance and pHOS for Lewis River coho salmon

JUVENILE ABUNDANCE

Introduction

Obtaining accurate and precise smolt abundance in systems such as the Lewis River is problematic because of the size of the river and fluctuating flows during outmigration periods. Methods to estimate abundance almost always rely on mark recapture techniques. Collection methods (e.g., traps, netting, seining) must be able to obtain a statistically valid sample size for marks and be able to recapture an adequate number of marks to develop a practical abundance estimate for each species.

Screw Trapping and Sampling

The primary method for estimating smolt abundance (for all species) is the use of two screw traps placed in tandem in near the Lewis River Golf Course. Traps will be placed in operation by March 1 of each year and removed by June 30. Trap deployment and removal may be affected by river conditions. For 2018, it is the intention to also deploy the traps during the fall release of HOR spring Chinook in October. The purpose of this fall deployment will be to evaluate the migration timing distribution of HOR spring Chinook after release from the hatchery.

Hatchery fish will be sampled according to the following protocols:

- Measured to fork length
- Noted for type of mark (e.g., adipose clip, CWT, BWT)
- Assigned a smolt index as described in objective 3 (parr, transitional, smolt, residual)
- All hatchery fish greater than 60 mm in length will be marked with an alcian blue tattoo and released approximately 1 kilometers upstream of the trap (swirly hole) to generate and adjust weekly trap efficiency estimates by species.
- Fish smaller than 60 mm are difficult to mark and there are also concerns with marking affecting survival.

Trap Efficiency and Test-Fish Release Power Analysis

The number of recaptures of marked fish, which are released upstream to test trap efficiency, influences confidence interval size around estimates of total out-migrants. The actual trap efficiency also has a large influence on the confidence interval size. To assess the influence of these two attributes on confidence interval size, a power analysis is provided to estimate the number of fish needed to mark and release based on trap efficiency (Figure D1). Estimates of trap efficiency in 2017 was on average 1.1%. This value represents the recapture rate of all marks, which was 35 out of 3,181 marks. The relatively small recapture rate affects confidence in the estimate. For example, average confidence in the 2017 estimates was ± 40% of the estimated abundance at the 95% confidence level.

Using total coho captures from the 2013 season (901 fish), estimates of total coho out-migrants were generated assuming true trap efficiency was 0.6%, 1.0%, and 2.0%. For each trap efficiency level, total number of test-fish released upstream was varied in a step-wise manner, starting at 160 up to 4,500 fish. For each trap efficiency and test-fish release level, total coho out-migrant and variance estimates were generated using the Bootstrap method (Thedinga et al., 1994). Confidence intervals were calculated for each out-migrant estimate based on the variance and transformed into a percentage of the total estimate, in order to compare confidence interval size between varying trap efficiency levels.

The relationship between true trap efficiency, the number of test-fish released upstream, and how these two attributes influence confidence interval size around estimates of total out-migrants is depicted in Figure D1. As true trap efficiency decreases, more test-fish must be released upstream in order to re-capture at least 15 to 20 fish. As trap efficiency and/or the number of test-fish released decreases, the size of the confidence interval around total out-migrant estimates dramatically increases. Based on this analysis, if the goal is to generate total out-migrant estimates with confidence intervals less than ±50% of the total estimate and CV less than approximately 30%, many more test-fish need to be released in the future, assuming a similar level of total trap captures as occurred in 2013. Based on this analysis, it is recommended to release at least 3,000 test-fish if true trap efficiency is 0.6%; release at least 2,000 test-fish if true trap efficiency is 1.0%; and release at least 1,000 test-fish if true trap efficiency is 2.0%. Releasing more test fish will further reduce confidence interval size and improve out-migrant estimates. Thus, it is the intent to mark all fish captured larger than

65 mm and release these fish upstream as marked groups for recapture. This includes hatchery releases, late winter steelhead hatchery releases, and naturally produced smolts. Using these other groups may help to achieve capture goals to meet trap efficiency precision goals.

If fish captures are insufficient for marking purposes, hatchery releases of coho and spring Chinook should be used as a surrogate for mark-recapture purposes. Fish should be marked with PIT tags prior to volitional release. A fixed PIT tag antenna may be installed at the pond outlet(s) to determine when the smolt entered the Lewis River and thus is available for capture.

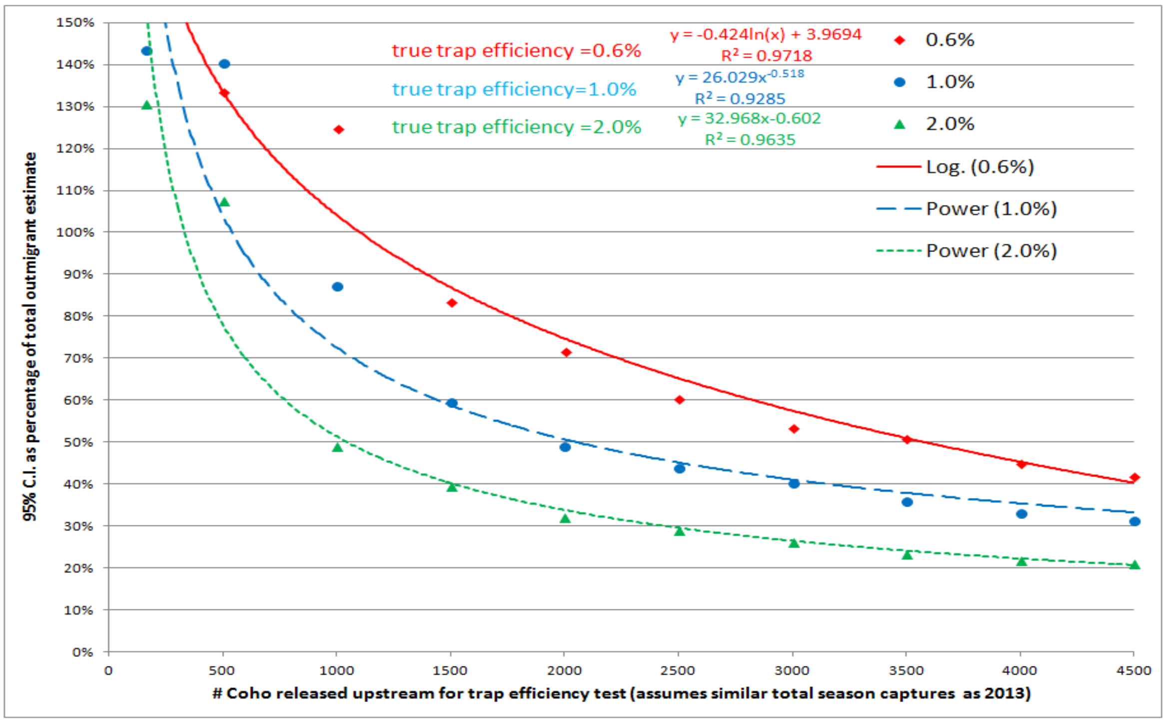


Figure D7. Power analysis for number of smolt released upstream of screw trap to achieve corresponding 95% confidence level at three trap efficiency levels (0.6, 1.0, and 2.0)

Deliverables

1. Length frequency of NOR salmonids captured at the trap
2. Migration timing of NOR and HOR salmonids based on weekly trap counts for each species
3. Summary of weekly tests of trap efficiency based on recapture rates of marked salmonids with capture efficiencies calculated for each species (including NOR and HOR)
4. Estimates of total salmonids passing the trap by species and origin (HOR and NOR) using Bootstrap and sum of discrete interval methods
5. CV estimates for total salmonids passing the trap for each species

Limitations and Specific Concerns

1. This study assumes that fish will migrate past the trap during deployment. When the trap is not deployed, there is an unknown number of fish migrating. Additionally, the proportion of non-migrants that remain in the river upstream of the trap as minijacks (salmon) or residuals (steelhead) is not known.
2. Trapping efficiency may not be the same between HOR and NOR smolts due to differences in size or behavior
3. The migration window of hatchery fish is typically very small (i.e., a few days) and if the traps are not in operation due to mechanical failure, an entire migration window may be missed.

OBJECTIVE 15: DETERMINE SPATIAL AND TEMPORAL DISTRIBUTION OF SPAWNING WINTER STEELHEAD, SPRING CHINOOK, AND COHO DOWNSTREAM OF MERWIN DAM

Redd surveys will be used to estimate spatial and temporal distribution of spawning. For steelhead, redd surveys are also used to estimate abundance, which is unlike redd surveys for salmon. Therefore, steelhead redd surveys have more effort associated and specific protocols to follow to avoid recounting redds. Redd surveys for salmon are used for distribution purposes only.

WINTER STEELHEAD

Distribution surveys of winter steelhead will follow the timing, frequency, and methods described under adult abundance in objective 14. To determine spatial and temporal distribution, redd data will be summarized using a map depicting the location and number of redds observed within the study area. In addition, a summary table noting the redds per mile for each section described under objective 16 will be provided.

In most instances, the same surveyor will be used for all surveys. If that is not possible, surveyors will be proficient and experienced in steelhead redd identification. Redd counts will be summarized by the same sections used for fall Chinook surveys described under objective 16. Redd data include date, section, redd unique identification, GPS accuracy, latitude, longitude, and redd status.

Frequency and Timing

Redd surveys are conducted regularly (every 7 to 10 days) throughout the known spawning season, which, based on past observations, is from April 1 to June 30. Surveys are intended to provide a census count of all redds constructed. Winter steelhead redd surveys may begin earlier if spawning activity is observed during tangle net operations. Surveys will not be performed if visibility is less than 3 feet or spill has been initiated from Merwin Dam. By marking redd locations via GPS, flagging, and detailed notes, double counting of redds is minimized and a total count of unique redds can be developed.

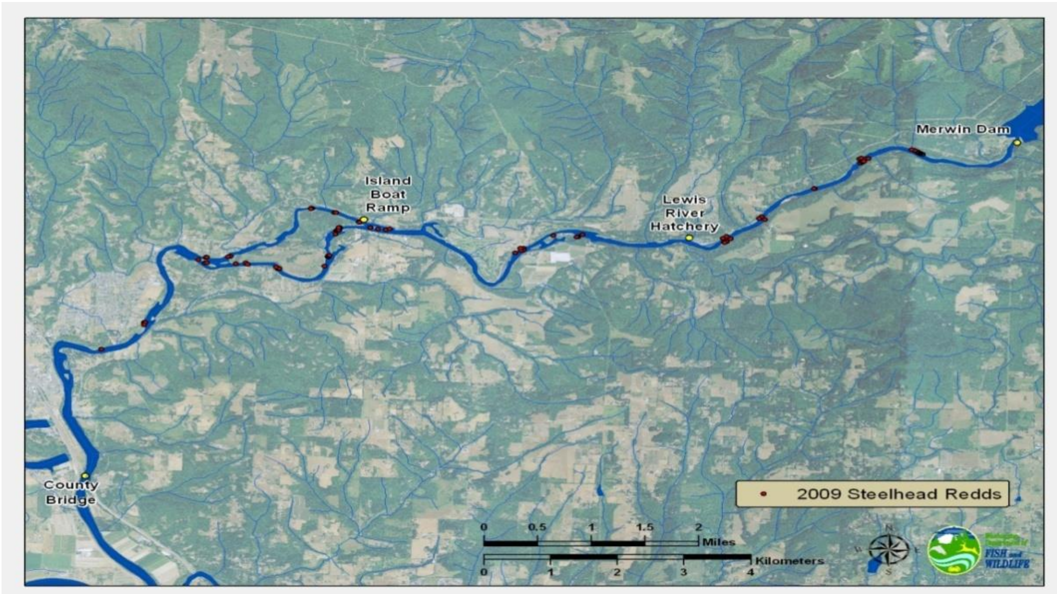


Figure D8. Example of data collected during 2009 winter steelhead redd surveys on the North Fork Lewis River indicating redd locations and survey area

SPRING CHINOOK AND COHO SALMON

All mainstem redd surveys will be performed by boat. Tributary sampling (for coho) will be performed by foot.

Redd counts will be enumerated by section in the mainstem. Live surveys will also be conducted weekly or biweekly in September and early October to correspond with the peak spawn period for spring Chinook. Live fish will be enumerated by section while redds will be delineated at a finer spatial resolution using counters and a handheld GPS. Redds will be assigned to a species (e.g., Chinook versus coho) based on the species of fish that is seen either on or around the redd. If a live fish is not seen on a redd, the redd is assigned to the most likely species based on the spawning habitat, size of redd, and previous knowledge of spawning distribution within the Lewis River.

All redds will be marked with a handheld GPS receiver. In instances where multiple redds are located within a defined area (e.g., tail out), the number of redds contained within this area can be counted as one GPS point. These clusters will be separated out as individual points upon entering into a spatial database for display in GIS maps. GPS locations and dates of new redds will be used as a measure of spatial and temporal distribution. GPS coordinates for each new redd will be maintained in a GIS database or acceptable alternative.

Frequency and Timing

A minimum of three redd surveys will be conducted during the peak spawning time. Peak spawning time will be determined by field crews conducting the carcass surveys. Additional surveys may be completed if the previous redd survey is determined to not have been the peak count based on subsequent surveys. For mainstem coho, a minimum of three redd surveys for each run (early and late) will be conducted near the peak spawning time for each run as determined by field crews (for a total of six redd surveys). Tributary sampling for coho redds will be completed 1 day per week in conjunction with tributary carcass sampling. Redd surveys for spring Chinook will be conducted during the peak redd construction period as determined by field crews, but is typically in mid to late September. A maximum of three redd surveys for spring Chinook will be performed during this peak period to evaluate redd distribution. Redd surveys will only be performed during favorable conditions. Favorable conditions are defined as visibility of at least 3 feet. Under no circumstances will surveys be conducted during periods of spill at Merwin Dam for safety and accuracy reasons.

Distribution Data Analysis

Redd counts and locations will be entered into a GIS database and provided in the Annual Operations Report as distribution maps for redds. Redds will be enumerated by section and reported in table format. Tables will be formatted to provide a temporal count by section and estimate of redds per mile.

Deliverables

1. Maps of redd distribution for all species indicating spawner spatial distribution (see Figure D8)
2. Tables of redds per mile for each of the five sections described under objective 16 to include all previous redd survey years
3. A cumulative distribution plot of the total number of redds counted over time will be developed to depict the temporal distribution of spawning

Limitations and Specific Concerns

- Accurate identification of redds depends on both the proficiency of the surveyor and river conditions (namely turbidity) on a given survey day. Poor visibility may be prolonged as experienced in 2016 and 2017 during winter steelhead redd surveys. This prevents the ability of surveyors to identify redds to evaluate distribution metrics and, in the case of winter steelhead, estimates of abundance.
- The ability to accurately identify species specific redds between coho and fall Chinook is challenging because both species share the same spawn timing. There are specific redd characteristics that differ between species such as substrate size (gravel vs cobble), location of redds (margins versus thalweg), and size of redds. However, these characteristics may also overlap based simply on differences in fish size. For example, smaller Chinook may select smaller substrate size preferred by coho or superimpose over existing coho redds. It must be noted that some (unknown) level of uncertainty exists in identifying redds in general, and this uncertainty is exacerbated by having to differentiate redds by species. To reduce uncertainty, surveys should only be conducted by surveyors that have extensive experience in identifying both coho and Chinook redds, and that this experience is specific to the Lewis River. Surveyors should be able to identify where substrate differences occur in the river and be able to accurately and

quickly identify live salmon species. By using experienced surveyors, misidentification is reduced, but certainly not eliminated and this uncertainty must be accepted.

OBJECTIVE 16: EVALUATE FALL CHINOOK AND CHUM POPULATIONS DOWNSTREAM OF MERWIN DAM.

BACKGROUND

Chinook Salmon

The LCR Chinook salmon (*Oncorhynchus tshawytscha*) ESU consists of 32 historical independent populations that are distributed from the mouth of the Columbia River upstream to the Hood River in Oregon (NMFS, 2013). LCR Chinook salmon exhibit two dominant adult migration patterns based on when individuals return to freshwater to spawn. These two dominant life-history strategies have been used to categorize populations as either spring or fall Chinook (Myers et al., 2006). Fall-run Chinook have been further separated into two stocks, "fall-run" and "late fall-run," and are referred to as tules and brights, respectively. Hereafter, the term "fall-run" Chinook will be used in reference to the combination of these two stocks while the terms "tule" and "bright" will be used to specify the specific fall-run stock.

The Lewis River watershed contains three of the 32 LCR Chinook salmon populations among which display each of the three unique run-types (spring, fall, and late-fall). WDFW, formally the Washington Department of Fisheries, has been monitoring Chinook in the Lewis River for decades. Specifically, adult spawning ground surveys have been conducted annually since 1964 and these data have been used to derive estimates of adult fall Chinook escapement. Juveniles (pre-smolt) have been sampled and have received CWTs since 1983 as part of the Lewis River Wild Fall Chinook Tagging Project (Hawkins, 2018a). CWT Chinook are then recovered in fisheries and on the spawning ground. Escapement estimates and CWT recoveries are used in conjunction to: 1) assess the effects of Lewis River flows (i.e., dam operations) on juvenile production and adult abundance; 2) reconstruct the Lower River Wild spawning stock component unit, which is one of the five Columbia River fall Chinook management units; and 3) evaluate abundance, survival, and fishery harvest as part of the Pacific Salmon Treaty, Pacific Fishery Management Council, Pacific Salmon Commission, and Columbia River Compact processes.

Over the years, the methods used to estimate adult escapement have changed. In 1976, a mark-recapture carcass tagging study was conducted to generate an estimate of escapement in the Lewis River (see "Area of Focus" below). From this estimate, an expansion factor was derived relating a peak count of live and dead Chinook in an index section to total abundance (McIssac, 1977). For the following two and a half decades, WDFW used peak count index surveys to generate estimates of Chinook escapement. In the early 2000s, WDFW revisited the methods that were being used to estimate the abundance of Lewis River Chinook. Specifically, there was concern that the peak count expansion factor was not producing accurate estimates as the peak spawn time period had shifted later into the fall when survey conditions were not as favorable (i.e., increased flows and turbidity during the new peak spawn time frame decreased survey visibility and thus estimates of abundance). Therefore, WDFW conducted three years (2000 to 2002) of mark-recapture carcass surveys and derived updated (age-specific) expansion rates based on carcass recoveries, which is known as the "bright-eye method." The bright-eye method has been used to estimate escapement annually since 2002. However, this method currently does not meet the monitoring recommendations that have been established for salmon and steelhead populations by NMFS (Crawford and Rumsey, 2011) and the AOP (H&S Subgroup 2015). These limitations led WDFW to reinitiate annual mark-recapture carcass surveys of Lewis River Chinook in 2013 to generate unbiased estimates of adult abundance and composition. WDFW is in the final stages of a comparative evaluation of abundance methods for Lewis River Chinook (Bentley et al., 2018), but a final decision on what methodology will be used moving forward has not been made. Therefore, the methods described in this objective to derive estimates of adult escapement are based on mark-recapture carcass surveys (see "Data Collection Methods") and JS abundance models (see "Analysis Methods").

Chum Salmon

The Columbia River chum salmon (*Oncorhynchus keta*) ESU consists of 17 historical independent populations that are distributed from the mouth of the Columbia River upstream to the Deschutes River in Oregon (NMFS, 2013). Historically, hundreds of thousands of chum adults returned annually to the LCR and the Lewis River population was estimated to have supported close to 100,000 chum at equilibrium, second only to the Cowlitz River (Johnson et al., 1997, Good et al., 2005). However, over the past 50 to 75 years, returns of chum salmon have dramatically decreased both within the Lewis River and throughout the Columbia River Basin. Today, 15 of the 17 historical Columbia River chum populations, including the Lewis River, are considered extirpated or nearly so (LCFRB 2010, NMFS, 2013). The low abundance of chum salmon in the Lewis River is seen directly in the monitoring data collected over the past several decades. For instance, over the past 10 years, an average of nine chum carcass (range: 0 to 28) have been recovered on the spawning ground over the course of the 4- to 5-month fall survey period.

SPECIFIC OBJECTIVES

Following the listing of many salmon and steelhead populations under the ESA, NMFS developed a framework to assess the status, trend, and long-term viability of "Viable Salmonid Populations" (McElhaney et al., 2000). This framework has been converted to a set of monitoring guidelines that focus on estimating Viable Salmonid Population indicators, which are broken up into four main categories: abundance, productivity, spatial distribution, and diversity (Crawford and Rumsey, 2011). Based on these recommendations, the specific objectives to evaluate Chinook and chum populations downstream of Merwin Dam include:

- Generate an "unbiased" estimate of adult fall Chinook (i.e., escapement) downstream of Merwin Dam with a CV on average of 15% or less.
- Generate an estimate of adult chum and spring Chinook (i.e., escapement) downstream of Merwin Dam. (Note: currently chum and spring Chinook abundance is low and thus generating estimates has been difficult.)

- Determine adult composition of fall Chinook on spawning grounds downstream of Merwin Dam (i.e., stock: spring, tule, bright; origin: wild, hatchery; sex; age).
- Evaluate the spatial and temporal distribution of fall Chinook and chum spawning downstream of Merwin Dam with the ability to detect a change in distribution of ± 15% with 80% certainty.
- Estimate juvenile fall Chinook abundance (reproductive success) downstream of Merwin Dam with a CV on average of 15% or less.

Area of Focus

The majority of Lewis River fall-run Chinook spawning occurs between the Lewis River Hatchery (RM 15.7) and the base of Merwin Dam (RM 19.5). Additional spawning occurs in the mainstem Lewis River between the bottom of Eagle Island (RM 10.0) and Lewis River Hatchery as well as in Cedar Creek and the East Fork Lewis River, which enter the Lewis River at RM 15.7 and 3.5, respectively.

The adult mark-recapture carcass tagging surveys are conducted in the Lewis River from the bottom of Eagle Island upstream to just below Merwin Dam. This total survey area has been delineated into five survey sections (Table D5). These survey sections were established during the original 1976 carcass tagging study and have remained constant since. Sections 1 to 4 are each approximately 1 mile in length and together make up the index count section dating back to the mid-1950s. Section 5 consists of a split channel surrounding Eagle Island. Cedar Creek and East Fork Lewis River Chinook have been surveyed and their data analyzed separately. Therefore, these data were not incorporated into this current evaluation. However, an effort will be made in the future to generate "total" Lewis River tule and bright abundance estimates that incorporate all major spawning areas.

Juvenile surveys are conducted in the Lewis River primarily from just upstream of the Lewis River Hatchery (~RM 16) downstream to County Bridge at ~RM 6. Occasionally, juveniles are sampled upstream of RM 16, but the majority of Chinook rearing occurs downstream of the Lewis River Hatchery. The total survey area is broken up into approximately 80 unique sample sites that distributed throughout the ~10 river-miles of river.

Table D5. Description of fall Chinook carcass survey sections on the North Fork Lewis River, 2013 – 2017

Reach Code	Length (miles)	Description
NFL-1	0.7	Upstream End: Pool Below Dam (RM 19.1) Downstream End: Back Eddy/Bottom of Sec No. 1 (RM 18.4)
NFL-2	0.8	Upstream End: Back Eddy/Bottom of Sec No. 1 (RM 18.4) Downstream End: Below Hagedorns (RM 17.8)
NFL-3	1.0	Upstream End: Below Hagedorns (RM 17.8) Downstream End: Top of Big Bar (RM 16.8)
NFL-4	1.1	Upstream End: Top of Big Bar (RM 16.8) Downstream End: Lewis R. Hatchery Boat Ramp (RM 15.7)
NFL-5	7.7*	Upstream End: Lewis River Hatchery Boat Ramp (RM 15.7) Downstream End: Bottom of Eagle Island (RM 10)

Note:
**Length includes both north and south channel around Eagle Island*

Data Collection Methods

Adult Abundance and Composition

Carcass surveys are conducted on the Lewis River to estimate abundance and composition (i.e., race, origin, age) of adult spring and fall Chinook spawners (i.e., escapement) and presence/absence of adult chum spawners. Each year, surveys begin in mid- to late-September and continue through mid-January to mid-February. This time period encompasses the large majority Chinook and chum spawn timing period in the Lewis River. One to four jet boats are used to navigate the Lewis River and sample Chinook carcasses. Surveys are conducted weekly given that stream conditions are conducive to staff safety and fish visibility. Carcass surveys typically occur on a single day per week and are aligned with when river flows are the lowest. During the peak of the run (November through early December), PacifiCorp normally provides five drawdowns from Merwin Dam that reduce flows in the lower river in an effort to increase carcass recovery rates. Occasionally, a second survey day in a week is required due to large numbers of carcasses. When a second survey day is needed for a given week, the lowest reach (No. 5) is surveyed on day 1 prior to the scheduled draw-down while the upper four reaches (Nos. 1 to 4) are surveyed on day 2 and align with the draw-down. This order of operations prevents carcasses tagged on day 1 from moving downstream into reaches surveyed on day 2. Multiple surveys per week are treated as a single sample period.

During each survey, recovered carcasses are sorted and processed in a sequential manner (Figure D9). First, carcasses are identified by species. It relatively easy to identify the species of a fall spawning carcass (Chinook, coho, chum) unless the carcass is completely deteriorated. In the past, Chinook carcasses were not separated by stock in the field. Rather all Chinook carcasses were assigned as a just a Chinook and later apportioned as either a spring- or fall-run fish based on the scale age read (FW 1 = fall, FW 2 = spring). Due to changes in hatchery rearing and release strategies of spring Chinook (i.e., a portion of hatchery juveniles being released as sub-yearlings), adult carcasses will have to be assigned as either spring or fall Chinook based on external characteristics. However, the reliability of these visual assignments has not been evaluated and there is some doubt to the accuracy (Hawkins, 2018b). Therefore, moving forward, stock assignment likely needs to be evaluated.

Second, carcasses are sorted based on their recovery status (i.e., recovered versus not recovered) and the several external features of the carcass. Carcasses that cannot be recovered (e.g., too deep, pinned in a log jam) are enumerated and recorded as a Carcass Category 5 (Figure D10). Each recovered carcass is initially examined for the presence of a tail. A carcass with a severed (i.e., missing) tail is indicative of a previously sampled/recorded fish and are subsequently ignored. Carcasses with intact tails are then sorted based on whether or not a surveyor could determine if the carcass has been previously tagged. Previously tagged carcasses would have a tag on the inside of both opercula (see below). Therefore, if a carcass is missing its head and/or opercula, its previous tag status could not be determined. These carcasses are enumerated, denoted as either a Carcass Category 1 or 2 (Figure D10) and have their tail severed. Carcasses recovered with a slit belly are assumed to be sport caught and are enumerated and denoted as a Carcass Category 6.

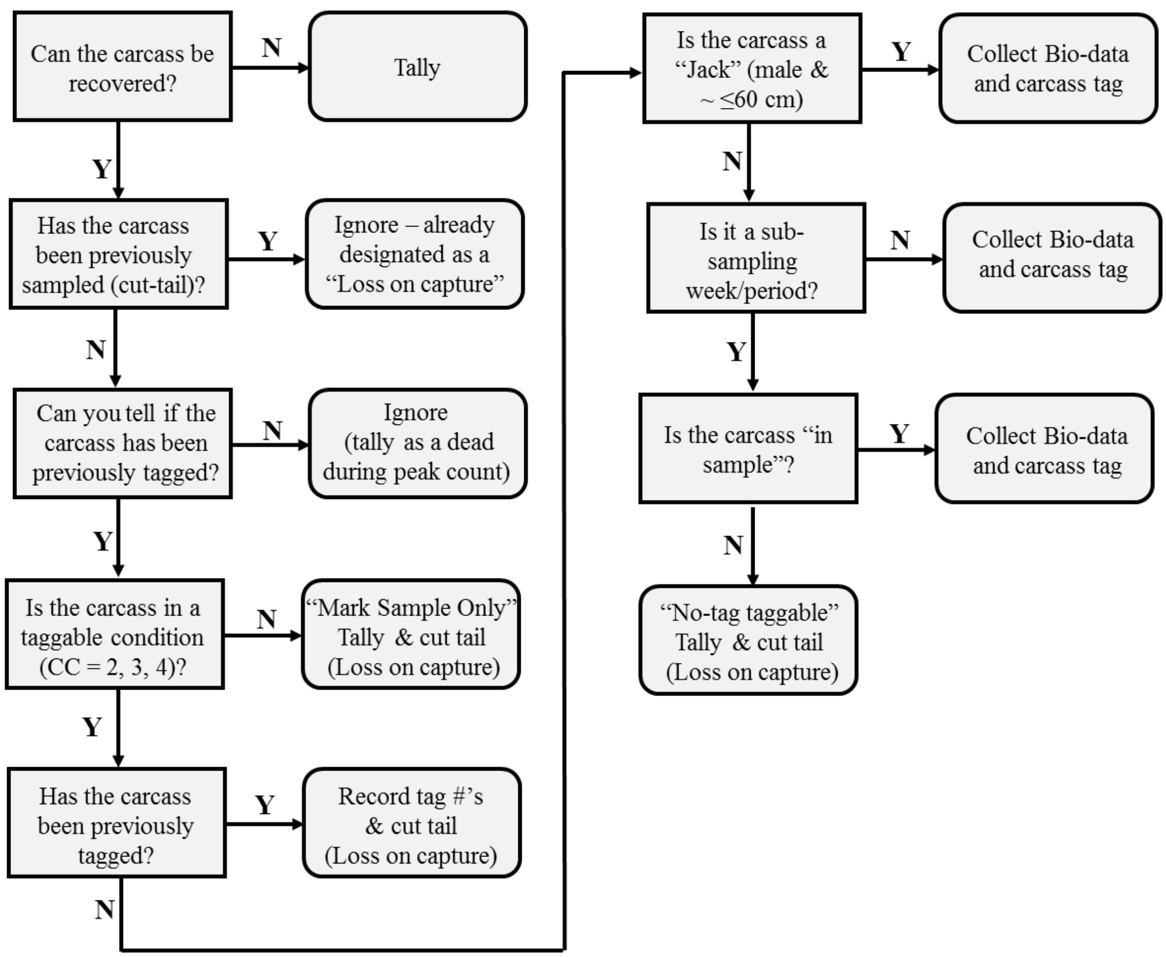


Figure D9. Sampling procedure for Fall Chinook carcass surveys on the North Fork Lewis River

Third, carcasses with intact heads and/or opercula are sorted as either taggable or untaggable based on their qualitative carcass condition category (Table D6). Taggable carcasses have numeric carcass condition scores of 2, 3, or 4 while untaggable carcasses are classified as either 5 or 6. Untaggable carcasses are designated as “mark sample only” fish, classified as either a “jack” or an “adult” group carcass (see below), have their adipose-fin status (see below) and Carcass Category recorded, examined for a CWT, have their tail severed to signify the carcass has been sampled (i.e., denoted as a “loss on capture” in JS model), and returned to the river.

Fourth, carcasses that are in taggable condition are then processed based on their capture history, size, and age. Carcasses are sorted into maiden and recapture recoveries. A recaptured carcass would have had a plastic numbered tag stapled to the inside of one or both opercula while a carcass with no opercula tags is classified as a maiden. Recaptured carcasses have their tag number(s) recorded, tag(s) removed, tail severed to denote the carcass was sampled, and returned to the river. Maiden captures are sorted into two groups based on their sex and fork length. The first group were classified as “jacks/group 1” and consisted of small(er) males whose fork length was less than approximately 60 cm. The second group were classified as “adults/group 2” and consisted of females and large(r) males who fork length was greater than or equal to approximately 60 cm. It should be noted that these group classifications were largely based on visual assessment of fish length. Therefore, a portion of the “jack” group carcasses consisted of small “adult” males and vice versa due to both inaccuracies in visually classifying carcasses by length (e.g., a 62 cm carcass placed into the “jack” group) and variability in length-at-age (e.g., a 62 cm carcass classified as an “adult” was in fact a true, age-2 jack). Regardless, this slight variation in the group classification of each carcass (i.e., “jacks” versus “adults”) did not have any impact on the accuracy of abundance estimates as age-distribution was apportioned using weekly scale samples (see below).

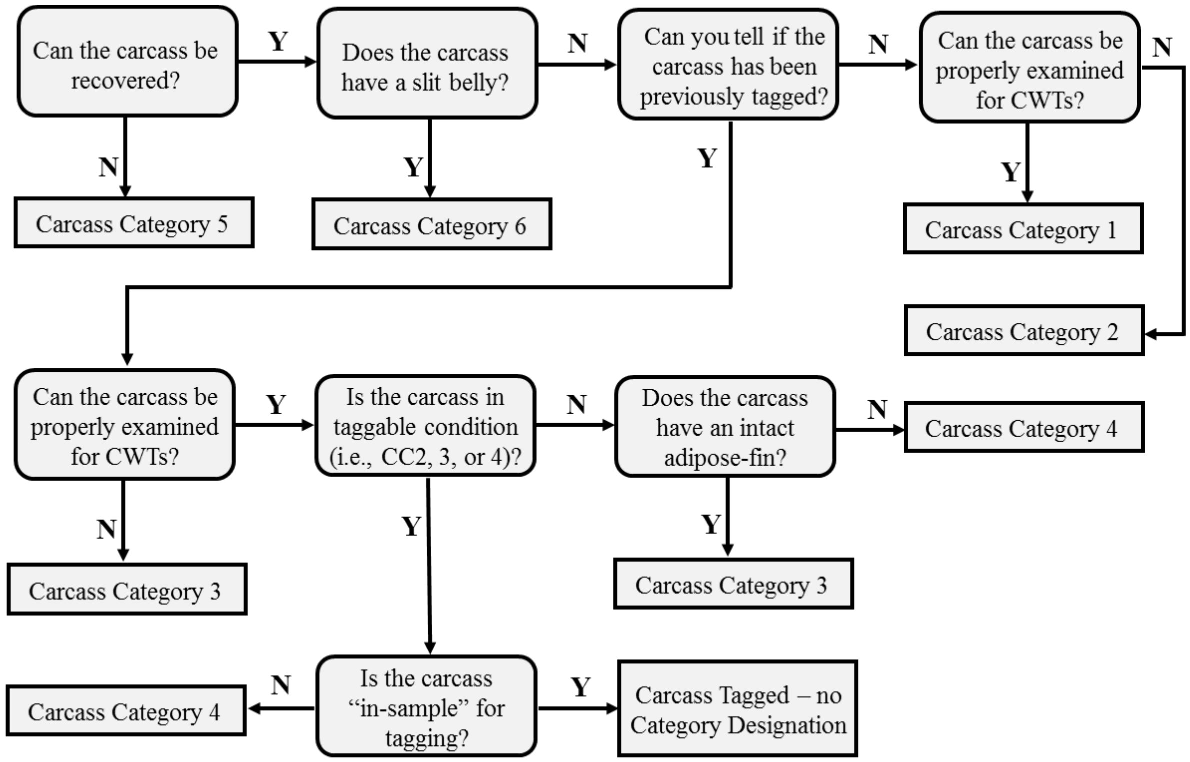


Figure D10. Diagram of how the Carcass Category of each individual fish is determined and classified for carcass surveys conducted on the North Fork Lewis River.

Note: Carcass Categories are only assigned to maiden fish (i.e., previously unsampled) carcasses that are not carcass tagged.

Fifth, carcasses are then processed based on the weekly sampling rate. Specifically, carcasses are sorted into two groups ("in-sample" or "out-of-sample") based on the sampling rate for a particular week. In all weeks, small (group 1) carcasses are sampled at a 1:1 rate due to the low overall recoveries of fish in this category. In most weeks, large (group 2) carcasses are sampled at a 1:1 rate. However, sub-sampling occurs in most years during peak weeks when the number of recovered carcasses is too high to sample at a 1:1 rate. Sub-sampling rates are predetermined based on the anticipated number of recoveries for a particular week and can vary from 1 in 2 to 1 in 10 among weeks and years. Out-of-sample carcasses have their tail severed to denote the carcass was sampled, and returned to the river. If an out-of-sample carcass has a missing adipose fin, it is also scanned for a CWT.

Lastly, in-sample (taggable, maiden) carcasses are bio-sampled and tagged. Carcasses are examined for the presence or absence of an adipose fin and CWTs. Prior to mid-November, all recovered carcasses are scanned for a CWT using a handheld wand regardless of adipose status due to the possible presence of double-index tagged strays. After mid-November, only carcasses with missing adipose fins are scanned for CWTs. Carcasses that wand positive for a CWT have their snouts removed and collected. All carcasses then have their sex, fork length, and condition recorded (Table D6), scales collected for aging, and are tagged. Chinook carcasses are tagged by stapling a plastic numbered tag on the inside of both opercles. Tagged carcasses are then returned to the river in the section they were collected (Table D5) and in flowing water to facilitate mixing with untagged carcasses.

Due to overall low abundance of chum salmon in the Lewis River, recovered carcasses are not tagged but rather bio-sampled and enumerated.

Table D6. Carcass condition categories codes and the associated description of carcasses

Category (Numeric)	Category (Alpha)	Description of Carcass Condition
1	L	Live, still kicking
2	F	Fresh, both eyes clear, gills bright red
3	D-	Slightly decayed, eyes cloudy, firm flesh
4	D	Decayed, eyes cloudy, soft flesh
5	D+	More decayed, eyes cloudy, very soft flesh
6	S	Skeleton, loosing flesh

Spatial and Temporal Distribution

In addition to carcass surveys, counts of live fish and redds will also be conducted to determine the spatial and temporal distribution of adult Chinook and chum. Based on historical information, counts will coincide with the presumed peak spawn time period for both tule and bright fall-run Chinook. Specifically, up to three counts will be conducted for tules in October (generally the second, third, and fourth weeks of October) and up to three counts will be conducted for brights in late November to early December (generally third and fourth weeks of November and first week of December). Live surveys will also be conducted weekly or biweekly in September and early October to correspond with the peak spawn period for spring Chinook. Counts will be performed by surveyors in a boat. One to two boats will be used per survey. Live fish will be enumerated by section while redds will be delineated at a finer spatial resolution using counters and a handheld GPS. Redds will be assigned to a species (e.g., Chinook versus coho) based on the species of fish that is seen either on or around the redd. If a live fish is not seen on a redd, the redd is assigned to the most likely species based on the spawning habitat, size of redd, and previous knowledge of spawning distribution within the Lewis River.

Juvenile Fall Chinook Abundance

Abundance of juvenile fall-run bright Chinook salmon will be estimated using CWT recoveries combined with recovered adult carcasses from carcass surveys (see above) and juvenile tagging surveys. Peak emergences of juvenile Chinook in the Lewis River below Merwin Dam generally occur from late March through mid-April. By the end of May, flows below Merwin Dam are typically stable (averaging less than 4,000 cubic feet per second), and the abundance of 50-mm juvenile fall Chinook is beginning to peak. Therefore, juvenile tagging operations will typically begin in the last week of May and continue through June. Juveniles will be sampled and subsequently tagged with CWTs and adipose-clipped. Historically, juveniles tagged in late May and June are recovered as adults 2 to 6 years later during fall Chinook carcass surveys in November through early January. Juvenile fall Chinook abundance for each BY is back-calculated using CWT tag rates by scale age of carcasses collected during the adult fall Chinook sampling period. The goal of the Lewis River Juvenile Fall Chinook Tagging Project is to tag 100,000 wild fall Chinook juveniles each year.

On each survey day, a single jet sled and a two- to three-person crew is used to capture juvenile Chinook. Seining activities typically begin around 5:00 AM and are conducted using a 4.5-foot (height) by 30-foot (length) heavy delta 1/4-inch mesh stick seine. The net mesh size reduces the catch of fish less than 47 mm limiting mortality and take of fish that are not of taggable size. Survey end times vary depending on catch rates and total catch. Captured fish are transferred into 5-gallon plastic buckets before being transferred into one of three plastic 50-gallon garbage cans partially filled with river water on the boat. Each 50-gallon can will hold approximately 1,000 juveniles. The fish in the cans are monitored for stress and the water is changed frequently. Loading density in each can is limited by air and water temperature as well as the size of the fish. Once the holding cans are at capacity, the juveniles are transported to the WDFW tagging trailer located at the Lewis River Hatchery to be processed. There, all captured fish are identified to species. A subsample is measured for fork length. Chinook juveniles that are at least 47 mm in length will then be adipose-fin clipped and tagged with a CWT. After processing, all fish are returned to the river except for small control groups which are held for tag loss estimates. Although these fish are NOR, they are adipose fin-clipped to denote that they have a CWT. This is necessary because in some fisheries and tributary carcass surveys, only adipose-clipped Chinook are scanned for CWTs. The long-term mortality estimate was calculated from the number of observed of CWT Chinook with fungus tail (tail rot) observed divided by the total CWT recaptures handled.

Seining activities at most sites are limited to once every 10 days. Available seining sites are based on weather, water conditions (e.g., height, flow), and timing. The daily total catch and the number of sets made (effort) are summarized by site (No. 1 to 80) and date. A few large single set catches are recorded individually. Methods of seining (stick and beach seines), processing (tagging (47 mm minimum criteria), quality control, and biological data collection (fork lengths and species composition) were performed as previously described by Norman (1985) and Hawkins (1996).

Data Management

Adult Abundance and Composition

Field data are recorded on a combination of scale cards and a white board. Individual carcasses that are bio-sampled and/or carcass tagged have their corresponding data (tag number, fork length, carcass condition, CWT sampling number, scales, and recovery section i.e., 1 to 5) recorded on the front of a scale card. Each column represents one carcass and each card holds approximately 19 samples. Details regarding survey date, section number, sample rate, and the number of carcasses sampled are recorded on the back of the scale card. Tag numbers from carcass recoveries and the number of non-taggable (“mark sample only”) carcasses are recorded on a white board. Specific details on field data recording methods and terminology can be found in the WDFW's "Stream Survey Manual" (WDFW, 2018). At the end of each survey day, the number of non-taggable carcasses are tallied and recorded by section in the "plus count" field on the back of a corresponding scale card. Field data are entered into WDFW's Traps, Weirs, and Surveys Access database as well as a separate Excel spreadsheet throughout the survey season. Entered data are provided QA/QC at the end of the season and any errors or missing information are corrected. Fish scales and CWT samples/recoveries are processed by WDFW laboratories in Olympia. Specific details how scales and CWTs are processed can be found in Rawding et al. (2014: page 12).

Spatial and Temporal Distribution

The adult fall Chinook carcass survey area is divided into five river sections: sections 1 to 4 extend from Merwin Dam (RM 19.1) to Lewis River Hatchery (RM 15.7) and section 5 extends from below Lewis River Hatchery to below Eagle Island (RM 10). Live, dead, and redd count data and the associated GPS data point names are electronically recorded using iPads. Following each survey, live, dead, and redd count data are entered into an Excel spreadsheet and subsequently uploaded into WDFW's Spawning Ground Survey database. GPS data are downloaded and entered into GIS.

Juvenile Fall Chinook

Juvenile collection data are recorded in field note books by date and capture location. These counts are approximations based on visual assessment. Fish are transported to the Lewis River Hatchery CWT tagging trailer and the tagging crew then sorts and enumerates fish by species. A subsample of tagged and untagged Chinook are measured prior to release of all fish. Tagging data are entered into the Regional Mark Information System (RMIS) database that is maintained by Pacific States Marine Fisheries Commission. Specifically, the RMIS database records by tag code the number of tagged juveniles released by release date, adipose fin clip status, and potential of tag loss.

Analysis Methods

Fall Chinook Abundance and Composition

The abundance and composition of fall-run Chinook spawners (i.e., escapement) is estimated using an "open" population JS model (Seber, 1982, Pollock et al., 1990). Specifically, it is a "super population" JS model that was developed by Schwarz et al., (1993) specifically for estimating salmon spawning escapement using mark-capture methods and was built upon previous work by Crosbie and Manly (1985) and Sykes & Botsford (1986). The super population model has been successfully implemented to estimate spawner escapement for other salmon populations within the LCR (Rawding et al., 2014) and other Washington state watersheds (Ashcraft et al., 2017).

A comprehensive description of the super population JS model, including summary statistics, fundamental parameters, derived parameters, and likelihoods is provided in Rawding et al., (2014). Briefly, total spawner escapement is estimated as the sum of "newly arrived" carcasses (i.e., gross births – B*) that enter the study system over the entire survey period. This estimate of new carcasses includes both the number of carcasses that were present (i.e., available to sample) during each sampling period as well as the number of carcasses that arrived after a particular sampling period but were lost/removed (e.g., washed out) before the subsequent sample period. A conceptual diagram of the JS model and its main components is shown in Figure D11.

Prior to running the JS model, fall Chinook carcass data are queried from the Traps, Weirs, and Surveys Access database for each individual survey year and ran through a series of summarizations and tests implemented through the program R (R Development Core Team, 2011). First, carcass data are run through a standardized set of decision rules that classify the stock (tule, bright), origin (hatchery, wild), sex (jack, female, male), and age of each individual carcasses based on their sampled biological data. These biological data are then summarized by sample period (i.e., week) and these summaries are subsequently used in the model to apportion the abundance estimates into reporting groups (see below). Second, recapture probabilities are evaluated by sex and size using logistic regression (Link and Barker, 2006). The results from these tests influence how carcass data are stratified (i.e., grouped; see below). Third, capture histories are generated for each individual carcass and then JS summary statistics (e.g., ni, mi, ui, Ri) are generated by week/period using the RMark package (Laake, 2013). Only tagged individuals or carcasses with a Carcass Category of 3 or 4 are used in the analysis. When necessary, weekly summary statistic carcass data are "partially" pooled to satisfy the JS modeling requirement for the number of marks and recaptures in individual periods. Fourth, four potential abundance models are evaluated for fit of using Bayesian Goodness of Fit (GOF) tests (Gelman et al., 1996).

The four models that are evaluated include a combination of static (s) or time varying (t) probability of capture (p), survival (ϕ), and entry (b*) among survey periods/weeks (i.e., ttt, stt, tst, sst). Capture probability is the odds of sampling a carcass that was present, survival probability is the odds that a carcass that was present in a sample period will remain in the study system until the next sample event, and entry probability is the odds that a carcass will enter/arrive into the study system in a particular period.

Based on the results of the logistic regression and GOF tests within and among years, we have chosen to standardize the overall JS modeling approach. Based on previous year's data and results, the logistic regression tests generally concluded that jacks (males less than 60 cm), females, and males (greater than or equal to 60 cm) had statistically different recapture rates among years. This result corroborates previous literature based on size and behavioral difference between these three groups. The GOF tests concluded that while simpler models (tst, stt, sst) sometimes provided adequate model fits for a carcass group (jacks, females, males) within a year, the completely time-varying (ttt) model always provided an adequate fit for all groups among all years. Therefore, abundance is estimated for the three carcass groups separately, but within the same model, using the time-varying (ttt) model JS model among all years.

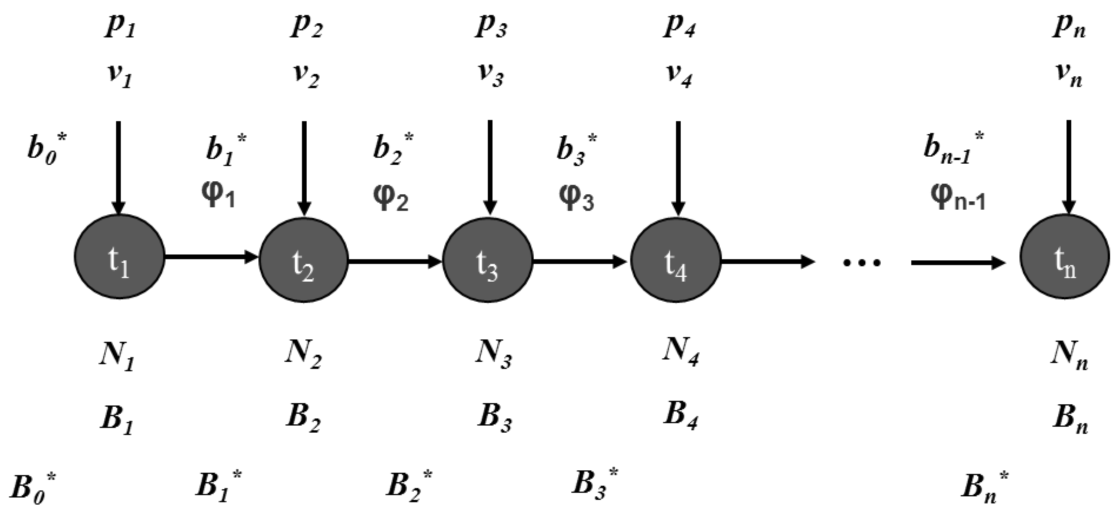


Figure D11. Conceptual diagram of "super population" Jolly-Seber abundance model

Note: Model developed by Schwarz et al. (1993) – diagram adapted from Schwarz and Arnason (2006)

Fundamental parameters of the model include: sample period i (ti), probability of capture at sample period i (pi), probability that a carcass captured at time i will be release, opposite of a loss-on-capture (vi), probability that a carcass enters the population between sample periods i and i+1, which is referred to as probability of entry (bi*), probability of a carcass surviving and remaining in the population between sample periods i and i+1 (ϕi). Derived parameters of the model include: population size at sample period i (Ni), number of fish that enter after sample period i and survive to sample period i +1 (Bi), and number of fish that enter between sampling period i-1 and i, these are referred to as gross births (Bi*). Total abundance is calculated as the sum of B* over all sample periods.

After abundance estimates are generated, weekly B* estimates are apportioned using summarized biological data by race (tule, bright), origin (wild, hatchery), sex (jack, female, male), and age. Specifically, abundance is estimated by race and origin using the weekly ratio of CWT recoveries and adipose-fin status (clipped, unclipped), respectively, and a binomial distribution. The same race and origin biological data set is used for all three groups scaled to the appropriate number of periods per group. Abundance estimates by sex are already calculated based on our three groupings. However, male carcasses need to be adjusted based on age data as field calls of jacks and adult males were "approximations" based on size. Abundance estimates are apportioned by age using a multinomial distribution. Age data are separated by group due to expected difference in age-distribution among the three groups. For each estimate, a vague "Haldine" beta distribution prior is used. Weekly estimates are summed across all sample periods to derive a total estimate of abundance and proportion by group.

The JS model is parameterized using a Bayesian framework. Here, parameters are estimated from the posterior distribution, which is calculated as the product of the prior distribution and the probability of the data given the model or likelihood (Gelman et al., 2013). Samples from the posterior distribution are obtained using Markov chain Monte Carlo simulations (Gilks, 2005) in WinBUGS (Lunn et al., 2000) using the R2WinBUGS package (Sturtz et al., 2005). WinBUGS implements Markov chain Monte Carlo simulations using a Metropolis within Gibbs sampling algorithm (Spiegelhalter et al., 2003). Two chains are run with the Gibbs sampler with an appropriate number of iterations and burn-in period so that the number of independent samples, as measured by effective sample size, is at least 4,000 for each parameter of interest. An effective sample size of 4,000 provides a 95% credible interval that has posterior probabilities between 0.94 and 0.96 (Lunn et al., 2012). A vague "Bayes-LaPlace" uniform prior is used for the JS abundance calculations. Initial values for each chain are automatically generated within the WinBUGS package. The sensitivity of the priors is evaluated based on the overlap between the prior and the posterior distribution (Gimenez et al., 2009). Model convergence is based on visual assessment of traceplots for chain mixing and evaluation of the Brook-Gelman-Rubin statistic (Su et al., 2001). Based on these steps, the reported posterior distributions are assumed accurate and that they represent the underlying stationary distributions of the estimated parameters.

Spring Chinook and Chum Abundance and Composition

In recent years, the numbers of spring Chinook and chum salmon returning to the Lewis River have been extremely low. During spawning ground surveys, there is typically only a handful to several dozen carcasses recovered each year. As a result, estimates of abundance through carcass recovery is challenging due to poor sample sizes. Alternative estimation methods (e.g., live/dead/redds counts) are largely ineffective due to both the overall low numbers of chum and spring Chinook seen each year, but also difficulty in getting accurate counts. While it is relatively easy to identify the species of a fish from a recovered carcass, it is difficult to get accurate assignment of species from visual counts of live fish and redds (Hawkins, 2018b). For instance, spring and fall Chinook overlap in spawn timing and it is challenging to separate the (potentially) relatively few spring Chinook from the thousands of fall Chinook that are often seen in large schools on the spawning ground.

Therefore, estimates of chum abundance and spring Chinook will be based on carcass recoveries and should be viewed as minimum estimate. Over the past several decades, WDFW has generated an estimate of spring Chinook abundance using the raw number of carcass recoveries and a recovery rate of ~50%, which is based on limited data from recoveries of spring Chinook and recoveries from fall Chinook during the same time period.

Spatial and Temporal Distribution

The third specific sub-objective of objective 16 is to "evaluate the spatial and temporal distribution of fall Chinook and chum spawning downstream of Merwin Dam with the ability to detect a change in distribution of ± 15% with 80% certainty." Put another way, to describe the spatial and temporal distribution (i.e., shape) of Chinook and chum abundance with a specified level of (un)certainty to detect change, if there is a change to detect. The current wording of this objective is very specific with regards to the amount of detectable change (i.e., the effect size) and the ability to detect a change (i.e., statistical power), but it does not include the specific metric for distribution. Distributions of data can be described many different ways. In general, distributions are typically described either by their central tendency (e.g., mean, median, mode) or variability (e.g., range, standard deviation, interquartile range). Unlike abundance, which typically has its distribution reported as either a mean or median, a "standard" metric is not used to describe the spatial and temporal distribution for salmon and steelhead.

For now, the spatial and temporal distribution of Chinook and chum abundance will be described using these same "standard" metrics (e.g., median and standard deviation) as are used for abundance. Specifically, the temporal distribution of spawner abundance will be described by calculating the median spawn date using weekly derived estimates of abundance (i.e., B*) from the JS model by race (tule, bright) and origin (hatchery, wild). Additionally, a cumulative distribution plot of abundance will be generated to depict the temporal distribution of spawning. The spatial distribution of abundance will be described through the use of redd counts. Redds will be enumerated by section and reported in table format. Tables will be formatted to provide a temporal count by section and estimate of redds per mile. Additionally, maps will be generated depicting counts of individual redds (via GPS data). Moving forward, thought should be put into what metrics of spatial and temporal distribution will be the most biologically meaningful with regards to conservation and recovery of populations within the Lewis River.

Juvenile Fall Chinook Abundance

Abundance of Lewis River juvenile fall Chinook will be estimated using a mark-recapture study design (Figure D12).

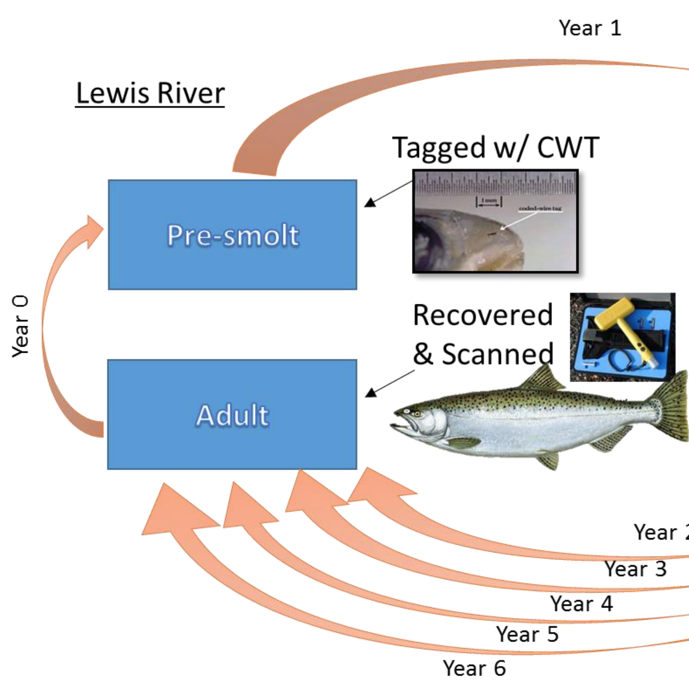


Figure D12. Conceptual diagram of mark-recapture approach used to estimate abundance of juvenile (pre-smolt) fall Chinook in the Lewis River

Specifically, juvenile abundance is based on the number of juveniles CWT tagged as "pre-smolts" prior to emigration and the total number of returning adults sampled as carcasses, and ultimately recovered with a CWT, on the spawning grounds 2 to 6 years later. Based on past data, the juveniles sampled and tagged appear to primarily represent wild, late fall-run (i.e., bright) Chinook as the majority of CWTs are recovered (as adults) in early November through mid-December. Therefore, only late-run adult Chinook data will be used for this analysis and thus the estimates of juvenile abundance will only be for the late-run Chinook component.

Abundance will be estimated by BY using a back-calculation approach and the Petersen estimator with a Chapman modification (Seber, 1973):

$$\widehat{N}_i = \frac{(n_1 + 1)(n_2 + 1)}{(m_2 + 1)} - 1$$

where:

- $\hat{N}$ = Estimated pre-smolt abundance for BY *i*
- n_1 = Number of pre-smolts tagged and released in a single BY *i*
- n_2 = Number of bright adults sampled (i.e., scanned) for CWTs across all return years for a single BY (sample period ~Nov. 8th to Dec. 15th)
- m_2 = Number of adults recovered with a CWT across all return years for a single BY (sample period ~Nov. 8th to Dec. 15th)

Variance of the abundance will be estimated using:

$$V(\widehat{N_i}) = \frac{(n_1 + 1)(n_2 + 1)(n_2 - m_2)(n_1 - m_2)}{(m_2 + 1)^2(m_2 + 2)} - 1$$

CV of the abundance will be estimated using:

$$CV(\widehat{N_i}) = \frac{\sqrt{V(\widehat{N_i})}}{\widehat{N}_i}$$

For example, in BY 2007, 54,714 juvenile fall-run bright Chinook were CWT tagged (n_1). In years, 2009 to 2013, carcasses were recovered on the spawning ground, sampled for CWTs, and assigned back to a BY based on scale age reads (Table D7). In total, 6,752 carcasses were sampled and, of those, 74 were recaptured from BY 2007.

Table D7. Example of adult fall-run bright Chinook salmon coded wire tag recovery data used to estimate juvenile abundance in brood year 2007 using a "back-calculated" mark-recapture estimator

Return Year	Age of Adult	Scanned for CWT (n2)	Recovered with CWT (m2)
2009	2	197	1
2010	3	928	7
2011	4	3,058	22
2012	5	2,466	42
2013	6	103	2
TOTAL		6,752	74

Therefore, the estimate of fall-run bright Chinook juvenile abundance in BY 2007 can be calculated as:

$$\widehat{N}_{\iota} = \frac{(54{,}714\ + 1)(6{,}752 + 1)}{(74 + 1)} - 1$$

$$\widehat{N}_{\iota} \approx 4.9\ million$$

With a CV equal to:

$$CV(\widehat{N_{\iota}}) = \frac{561{,}581}{4.9\ million}$$

$$CV(\widehat{N_{\iota}}) \approx 11\%$$

Assumptions

Adult Abundance and Composition

When the assumptions of a super population JS model are met, it produces unbiased estimates of escapement with known levels of precision. Within the JS model, there are specific assumptions as to how recruitment (i.e., newly arrived carcasses) is modeled, but overall there are a total of four critical assumptions for open population models that must be met to obtain unbiased estimates (Seber, 1982):

1. *Equal Catchability*: Each carcass that is present in the study system during a specific sample event, whether tagged or untagged, has the same probability of being sampled
2. *Equal Survival*: Each carcass that is present in the study system during a specific sample event, whether tagged or untagged, has the same probability of surviving (i.e., persisting) to the next sampling period.
3. *Tag Loss and Recovery*: Tagged carcasses do not lose their marks and all marks are recognized and read properly on recovery

4. *Instantaneous Sampling*: All samples are instantaneous, i.e., sampling time is negligible, and each release is made immediately after the sample.

These four assumptions will be assessed and dealt with each year using the following approach:

1. *Equal Catchability and Survival*: The first two assumptions will be evaluated using two methods. First, capture probabilities will be assessed by sex and size using logistic regression (Link and Barker, 2006). The results from these tests will influence how carcass data are stratified (i.e., grouped). Second, abundance will be estimated using four separate models with static or timing probabilities of capture, survival, and entry among sample periods. The four models will be evaluated for fit using Bayesian GOF tests (Gelman et al., 1996). Based on previous year's data, estimates will be stratified into three groupings (jacks, females, and adult males) and run using a timing variation "ttt" model (see "Analysis Methods") unless there is evidence for unequal capture probabilities within one of these groups or data limitations (i.e., small sample size).
2. *Tag Loss and Recovery*: Tag loss will be assessed through double tagging of carcasses. Correct reporting of carcasses will be maximized through the development of standardized datasheets and protocols and adequate training of field crews.
3. *Instantaneous Sampling*: In order to meet this assumption of instantaneous sampling, the survey duration will be short (1 to 2 days) relative to the duration between surveys (5 to 6 days) and surveys are conducted weekly for the entirety of the study period.

Spatial and Temporal Distribution

Estimates of temporal distribution are based on estimates of adult abundance. Therefore, the assumptions that are outlined above apply here and must be met to generate unbiased estimates of temporal distribution.

Descriptions of spatial distribution are based on peak redd count data. Therefore, one critical assumption is that the spatial distribution of adults during peak spawning is representative of the spatial distribution throughout the entire run. Additionally, redds must be identified correctly. Redd identification and counts can be difficult due to poor survey conditions, superimposition, or possible overlap in spawn timing with that of another species. These potential sources of error will be minimized by conducting redd counts on days with highest visibility, proper training of surveyors, and maximized use of experienced surveyors.

Juvenile Abundance

The "back-calculated" approach that will be used to derive estimates of abundance for juvenile (pre-smolt) late fall-run (i.e., bright) Chinook is based on four assumptions that are inherent of any Petersen mark-recapture estimator (Rawding and Rodgers, 2013):

1. *Probability of Capture*: One of the three conditions must be met – (a) All juvenile Chinook have an equal probability of being marked (i.e., CWT), (b) all adults carcasses have an equal probability of being inspected for CWTs, or (c) CWT juveniles mix completely with unmarked fish between sampling events

2. *Closure*: There is no recruitment or emigration between sample events
3. *Tagging Mortality*: There is no tag-induced mortality
4. *Tag Loss and Recovery*: Tagged juveniles do not lose their marks prior to being sampled as carcasses and all marks are recognized and read properly on recovery.

These four assumptions will be assessed and dealt with each year using the following approach:

1. *Probability of Capture*: This assumption would be violated if tagged juveniles are not representative of the overall population such that the capture or recapture probability of tagged versus untagged fish varies over time. For instance, if a portion of the juveniles are too small to be sampled and/or tagged and these individuals experience lower ocean survival then the estimate of juvenile abundance will be biased low. Violation of this assumption will be minimized by: 1) sampling and tagging juveniles across the majority of rearing fall Chinook rearing locations; 2) sampling and tagging juveniles throughout the peak of the juvenile outmigration; 3) tagging juveniles down to 47 mm, which should cover the majority of the size distribution of outmigrating fall Chinook smolts; and 4) sampling all adipose fin-clipped adults recovered on the spawning grounds throughout the spawning time period. However, due to sampling and tagging constraints, it is likely that the estimate of abundance is not representative of all fall-run juveniles. Specifically, based on existing recovery data, most CWTs are recovered from early November through mid-December while fall-run Chinook are recovered from September through February. Therefore, any wild production from tules or "late" late-run brights (non-CWT brights) that primarily spawn from mid-December through January are not represented in the juvenile abundance estimate. Additionally, the derived estimate of juvenile abundance would only represent fall-run Chinook that rear in the Lewis River at least until late-May and June. Therefore, any wild production from juveniles that migrate out of the Lewis River earlier in the spring (e.g., fry) would not be represented in the juvenile abundance estimate.
2. *Closure*: This assumption would be violated if additional recruitment occurs into a cohort or if a portion of the cohort dies. While the birth component of this assumption is likely met (i.e., tagged over entire juvenile outmigration and little to no strays of wild brights), the back-calculation approach to estimating abundance clearly violates the death component. Mortality is expected between tagging and recapture periods and should not produce a biased abundance estimate unless the mortality rate differs between marked and unmarked fish. Differential mortality is discussed under assumption three below.
3. *Tagging Mortality*: This assumption would be violated if mortality rates differed between tagged and untagged juveniles (i.e., tagging influences mortality rates). Violation of this assumption is minimized by proper training of staff who administer the CWTs. Delayed mortality will also be monitored by holding a sub-sample of tagged fish post tagging, which will allow tagging estimates to be adjusted for any post-release mortality, if necessary.
4. *Tag Loss and Recovery*: This assumption will be violated if there is tag loss and/or recovery of CWTs are not properly identified/recorded. Violation of this assumption will

be minimized by proper training of staff who administer the CWTs and surveyors sampling adults for CWTs. Tag loss in juveniles will be monitored by holding a sub-sample of tagged fish post tagging, which will allow tagging estimates to be adjusted for any post-release tag loss, if necessary. Handheld CWT detectors will be tested prior to each survey to ensure they are functioning properly.

Deliverables

Based on the outlined objectives, the following annual estimates will be generated and reported in an appendix to the Lewis River Annual Operations Report:

1. Abundance and composition (race, origin, sex, age) for adult fall Chinook downstream of Merwin Dam with estimate of uncertainty
2. Presence/minimum counts for adult chum and spring Chinook
3. Spatial and temporal distribution of Chinook and chum spawning downstream of Merwin Dam
4. Abundance of juvenile fall bright Chinook downstream for Merwin Dam with an estimate of uncertainty for BY 6 years prior to most recent return year

OBJECTIVE 17: ANNUAL REVIEW OF EXISTING AND PROPOSED HARVEST REGULATIONS (IF ANY) TO DETERMINE IF RECOMMENDATIONS ARE WARRANTED TO PROTECT SUPPLEMENTATION PROGRAM OBJECTIVES.

The H&S Subgroup, through its annual planning efforts to implement the H&S Plan, should review current rule making activity of the WDFW each year to ensure that harvest rules are consistent with the goals of the Settlement Agreement. Proposed rules are readily available on the WDFW website at http://wdfw.wa.gov/about/regulations. In addition, the H&S Subgroup may make recommendations to the WDFW and ACC that protect supplementation programs and are consistent with the Settlement Agreement goals and WDFW policies.

SECTION E. REPORTING REQUIREMENTS

Annual reporting of plan implementation and monitoring of objectives is provided each year as part of the Lewis River Annual Operations Report distributed in April of each year. At a minimum, the annual report will include the following:

1.0 ADULT COLLECTION AND SPAWNING

- Collection numbers by location and method
- Collection numbers compared to targets
- Genetic assignment results for steelhead
- Spawning protocols and numbers
- Transportation numbers by date, species, and sex ratios (actual versus goals)
- Distribution of all collected species
- Disposition of any species

2.0 EGG INCUBATION AND JUVENILE REARING/RELEASE

- Egg take – actual versus goals
- Egg to fry survival – numbers of fish ponded
- Pathogen screening results
- Rearing strategies that differ from routine operations (e.g., use of circular rearing strategies)
- Smolt releases, length, and location (actual versus goals)
- Tagging and marking summary (PIT tags and BWTs)

3.0 MONITORING AND EVALUATION

Results obtained for each objective presented in this plan. At a minimum, these results will include the following:

- Adult escapement estimates (abundance) downstream of Merwin Dam
- Adult composition (hatchery versus natural origin) on spawning grounds downstream of Merwin Dam
- Spatial and temporal distribution of spawning downstream of Merwin Dam
- Juvenile migration and residualism estimates of hatchery releases downstream of Merwin Dam
- Hatchery juvenile monitoring for ecological interactions with NOR smolts
- Summaries of screw trapping results including locations fished, time periods fished, catch rates (relative abundance) by species (composition), trapping efficiency, and estimates of juvenile abundance by species
- Distribution maps of redd locations and counts for each species
- Estimate of N_e for late winter steelhead based on genetic results, sex ratios, redd surveys, and trap and tangle netting collections

4.0 CONSISTENCY AND ADHERENCE WITH HSRG GUIDELINES

Annual reporting will provide the status and measures implemented to track the consistency of hatchery operations with recommendations of the HSRG recommendations for the Lewis River Hatchery complex.

REFERENCES

Ashcraft, S., A. Edwards, M. Zimmerman, and M. Scharpf, 2017. *Final Report – Grays Harbor Fall Chum Abundance and Distribution, 2015-2015*. Washington Department of Fish and Wildlife.

Bentley, K., D. Rawding, S. Hawkins, J. Holowatz, S. Nelsen, J. Grobelny, and T. Buehrens, 2018. Estimates of Escapement and an Evaluation of Abundance Methods for North Fork Lewis River Fall-Run Chinook Salmon, 2013 – 2017. Washington Department of Fish and Wildlife, Olympia, Washington. FPT 18-XX.

Buehrens, T. W., *In Prep*. A Multivariate State-Space Method for Estimating Coho Salmon Abundance in the Lower Columbia ESU.

Christie, M. R., M. J. Ford, and M. S. Blouin, 2014. "On the Reproductive Success of Early-Generation Hatchery Fish in the Wild." *Evolutionary Applications* 7(8): 883–896.

Christie, M., M. Marine, R. French, and M. Blouin, 2012. "Effective Size of a Wild Salmonid Population Is Greatly Reduced by Hatchery Supplementation." *Heredity* 109:254-260.

Crawford, B., and S. Rumsey, 2011. *Guidance for Monitoring Recovery of Pacific Northwest Salmon and Steelhead listed under the Federal Endangered Species Act.* NW Region: National Marine Fisheries Service.

Crosbie, S. F., and B. F. J. Manly, 1985. "Parsimonious Modelling of Capture-Mark-Recapture Studies." *Biometrics* 41(2):385-398.

Crow, J. F., and N. E. Morton, 1955. "Measurement of Gene Frequency Drift in Small Populations." *Evolution* 9(2): 202-214.

Frankham, R., C. J. A. Bradshaw, and B. W. Brook, 2014. "Genetics in Conservation Management: Revised Recommendations for the 50/500 Rules, Red List Criteria and Population Viability Analyses." *Biological Conservation* 170: 56-63.

Franklin, I. R., 1980. "Evolutionary Change in Small Populations." *Conservation Biology an Evolutionary-Ecological Perspective*. Editors M. E. Soule and B. A. Wilcox. Sunderland, Massachusetts: Sinauer; pp. 135-150.

Franklin, I. R., and R. Frankham, 1998. "How Large Must Populations Be to Retain Evolutionary Potential?" *Animal Conservation* 1(1): 69-70.

Freymond, B., and S. Foley, 1986. *Wild Steelhead Spawning Escapement Estimates from Boldt Case Rivers 1985*. Washington Department of Game, Fish Management Division, Olympia.

Fulton, T.W., 1904. "The Rate of Growth of Fishes." *22nd Annual Report of the Fishery Board of Scotland* 1904 (3):141-241.

Gallagher, S. P., P. K. J. Hahn, and D. H. Johnson, 2007. "Redd Counts." *Salmonid Field Protocols Handbook: Techniques for Assessing Status and Trends in Salmon and Trout Populations.* Editors D. H. Johnson, B. M. Shrier, J. S. O'Neal, J. A. Knutzen, X. Augerot, T. O'Neil, and T. Pearsons. Bethesda, Maryland: American Fisheries Society; pp. 197-234.

Gelman, A., J. B. Carling, H. S. Stern, D. B. Dunson, A. Vehtari, and D. Rubin, 2013. *Bayesian Data Analysis.* Third edition. CRC Press, Boca Raton, Florida: CRC Press.

Gelman, A., X. Meng, and H. Stern, 1996. "Posterior predictive assessment of model fitness via realized discrepancies." *Statistica Sinica* 6: 773-807.

Gilks, W.R., 2005. "Markov Chain Monte Carlo." *Encyclopedia of Biostatistics*. Chichester, England: John Wiley & Sons, Ltd.

Gimenez, O., B. J. T. Morgan, and S. P. Brooks, 2009. "Weak Identifiability in Models for Mark-Recapture-Recovery Data." *Modeling Demographic Processes in Marked Populations*. Editors D. L. Thomson, E. G. Cooch, and M. J. Conroy. Boston, Massachusetts: Springer-Verlag; 1055-1067.

Glaser, Bryce (Washington Department of Fish and Wildlife), 2009. Memorandum to Erik Lesko, PacifiCorp. Regarding: Steelhead genetic assignment to early winter hatchery stocks in the Lewis River. January 29, 2009.

Good, T. P., R. S. Waples, and P. Adams, editors, 2005. *Updated Status of Federally Listed ESUs of West Coast Salmon and Steelhead.* U.S. Department of Commerce, National Oceanic and Atmospheric Administration Technical Memorandum, NMFS-NWFSC-66. June 2005.

Gorbman, A., W. W. Dickhoff, J. L. Mighell, E. F. Prentice, and F. W. Waknitz, 1982. "Morphological Indices of Developmental Progress in the Parr-Smolt Coho Salmon, Oncorhynchus Kisutch." *Aquaculture* 28(1982):1-19.

Hausch, S., and M. Melnychuk, 2012. "Residualization of Hatchery Steelhead: A Meta-Analysis of Hatchery Practices." *North American Journal of Fisheries Management* 32:905-921.

Hawkins, S., 1996. *Results of Sampling the Lewis River Natural Spawning Fall Chinook Population in 1995*. Washington Department of Fish and Wildlife, Columbia River Progress Report 96-06. April 1996.

Hawkins, S., 2018a. *Lewis River Wild Fall Chinook Tagging Project, 2017.* Washington Department of Fish and Wildlife, Columbia River Progress Report.

Hawkins, Shane (Washington Department of Fish and Wildlife), 2018b. Personal communication with Kale Bentley (Washington Department of Fish and Wildlife). March 2018.

Hedrick, P. W., D. Hedgecock, and S. Hamelberg, 1995. "Effective Population Size in Winter-Run Chinook Salmon." *Conservation Biology* 9(3): 615-624.

Hill, W.G., 1981. "Estimation of Effective Population Size from Data on Linkage Disequilibrium." *Genetical Research* 38(3): 209-216.

HSRG (Hatchery Scientific Review Group), 2014. *On the Science of Hatcheries: An Updated Perspective on the Role of Hatcheries in Salmon and Steelhead Management in the Pacific Northwest.* Hatchery Scientific Review Group.

Johnson, O. W., W. S. Grant, R. G. Kope, K. Neely, F. W. Waknitz, and R. S. Waples, 1997. *Status Review of Chum Salmon from Washington, Oregon, and California.* U.S. Department of Commerce, National Oceanic and Atmospheric Administration Technical Memorandum, NMFS-NWFSC-32. December 1997.

Kéry, M., and M. Schaub, editors, 2012. *Bayesian Population Analysis Using WinBUGS A Hierarchical Perspective*. Cambridge, Massachusetts: Academic Press.

Kimura, M., and J. F. Crow, 1963. "The Measurement of Effective Population Number." *Evolution* 17(3): 279-288.

Kinsel, C., P. Hanratty, M. Zimmerman, B. Glaser, S. Gray, T. Hillson, ... and S. VanderPloeg, 2009. *Intensively Monitored Watersheds: 2008 Fish Population Studies in the Hood Canal and Lower Columbia Stream Complexes.* Washington Department of Fish and Wildlife, Olympia.

Laake, J. L., 2013. *RMark: An R Interface for Analysis of Capture-Recapture Data with MARK*. AFSC Processed Rep 2013-01, Alaska Fisheries Science Center, NOAA, March 2013.

LCFRB (Lower Columbia Fish Recovery Board), 2010. *Lower Columbia Salmon Recovery and Fish and Wildlife Subbasin Plan.*

Lebreton, J., J. B. Nichols, R. J. Barker, R. Pradel, and J. A. Spendelow, 2009. "Modeling Individual Animal Histories with Multistate Capture-Recapture Models." *Advances in Ecological Research* 41: 87-173.

Lebreton, J., and R. Pradel, 2002. "Multistate Recapture Models: Modelling Incomplete Individual Histories." *Journal of Applied Statistics* 29(1-4)353-369.

Link, W. A., and R. J. Barker, 2006. "Model Weights and the Foundation of Multi-Model Inference." *Ecology* 87: 2626-2635.

Lunn, D. J., A. Thomas, N. Best, and D. Spiegelhalter, 2000. "Winbugs — A Bayesian Modelling Framework: Concepts, Structure, and Extensibility." *Statistics and Computing* 10: 325-337.

Lunn, D., C. Jackson, N. Best, A. Thomas, and D. Spiegelhalter, 2012. *The BUGS Book: A Practical Introduction to Bayesian Analysis*. Boca Raton, Florida: CRC Press.

McElhany, P., M. H. Ruckelshaus, M. J. Ford, T. C. Wainwright, and E. P. Bjorkstedt, 2000. *Viable Salmonid Populations and the Recovery of Evolutionarily Significant Units*. U.S. Department of Commerce, National Oceanic and Atmospheric Administration Technical Memorandum. NMFS-NWFSC-42. June 2000.

McIssac, D., 1977. *Total Spawner Population Estimate for the North Fork Lewis River Based on Carcass Tagging, 1976*. Columbia River Laboratory Progress Report, Washington Department of Fisheries. Report No. 77-01.

Myers, J., C. Busack, D. Rawding, A. Marshall, D. Teel, D. M. Van Doornik, and M. T. Maher, 2006. *Historical Population Structure of Pacific Salmonids in the Willamette River and Lower Columbia River Basins.* U.S. Department of Commerce, National Oceanic and Atmospheric Administration Technical Memorandum, NMFS-NWFSC-73.

Nei, M., and F. Tajima, 1981. "Genetic Drift and Estimation of Effective Population Size." *Genetics* 98: 625-640.

NMFS (National Marine Fisheries Service), 2013. *ESA Recovery Plan for Lower Columbia Chinook, Lower Columbia Coho, Columbia River Chum and Lower Columbia Steelhead.* National Marine Fisheries Service, Northwest Region.

NMFS, 2016. *2016 5-Year Review: Summary and Evaluation of Lower Columbia River Chinook Salmon, Columbia River Chum Salmon, Lower Columbia River Coho Salmon, Lower Columbia River Steelhead.* NMFS West Coast Region. May 2016.

Norman, G., 1985. *North Fork of the Lewis River Fall Chinook Natural Spawning Escapement 1984.* Washington Department of Fisheries.

PacifiCorp and Cowlitz County PUD, 2004. Settlement Agreement for the Relicensing of the Lewis River Hydroelectric Projects, FERC Project Nos. 935, 2071, 2111, 2213. Cowlitz, Clark and Skamania Counties, Washington. November 2004.

PacifiCorp and Cowlitz County PUD, 2010. Aquatic Monitoring and Evaluation Plan for the Lewis River. Portland, Oregon.

PacifiCorp and Cowlitz County PUD, 2014. Lewis River Hatchery and Supplementation Plan (FERC Project Nos. 935, 2071, 2111, 2213). Version 2.0. Portland, Oregon. December 2014.

Piper, R. G., I. B. McElwain, L. E. Orme, J. P. McCraren, L. G. Fowler, and J. R. Leonard, 1982. *Fish Hatchery Management*. U.S. Department of the Interior, U.S. Fish and Wildlife Service, Washington, DC. 1982.

Pollock, K. H., J. D. Nichols, C. Brownie, and J. E. Hines, 1990. Statistical Inference for Capture-Recapture Experiments. *Wildlife Monographs* 107: 1-97.

R Development Core Team, 2011. R: A Language and Environment for Statistical Computing. The R Foundation for Statistical Computing. Vienna, Austria.

Rannala, B., and J. Mountain, 1997. "Detecting Immigration by Using Multilocus Genotypes." *Proceedings of the National Academy of Sciences of the United States of America* 94(17): 9197-9201.

Rawding, D., and J. Rodgers, 2013. *Evaluation of the Alignment of Lower Columbia River Salmon and Steelhead Monitoring Program with Management Decisions, Questions, and Objectives.* Pacific Northwest Aquatic Monitoring Partnership (PNAMP).

Rawding, D., B. Glaser, and T. Buehrens, 2014. *Lower Columbia River Fisheries and Escapement Evaluation in Southwest Washington, 2010.* Washington Department of Fish and Wildlife, FPT 14-10.

Roberts, Aaron, (WDFW), 2013. Personal communication with Erik Lesko (PacifiCorp).

Royle, J. A., and R. M. Dorazio, editors, 2008. *Hierarchical Modeling and Inference in Ecology.* San Diego, California: Academic Press.

Ryman, N., and L. Laikre, 1991. "Effects of Supportive Breeding on the Genetically Effective Population Size." *Conservation Biology* 5(3): 325-329.

Schwarz, C. J., and A. N. Arnason, 2006. "Jolly-Seber Models in MARK." *Program MARK: A Gentle Introduction.* Fifth edition. Editors E. Cooch and G. White. Available at: http://www.phidot.org/software/mark/docs/book.

Schwarz, C.J., R. E. Bailey, J. R. Irvine, and F. C. Dalziel, 1993. "Estimating Salmon Spawning Escapement Using Capture–Recapture Methods." *Canadian Journal of Fisheries and Aquatic Sciences* 50(6): 1181-1197.

Seber, G. A. F., 1973. *The Estimation of Animal Abundance.* London, England: Charles Griffin and Company Limited.

Seber, G. A. F., 1982. *The Estimation of Animal Abundance and Related Parameters*. London, England: Charles Griffin and Company Limited.

Spiegelhalter, D., A. Thomas, N. Best, and D. Lunn, 2003. *WinBUGS User Manual*. Version 1.4. MCR Biostatistics Unit, Institute of Public Health and Epidemiology and Public Health. Imperial College of Medicine, United Kingdom.

Stephenson, J. J., M. R. Campbell, J. Hess, C. Kozfkay, A. Matala, M. McPhee, P. Moran, S. Narum, M. Paquin, O. Schlei, M. Small, D. van Doornik, and J. Wenburg, 2008. "A Centralized Model for Creating Shared, Standardized, Microsatellite Data That Simplifies Inter-Laboratory Collaboration." *Conservation Genetics* 10:1145.

Sturtz, S., U. Ligges, and A. Gelman, 2005. "R2WinBUGS: A Package for Running WinBUGS from R." *Journal of Statistical Software* 12(3): 1-16.

Su, Z., M. D. Adkison, and B. W. Van Alen, 2001. "A Hierarchical Bayesian Model for Estimating Historical Salmon Escapement and Escapement Timing." *Canadian Journal of Fisheries and Aquatic Sciences* 58(8): 1648-1662.

Sykes, S., and L. Botsford, 1986. "Chinook Salmon, Oncorhynchus Tshawytscha, Spawning Escapement Based on Multiple Mark-Recapture of Carcasses." *Fishery Bulletin* 84: 261-270.

Thedinga, J., M. Murphy, S. Johnson, J. Lorenz, and K. Koski, 1994. "Determination of Salmonid Smolt Yield with Rotary-Screw Traps in the Situk River, Alaska, to Predict Effects of Glacial Flooding." *North American Journal of Fisheries Management* 14: 837-851.

Volkhardt, G. S., 2007. "Rotary Screw Traps and Inclined Plane Traps." *Salmonid Field Protocols Handbook: Techniques for Assessing Status and Trends in Salmon and Trout Populations*. Bethesda, Maryland: American Fisheries Society; 235-266.

Wang, J., 2005. "Estimation of Effective Population Sizes from Data on Genetic Markers." *Philosophical Transactions of the Royal Society B Biological Sciences* 360(1459): 1395-1409.

Wang, J., 2009. "A New Method for Estimating Effective Population Sizes from a Single Sample of Multilocus Genotypes." *Molecular Ecology* 18: 2148-2164.

Waples, R. S., 1989. "A Generalized Approach for Estimating Effective Population Size from Temporal Changes in Allele Frequency." *Genetics* 121: 379-391.

Waples, R. S., 2006. "A Bias Correction for Estimates of Effective Population Size Based on Linkage Disequilibrium at Unlinked Gene Loci." *Conservation Genetics* (7): 167-184.

WDFW (Washington Department of Fish and Wildlife), 2006*. The Salmonid Disease Control Policy of the Fisheries Co-Managers of Washington State.* July 2006.

WDFW, 2017a. *2017 Stream Survey Manual.* Washington Department of Fish and Wildlife, Region 5, ESA Anadromous Fish Investigations Unit.

WDFW, 2017b. *2017 Coho Protocols.* Washington Department of Fish and Wildlife.

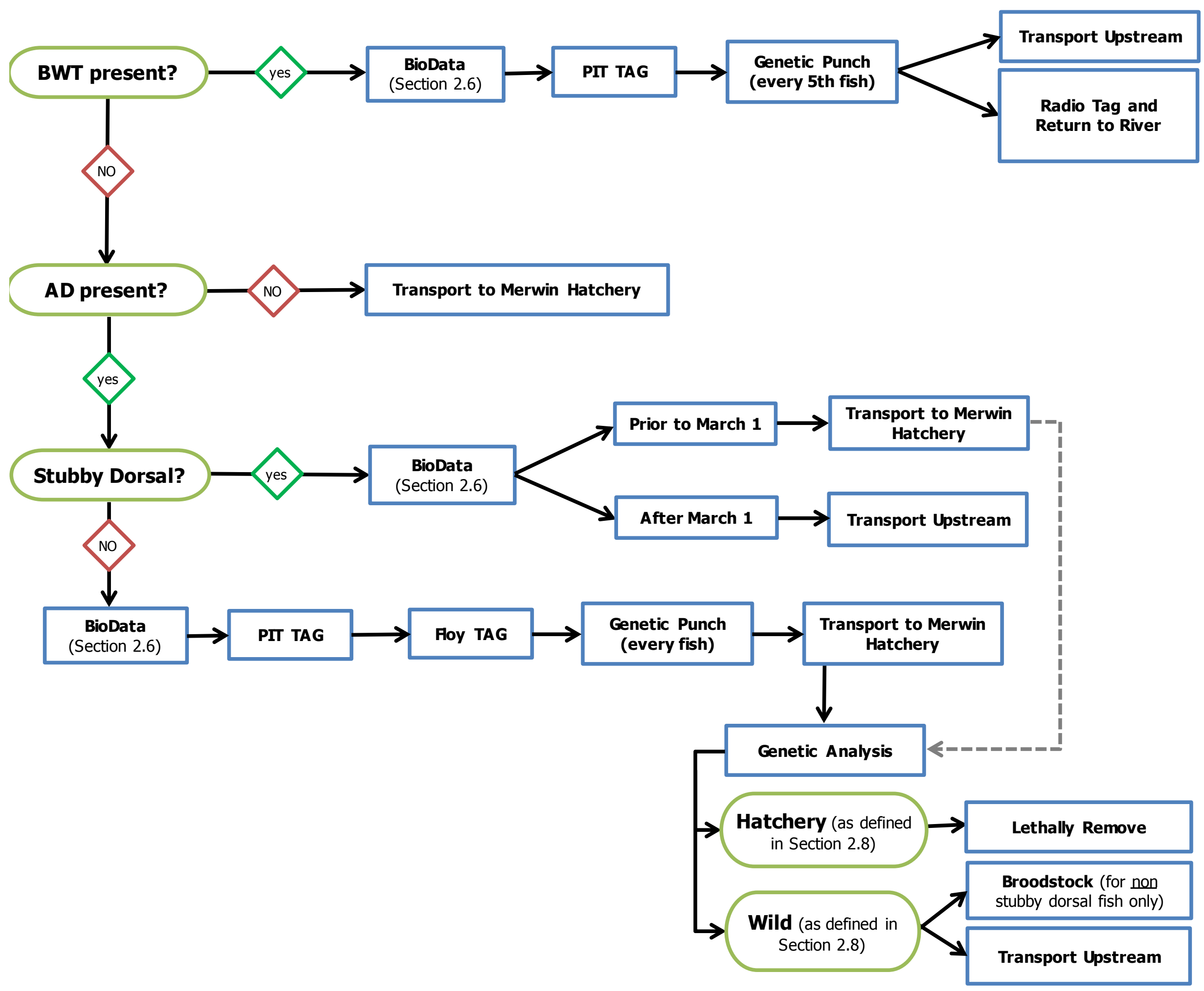
WDFW, 2018. *2018 Stream Survey Manual.* Washington Department of Fish and Wildlife, Region 5, ESA Anadromous Fish Investigations Unit.

WDFW and PacifiCorp, 2014. *Draft Hatchery and Genetic Management Plan (HGMP).* Lewis Subbasin/Lower Columbia Province. July 2014

Winans, Gary (National Oceanic and Atmospheric Administration Northwest Fisheries Science Center), 2015. Personal communication with Erik Lesko (PacifiCorp). January 2015.

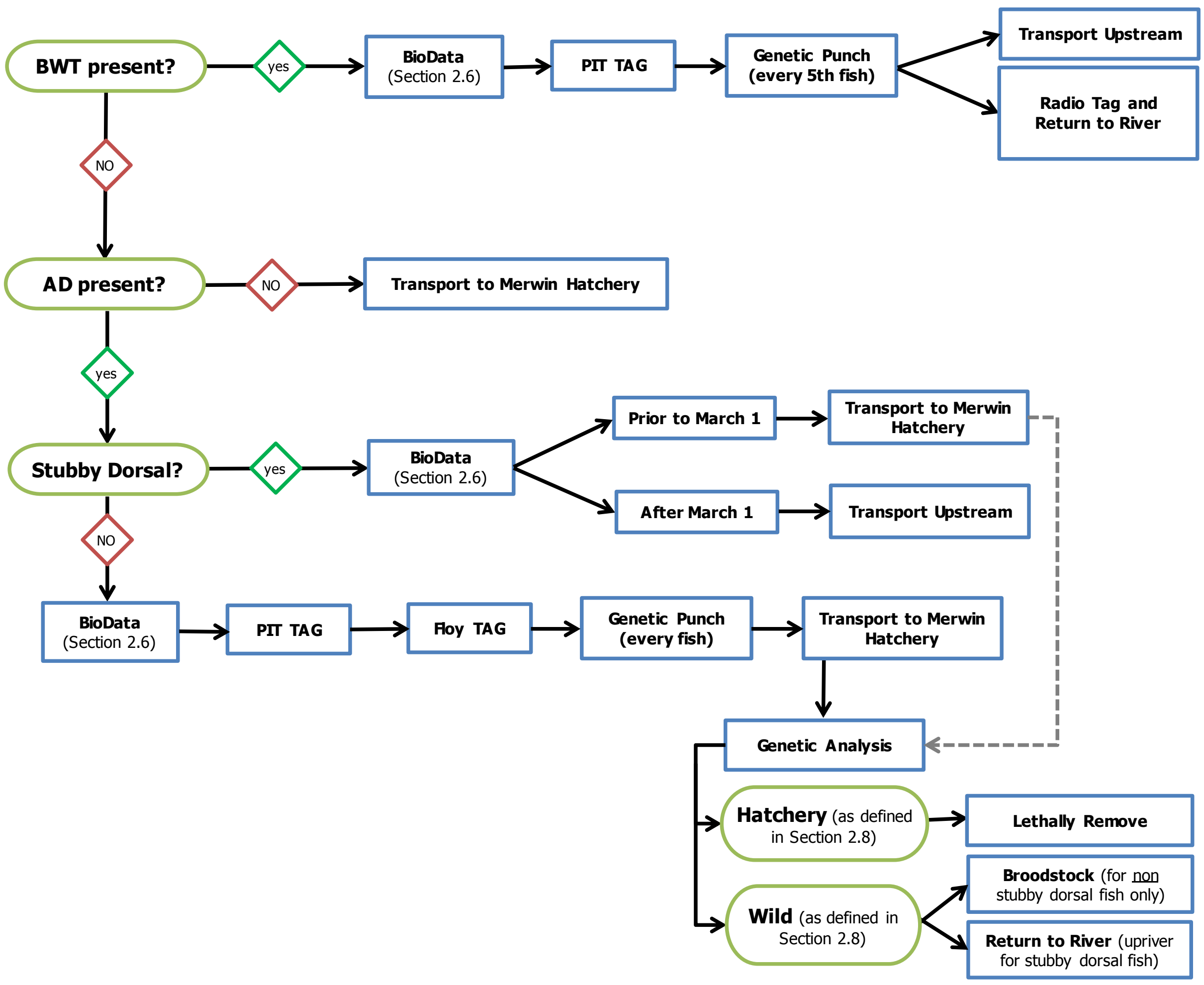
Zuur, A., E. Leno, N. Walker, A. Saveliev, and G. Smith, 2009. *Mixed Effects Models and Extensions in Ecology with R.* New York: Springer.

APPENDIX A: Handling and Sampling Protocol for Steelhead Captured in the Merwin Collection Facility



(Note: All Kelts released back to the river regardless of origin.)

APPENDIX B: Handling and Sampling Protocol for Steelhead Captured During In-River Netting



(Note: All kelts released back to the river regardless of origin.)

APPENDIX C: Summary of Section D Monitoring Objectives, Frequency, Timing, and Study Area

No.	Objective	Frequency	Timing	Study Area
1	Evaluate the effects of hatchery plants on reintroduced species.	Placeholder. Moved to Aquatic Monitoring and Evaluation Plan		
2	Determine proportion of hatchery origin winter steelhead, spring Chinook salmon, and coho salmon on spawning grounds downstream of Merwin Dam and evaluate precision of proportion of hatchery origin spawner estimates and ability to determine the trend toward Hatchery and Genetic Management Plan targets over time.	Once per week	Steelhead: Mar 1 – May 31 Chinook and Coho: Sep 1 – Jan 31	Merwin Dam (river mile 19.4) to the downstream end of Eagle Island (river mile 10)
3	Develop and monitor hatchery protocols to reduce hatchery effects on juvenile native and Endangered Species Act-listed species present downstream of Merwin Dam.	Annually	June – Dec	Lewis River Hatchery Complex
4	Estimate juvenile release behavior or residualism after release from hatcheries downstream of Merwin Dam.	Annually	February – June	Between Colvin Creek (river mile 16) to downstream end of Eagle Island (river mile 9.4)
5	Produce an annual hatchery operations report.	Annually	April 1: Hatchery Operations Report	Lewis River Hatchery Complex
6	Monitor rearing conditions to be consistent with producing a high quality smolt that emigrates quickly with a relatively high rate of survival.	Annually	June – Dec: AOP development April 1: Hatchery Operations Report	Lewis River Hatchery Complex
7	Monitor hatchery upgrades.	Annually	April 1: Hatchery Operations Report	Lewis River Hatchery Complex
8	Adopt release strategies that are consistent with Hatchery Scientific Review Group and Hatchery and Genetic Management Plan recommendations.	Annually	June – Dec: Annual Operating Plan development April 1: Hatchery Operations Report	Lewis River Hatchery Complex

No.	Objective	Frequency	Timing	Study Area
9	Monitor production levels and program release numbers.	Annually	April 1: Hatchery Operations Report	Lewis River Hatchery Complex
10	Submit and gain Hatchery and Genetic Management Plan approval for all hatchery programs on the North Fork Lewis River.	NA	Submittal: October 2014 Approval: 2018 (anticipated)	Lewis River Hatchery Complex
11	Determine the genetic effective population size of late winter anadromous Rainbow Trout (steelhead) downstream of Merwin Dam.	Annually	2018 (including evaluation of previous years)	North Fork Lewis River
12	Develop sampling protocols for supplementation adults returning to traps or in-river capture.	Annually	June – Dec: AOP development	Merwin Collection Facility
13	Effects of upstream adult and juvenile supplementation of Endangered Species Act-listed species.	Placeholder, moved to Aquatic Monitoring and Evaluation Plan		
14	Estimate adult and juvenile abundance of winter steelhead, coho, and spring Chinook downstream of Merwin Dam.	Steelhead Adults: every 7 – 10 days Chinook Adults: 1 day per week Coho Adults: 4 days per week Juveniles: continuous	Steelhead Adults: Apr – June Chinook Adults: Aug 15 – Oct 30 Coho Adults: Oct 15 – Jan 31 Juveniles: Mar 1 – June 30	Merwin Dam (river mile 19.4) downstream to the County Bridge in Woodland Washington (river mile 5.6).
15	Determine spatial and temporal distribution of spawners downstream of Merwin Dam.	Steelhead: every 7 – 10 days Chinook: max of 3 surveys Coho: max of 6 surveys	Steelhead: Apr – June Chinook: September Coho: October and December	Merwin Dam (river mile 19.4) downstream to the County Bridge in Woodland Washington (river mile 5.6).
16	Evaluate fall Chinook and chum populations downstream of Merwin Dam.	Juveniles: 2 – 4 days per week Adults: 1 – 3 days per week	Juveniles: May – June Adults: September – Jan 31	Merwin Dam (river mile 19.4) downstream to the County Bridge in Woodland Washington (river mile 5.6).
17	Review of existing and proposed harvest regulations annually.	Annually	June – Dec: AOP development	North Fork Lewis River

APPENDIX D: Lewis Spring Chinook Salmon Rearing and Release Evaluation Plan

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INTRODUCTION

Washington Department of Fish and Wildlife (WDFW) staff met several times in late 2016 and throughout 2017 to discuss strategies to improve survival rates of Lewis River (Lewis River) Hatchery spring Chinook salmon. Potential changes to rearing strategies and release timing included changes in feed composition and growth rate to more closely mimic wild fish physiology, and release dates that more closely match timing of smoltification.

This document describes the basic framework for conducting work to evaluate the timing of different volitional release periods corresponding to different ages and stages of juvenile maturation with the overall goal of improving the performance of Lewis River Hatchery spring Chinook salmon. Future work may include the addition of treatment groups in which feeding and growth will be reduced in fall and winter in order to minimize early smolting and the propensity for precocity in fish released as yearlings.

APPROACH

Background

In the past, yearling spring Chinook salmon smolts were released volitionally beginning in February. Substantial decreases in numbers of returning adult Lewis River Hatchery spring Chinook began in the late-2000s, generating concerns about survival of juveniles leaving the hatchery. In recent years, Lewis River Hatchery and fish health staff have observed increasing mortality among juveniles beginning in summer months, along with increased incidence of disease (bacterial kidney disease and flag tail). A high mortality rate during hatchery rearing is counter-productive to the increase in hatchery production that is necessary to move toward the Hatchery and Supplementation Plan goal of releasing 1.25 million smolts annually. In addition, fish held until February may be prevented from earlier volitional migration if they smolt in the preceding summer or fall, which is counter to Hatchery Scientific Review Group recommendations on volitional release.

Smolting and emigration is typically associated with spring months in the year after emergence for spring Chinook salmon; however, spring Chinook can also exhibit plasticity in smolt timing. Spring Chinook salmon can also smolt in autumn, particularly if they have experienced high growth in the preceding summer (Beckman et al., 1998). Lewis River Hatchery personnel observe smolting behavior and characteristics (e.g., increased activity, silvering, descaling) at three distinct times during hatchery rearing: 1) in their first spring after hatching (approximately June); 2) first autumn (October); and 3) second winter (February). It is hypothesized that restricting volitional migration of fish that smolt in their first year of rearing stresses the fish, reducing their resistance to pathogens that are prevalent in the hatchery environment.

Another concern is the unknown proportion of precociously mature males in the Lewis River Hatchery Program. Males exhibiting precocious characteristics have been observed at the time of release from Lewis River Hatchery and sexually mature yearlings have been observed in September during passive integrated transponder (PIT) tagging of juveniles destined for upriver acclimation sites (WDFW, 2016). Fish held at Lewis River Hatchery through the winter for

February release may experience high growth rates, which is known to increase the likelihood that a male fish will mature the following fall (Larsen et al., 2006).

Beginning with brood year (BY) 2013, WDFW began an early release program in an attempt to minimize in-hatchery mortality. Three different release strategies were used for BY 2013 (Table 1). One group was released in October at ~12 fish per pound (fpp) after being transferred from Speelyai Hatchery to Lewis River Hatchery in May 2014. A second group was released at ~8 fpp in February after being transferred from Speelyai Hatchery to Lewis River Hatchery in May 2014; this was the strategy used in most previous years. A third group was released at 12 fpp in February after transfer from Speelyai Hatchery to Lewis River Hatchery in December 2014 and January 2015. It is notable that the water temperatures of the hatcheries differ from two nearby unimpounded tributaries; water temperatures in Canyon Creek and the Lewis River inflow to Swift Reservoir (upstream of impounded sections of the Lewis River) peak in July or August and decline sharply starting in September, compared to temperatures in the hatcheries that remain elevated until late October or November (Figure 1). It is also notable that temperatures differ considerably between Speelyai and Lewis River hatcheries; between the months of June and December, fish held at Speelyai Hatchery would experience cooler temperatures that more closely match the natural decline in the fall and early winter to which salmon are adapted compared to the Lewis River Hatchery. Fish reared in colder water temperatures at Speelyai Hatchery experience slower growth and require less feed in summer and fall, achieving a smaller size at release while still meeting bioenergetic demands of the fish. BY 2014 was intended to be split into fall and spring release groups, but roughly 38% of the fish were released in August 2015 due to a hatchery water issue, about 9% were released in February 2016, and the remainder released in October 2015. BYs 2015 and 2016 were released only in October, due to low numbers of available fish for release and concerns about excessive in-hatchery mortality rates if fish were held until February.

Table 1. Numbers released by month and size since implementing October release strategy

Brood Year	October Release	February Release	
	12 fpp	**12 fpp**	**8 fpp**
2013[a]	430,303	468,765	217,805
2014	1,127,910[b]	0	116,775
2015[c]	506,547	0	0
2016[d]	402,224	0	0

Notes:

a. Two strategies were used for the February 2015 release. One group was moved from Speelyai Hatchery to Lewis Hatchery in December and reared to 8 fpp, the second group was moved from Speelyai Hatchery to Lewis River Hatchery in June and reared to 12 fpp.

b. Includes 661,020 released on time in October 2015 and 466,890 released early on August 3, 2015, due to high water temperatures and mortality during summer 2015.

c. All fish were released in October 2016 due to low brood numbers and high mortality during summer 2016.

d. All fish were released in October 2017 due to low brood numbers.

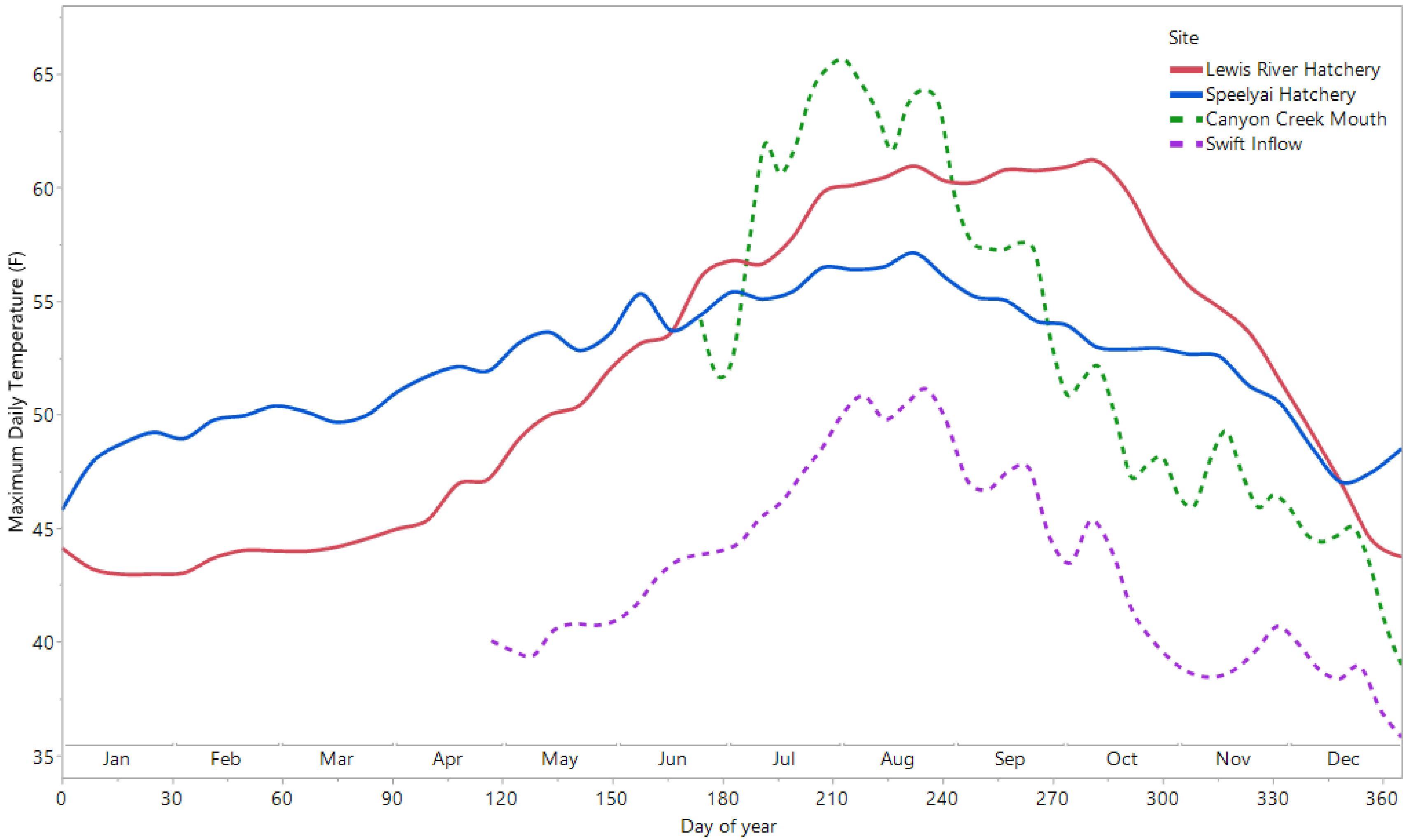

Figure 1. Maximum daily temperature at Lewis River Hatchery and Speelyai Hatchery in 2016

Notes: Canyon Creek and the Lewis River inflow at Swift Reservoir are two nearby unimpounded tributaries that represent a natural temperature profile. Data from Lewis River Hatchery (elevation 40 feet) and Speelyai Hatchery (elevation 245 feet) were collected in 2016 (WDFW, 2017). Data from Canyon Creek (elevation 300 feet) and Swift Inflow (elevation 1,000 feet) were collected in 1999 (PacifiCorp and Cowlitz PUD, 2004).

Objectives

Evaluate release strategies to optimize the number of adult returns of Lewis River Hatchery spring Chinook salmon. The results of the evaluation will be used to identify the rearing and release strategy that maximizes in-hatchery and post-hatchery survival rates for juvenile spring Chinook salmon as it relates to release date, size at release, rearing location, and age at release.

Treatment Variables

To evaluate the effects of different rearing and release strategies, the treatments described in the following sections will be used.

Feed and Growth Profiles

For the initial phase of a rearing and release evaluation, all study fish will be held at Speelyai Hatchery. During the fry rearing stage until June, all fish will be fed the same food at rates that differ among fish that have emerged at different times to produce a uniform fish size of 130 fpp by June. After June, all juvenile fish in the treatment and control groups will be fed the same low lipid diet of Bio Clark (18% fat and 47% protein), but different feed schedules by group to reach size targets of 8 or 12 fpp. The end-of-month target sizes for each release group and feeding strategies are summarized in Tables 2 and 3.

Table 2. Juvenile Chinook end-of-month target size (fpp)

Release group	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb
October release at 12 fpp. Transfer to Lewis in May at 135 fpp	475	280	180	150	120	70	40	20	12.5	12				
February release at 8 fpp. Transfer to Lewis in May at 135 fpp	475	280	180	150	120	80	58	30	20	16	12.5	10	8.5	8
February release at 8 fpp. Transfer to Lewis in Dec at 14 fpp.	475	280	180	150	135	57.6	42.0	30.0	21.5	16.8	14.5	11.0	9.0	8
February release at 12 fpp. Transfer to Lewis in Dec at 18 fpp	475	280	180	150	135	57.6	42.0	33.0	25.0	20.0	18.5	15.5	13.0	12

Note:
Blue shaded cells indicate fish being held at Speelyai Hatchery.

Table 3. Feed type and size by fish size

Feed Size	Fish Size (fpp)
MASH Bio Vita Starter	Ponding – 1,000
No. 0 Bio Vita Starter	1,000 – 570
No. 1 Bio Vita Starter	570 – 300
No. 2 Bio Vita Starter	300 – 150
1.2 mm Bio Clarks Fry	150 – 90
1.5 mm Bio Clarks Fry	90 – 60
2.0 mm Bio Clarks Fry	60 – 25
2.5 mm Bio Clarks Fry	25 – 8

Broodstock Selection

The study will use Lewis River spring Chinook salmon when the broodstock is abundant enough to support study needs. In future years, Kalama stock may be used if broodstock goals are not met with Lewis River stock, depending on the abundance and availability of both stocks. Surplus juveniles, in excess of Lewis River program production goals, will be used for a sub-yearling June release group.

Release Strategies

Five different rearing and release strategies will be employed:

1. Release yearling fish in February (of their second year) from Lewis River Hatchery at 8 fpp, reared at Speelyai Hatchery until June (of their first year) and then transferred to Lewis River Hatchery. Justification: this was the primary strategy used prior to BY 2013. A long time-series of survival data for this release strategy is available, and survival has decreased in recent years. Continuing this release group will allow for assessing relative success of other groups. A modest number of fish will be included in this group due to concerns about in-hatchery mortality.
2. Release yearling fish in February (of their second year) from Lewis River Hatchery at 12 fpp, reared at Speelyai Hatchery until December (of their first year) and then transferred to Lewis River Hatchery. Justification: this strategy was used for a group of fish from BY 2013 but has not been used since. Assumption: The advantage of rearing fish at Speelyai Hatchery through the summer and fall is that water temperatures are lower and disease is less likely to develop. Preliminary smolt-to-adult (SAR) survival of this group for BY 2013 was the highest of any release group in many years. The intention is to replicate, as closely as possible, the strategy used for this group in BY 2013. Due to space constraints at Speelyai Hatchery, there will be a modest number of fish in this group.
3. Release yearling fish in February (of their second year) from Lewis River Hatchery at 8 fpp, reared at Speelyai Hatchery until December (of their first year) and then transferred to Lewis River Hatchery. Justification: this is a new release strategy that mimics release strategy No. 2, except fish would be reared to a larger size. Assumption:

larger fish should survive better than smaller fish after release. Due to space constraints at Speelyai Hatchery, there will be a modest number of fish in this group.

4. Release yearling fish in October (of their first year) from Lewis River Hatchery at 12 fpp, reared at Speelyai Hatchery until June (of their first year) and then transferred to Lewis River Hatchery. Justification: this strategy has been used each year starting with BY 2013 (released in 2014). Assumption: releasing fish in October will avoid the increase in mortality of juveniles observed during fall months within the hatchery. This will be the largest release group because: 1) preliminary SAR survival of this group for BY 2013 was promising; and 2) there is sufficient space to hold this large group at Lewis River Hatchery.
5. Release subyearling fish in June (of their first year) at 130 fpp, reared exclusively at Speelyai Hatchery and released in the lower Lewis River. Fish will be released volitionally after June 1 when fish show signs of smoltification. Justification: this group may avoid the increase in mortality of juveniles observed during summer months within the hatchery by releasing them in early summer. Assumption: this would be a new release strategy, with a high amount of uncertainty, thus will only be used if surplus adults are available for broodstock above and beyond those needed to achieve target releases for strategies 1 through 4.

Prior to 2018, 100,000 smolts were released as part of an integrated (50% natural-origin broodstock) hatchery group that was designated for acclimation upstream of Swift Reservoir. The ACC agreed in June 2018 the BY2017 acclimation group should be marked with a ventral fin clip and released downstream of Merwin Dam due to relatively low collection rates of juvenile Chinook observed at the Swift FSC. The ACC also agreed that starting with BY2018, hatchery release groups would be produced entirely from HOR broodstock (i.e., segregated). The distribution of these fish among rearing and release groups will be described as part of the 2019 AOP.

Study Design

The study design will test release strategies described above and will include appropriate numbers of fish per experimental test group to provide statistically significant results (see Attachment A, Sample Size and Statistical Power for Detecting Changes in SAR). The release groups and treatment variables proposed for the evaluation are summarized in Table 4.

Table 4. Release groups planned to begin with brood year 2017

Release Group	Release Month	Transfer Month to Lewis River Hatchery	Rearing Environment at Speelyai Hatchery	Size (fpp)	Total Number at Ponding	Losses Pre-Marking[1]	Number Tagged	Post-Tagging Mortality Rate[2]	Expected Tag Release	Expected Total Release	Mitigation Goal
1	February	June 2018	Raceway	8	200,000	6,000	75,000	24.0%	57,000	147,440	150,000
2	February	Dec 2018	Asphalt pond	12	200,000	6,000	75,000	9.0%	68,250	176,540	175,000
3	February	Dec 2018	Raceway	8	170,000	5,100	75,000	9.0%	68,250	150,059,	150,000
4	October	June 2018	Raceway	12	950,000	28,500	75,000	10.0%	67,500	829,350	825,000
5[3]	June	NA	Raceway	80	52,000	1,560	50,440	0.6%	50,137	50,137	50,000
	TOTAL				1,572,000	47,160	350,440		311,137	1,353,526	1,350,000[4]

Notes:

[1]A pre-marking mortality rate of 3% applied to all groups

[2]Mortality rates averaged for BY 2011 through 2015 wherever release size and timing were similar. Mortality rates for potential June releases were derived from hatchery records. Mortality rates for October and February releases were derived by subtracting the RMIS release numbers from the original number tagged for each group. Mortality rate for release groups 2 and 3 was assumed to be the same as the 12 fpp release group from BY 2013

[3]Implementation of Group 5 is contingent on surplus broodstock. A minimum of 50,000 fish will be planted. Up to 250,000 may be reared and planted if sufficient broodstock are available. All fish from this release group will be adipose fin-clipped; 50,000 fish will be marked with CWT. No surplus fish were available from BY2017 to initiate a June release group in 2018.

[4] The allocation of 100,000 Chinook salmon smolts among rearing and release groups that were formerly released upstream of Swift reservoir and the maximum number of surplus or program smolts released in June will be updated in the 2019 AOP

Marking

All fish from each of the October and February release treatment groups will be marked with unique coded wire tags (CWTs) to allow for SAR to be estimated separately for each test group after adults return to the Lewis River Hatchery trap. Up to 50,000 fish from the June subyearling release group will be marked with CWTs.

If Kalama stock are used, they will be uniquely marked so they can be identified upon return and disposed of appropriately.

Disposition of Study Fish

Lewis River spring Chinook salmon adults that are identified as having originated from this release evaluation by presence of a CWT may be used in the Lewis River hatchery production program or as broodstock in the supplementation program. CWTs must be collected from lethally sampled fish to determine release group ID; therefore, any adult fish with a CWT would not be transported upstream for the adult supplementation program.

Any returning adult Kalama-stock spring Chinook salmon originating from this evaluation will not be used in Lewis River hatchery production or supplementation programs if broodstock collection goals can be met using only the Lewis River stock. Surplus Kalama-stock spring Chinook salmon will be terminated upon return to the Lewis River Hatchery facilities[9].

Study Duration

At least 3 BYs of fish will be released as part of this study, and rearing and release treatments will be repeated in each year. The strategies will be evaluated each year and changes might be made if substantial problems are discovered. Survival will be monitored for 4 years following the release of the last treatment group, until 2025.

Within Hatchery Monitoring

During hatchery rearing, test groups will be monitored to ensure fish welfare and to characterize observed growth rates, smoltification status, and precocity rates. This is done by randomly sampling 100 fish from the general population in each raceway from three locations for a total of 300 fish per raceway. If needed, fish are sedated using MS-222. Individual fork lengths and total sample group weights are recorded. These data are used to estimate growth and performance parameters listed below for each raceway. Visual cues of precocity include dark and/or bronze coloring, rounded and robust body size, milt release. About a month prior to release, the quality assurance and quality control protocol extends this process to 500 fish from each raceway. Again, individual fork lengths and total sample group weights are recorded as well as a visual confirmation of adipose clip. At the time of release, individual fish weights,

[9] The disposition of surplus adult returns originating from this evaluation may change pending further discussion among the Lewis River Hatchery and Supplementation Subgroup about incorporation of both CWT Lewis River-stock and Kalama-stock adults into supplementation and reintroduction programs.

lengths, and visual assessments of smolt development will be recorded, as described in objective 3.

Specific monitoring activities would include:

Monthly

- Size (fork length and weight)
- Condition factor (K)
- Visual assessment of smolt behavior and appearance
- Presence of milting fish

Fish health checks as needed prior to release

- Routine fish health evaluations and screens
- Pathology investigations for mortality events
- Necropsy of mortalities in late summer and autumn for evidence of mature gonads
- Screening for bacterial kidney disease prevalence among juvenile release groups conducted at time of transfer from Speelyai Hatchery to Lewis River Hatchery

At time of release

- Size (fork length and weight)
- Condition factor (K)
- Visual assessment of smolt behavior and appearance[10]
- Additional screening for bacterial kidney disease prevalence among juvenile release groups
- October: lethally sample at least 20 immature fish (~10 males) per treatment group to weigh testes to establish a baseline for early testis growth. Cull and weigh testes of any obviously precocious males.
- February: Weigh testes from at least 20 immature fish (~10 males) and 10 mature (if present) males per raceway or rearing group.[11]

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[10] If desired in the future, the intensity of smoltification or proportion of groups that are fully smolted can be more accurately assessed monthly or at the time of release by sampling a physiological marker of smolting (gill Na+,K+ ATPase), requiring the lethal sampling of 25 fish per group.

[11] If desired in the future, early male maturation rate may be quantified by lethally sampling 300 randomly sampled fish (~150 males) to collect blood and measure 11-ketotestosterone, the physiological marker of early testis maturation.

Analysis

After 3 years of implementation, in-hatchery survival rates, size-at-release, condition factor at release, fish health (frequency or rates of disease), and physiological status at the time of release will be compared between treatment groups.

Final SARs will be evaluated approximately 6 years following production of each BY (e.g., in 2023 for BY 2017). Preliminary SAR of the test groups will be reviewed and compared beginning in late-2021, after age-3 and -4 adults from BY 2017 return (see Table 5). Comparisons may be made among mean SARs of: 1) each treatment group across BYs to evaluate the effect of rearing and release strategies on survival; and 2) each release year, to investigate effects of rearing and release strategies on survival independent of the effects of inter-annual environmental variation. Comparisons in the ages of returning adults will be made between treatment groups to identify any shift in population age structure among treatments. Comparisons will be made in context of interannual trends observed in other Lower Columbia stocks including the Cowlitz and Kalama spring Chinook to discern whether survival of a given cohort may have been affected by conditions downstream of the Lewis River experienced by all stocks (e.g., poor ocean conditions affecting a single cohort).

Table 5. Lifespan of study fish from three replicate years

Study Year	Spawn	Emergence	Release	Return Age 2+	Return Age 3+	Return Age 4+	Return Age 5+	Return Age 6+
2017	BY 2017							
2018	BY 2018	BY 2017	BY 2017					
2019	BY 2019	BY 2018	BY 2017, BY 2018	BY 2017				
2020	*	BY 2019	BY 2018, BY 2019	BY 2018	BY 2017			
2021	*		BY 2019	BY 2019	BY 2018	BY 2017		
2022	*				BY 2019	BY 2018	BY 2017	
2023	*					BY 2019	BY 2018	BY 2017
2024	*						BY 2019	BY 2018
2025	*							BY 2019

Note:
**Continuing study releases after BY 2019 will be reevaluated after 3 years of releases are complete (see following section).*

Decision Making

The results of the study will be used to make specific management and operational decisions for the Lewis River spring Chinook salmon program.

If there is a statistically supported difference in total survival (in-hatchery plus post-release) or age at return between release groups, future operations will change to adopt the rearing treatment conditions used for the group with the highest total survival to age 4+ or older.

Metrics that will be considered include in-hatchery survival, SAR, proportion of males maturing at age 2+ (minijacks) and 3+ (jacks), and mean or median age at return of the population. Interannual differences in the river and ocean conditions will affect cohort survival differently depending on the year of release, therefore the mean or median of three release years will be evaluated to discern whether effects of hatchery rearing on SAR or age at return are greater in magnitude than effects of the river or ocean environment. Physiological measurements of smolt and reproductive development will be used to discern a mechanism for differential fish health and survival between treatment groups.

The Lewis River program will consider changing release goals based on total survival of all groups. If total survival of subyearling releases significantly exceeds total survival of yearling releases, the program will consider releasing all fish at the age that demonstrates highest survival. The program may also consider releasing a proportion of each cohort at two or three different ages if inter-annual variation in survival between release ages or tradeoffs between in-hatchery survival, SAR, total number returning, and age at return, supports spreading risk across more than one release age.

Deliverables

The results of this evaluation will be summarized in data submissions to WDFW Fishbooks and a PacifiCorp-managed database monthly throughout the study, annual interim updates in the Lewis River Annual Operations Report, and in a final completion report at the conclusion of the study. Specific elements of these deliverables are described below:

Monitoring Data Submissions (monthly)

- Within hatchery monitoring (see above)
    - Fish health
    - Size and growth rates
    - Smoltification status
    - Observed precocity

Lewis River Annual Operations Report (annually)[12]

- Summary of within hatchery monitoring results to date beginning in 2018
- Interim number of adult returns from each BY would be reported beginning in 2019
- Preliminary survival estimates for returning adults from each BY would be calculated beginning in 2021

Completion Report (year 2025)

- Summary of monitoring results
- Comparison of in-hatchery survival and SARs among treatment groups

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[12] Within-hatchery monitoring will begin in 2018 on BY 2017 fish to be released in October of 2018 and February of 2019.

- Key conclusions
- Recommendations for future rearing and release practices

Limitations and Specific Concerns

The successful implementation of the evaluation will depend on the following factors that require consideration and coordination before the study begins.

1. *Adequate numbers of broodstock from the Lewis River program.* Recent returns have fluctuated greatly in number each year and the availability of broodstock over the course of this multi-year evaluation are uncertain. The effect of release treatments on survival and tag recovery may affect availability of spring Chinook salmon returns for supplementation purposes. The use of surplus Kalama River broodstock as a surrogate for Lewis River has been discussed as a less preferred option if sufficient Lewis River fish do not return.
2. *Sufficient numbers of marked adult returns to conduct statistical evaluations.* Detecting a significant difference among test groups will require sufficient numbers of returning adult fish from each test group (see Attachment A, Sample Size and Statistical Power for Detecting Changes in SAR).
3. *Maintaining pre-programmed release dates throughout the evaluation.* It is anticipated that the health (i.e., disease related mortality) of fish within the hatchery may trigger concerns about the necessity for early release of treatment fish. The integrity of the evaluation will require maintaining the targeted release dates for treatment fish and tolerance levels for mortality rates should be discussed and resolved prior to the implementation of the evaluation.
4. *The evaluation will need to be managed carefully, by project leads at PacifiCorp (Erik Lesko) and WDFW (staff member TBD) with oversight by the Hatchery and Supplementation Subgroup.* Even with dedicated leads, hatchery studies often present challenging coordination environments because of the number of people involved and the extra work required by the study itself.
5. *Release location consistency.* Fish from all treatment groups will be released in the same location near the Lewis River Hatchery.

REFERENCES CITED

Beckman, B.R., and W.W. Dickhoff, 1998. Plasticity of Smolting in Spring Chinook Salmon: Relation to Growth and Insulin-like Growth Factor-I. *Journal of Fish Biology* 53(4):808–826.

Larsen, D.A., B.R. Beckman, C.R. Strom, P.J. Parkins, K.A. Cooper, D.E. Fast, and W.W. Dickhoff, 2006. Growth Modulation Alters the Incidence of Early Male Maturation and Physiological Development of Hatchery-Reared Spring Chinook Salmon: A Comparison with Wild Fish. *Transactions of the American Fisheries Society* 135(4):1017–1032.

PacifiCorp and Cowlitz PUD, 2004. Lewis River Hydroelectric Projects, FERC Project Nos. 935, 2071, 2111, 2213, Final Technical Reports, 3.0 Water Quality. April 2004.

WDFW, 2016. Personal communication between Lewis River Hatchery Program staff, Washington Department of Fish and Wildlife and Erik Lesko, PacifiCorp. September 26, 2016.

WDFW, 2017. Lewis River Complex Operations Program for January 1, 2016 to December 31, 2016. WDFW Fish Program Hatcheries Division.

Attachment A
Sample Size and Statistical Power for Detecting Changes in SAR

Sample sizes of coded wire tag (CWT)-marked fish required to detect changes in smolt to adult returns (SAR) were calculated to inform monitoring and evaluation of rearing or release strategies for North Fork Lewis River spring-run Chinook salmon. A Two-Proportion Sample Size and Power Test was performed using the 'pwr' package written for R by Champely et al. (2018) based on effects sizes and notations from Cohen 1988.

Results are presented as the required sample size of CWT-marked fish to detect differences between SAR values that have been observed in recent program years (Figure A-1), and the increase in statistical power with increasing SAR values at a fixed sample size (50,000 fish per group; Figure A-2).

Figure A-1 demonstrates that as absolute SAR values and differences between SAR values increases, the sample sizes needed to detect real differences between groups decreases. For instance, to detect a difference in SAR between 0.05% and 0. 10% with statistical confidence will require minimum sample sizes of 10,000 to 50,000 fish, whereas detecting a relatively small difference in SAR between 0.10% and 0.13% will require 500,000 to 1,000,000 tagged fish.

Figure A-2 demonstrates that as the absolute SAR values and differences between SAR values increases, the ability to detect real differences between groups improves. For instance, if comparing two treatment groups of 50,000 juveniles, confidence that the difference between SARs of 0.04% and 0.05% is low, with less than 20% power; however, the confidence to detect a difference between 0.05% and 0.10% is high, with at least 80% power.

For reference, Table A-1 provides SAR by release groups (CWT only and CWT+AD clip) for the past 10 years available in the Regional Mark Information System and Washington Department of Fish and Wildlife databases for Lewis River Hatchery spring Chinook.

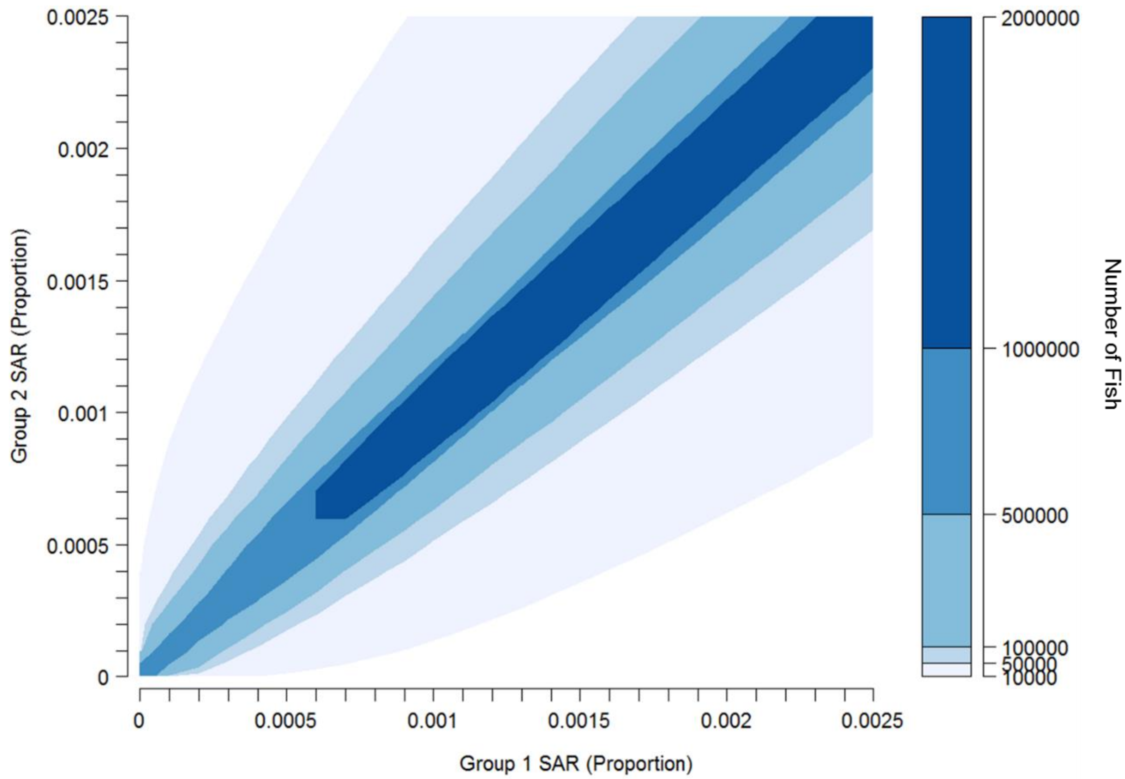

Figure A-1. Change in the necessary sample size with change in smolt-to-adult ratio and constant power (0.8)

Notes: Power = 0.80 and Alpha = 0.05

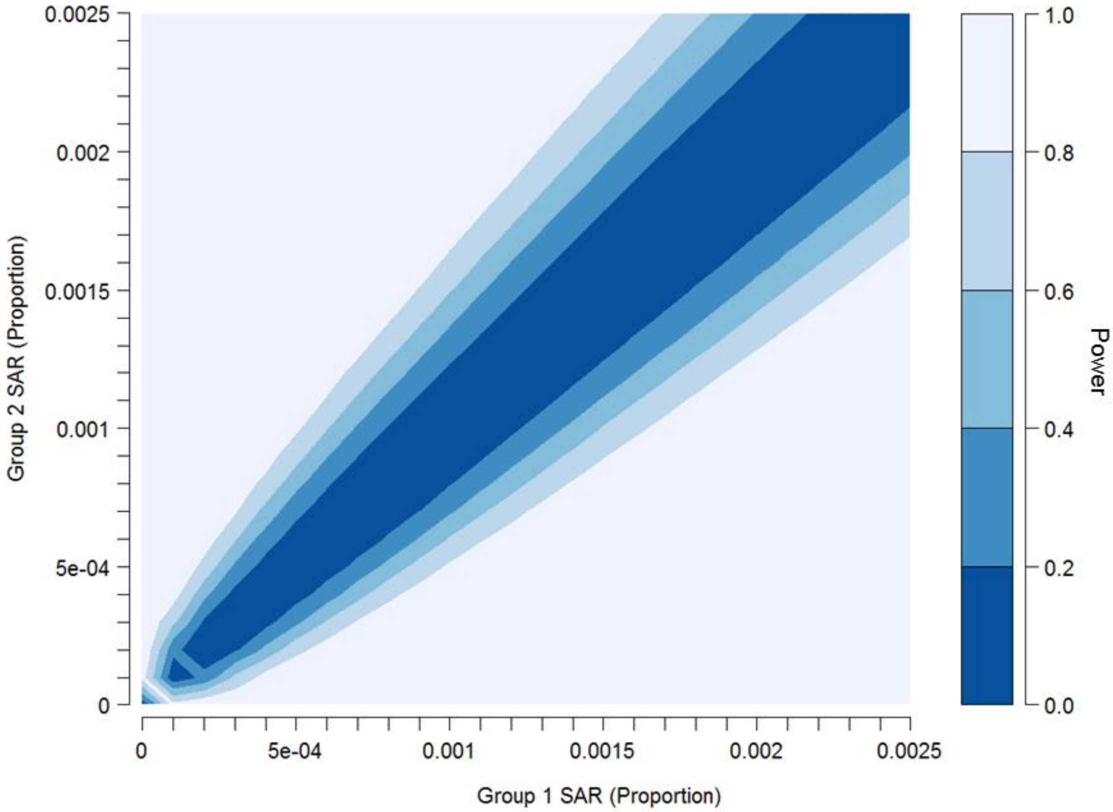

Figure A-2. Change in statistical power with change in smolt-to-adult ratio and constant sample size between two treatment groups (n = 50,000 per treatment)

Notes: Sample size (n) = 50,000 and Alpha = 0.05

Table A-1. Brood years 2002 to 2013 of Lewis River Hatchery spring Chinook smolt-to-adult ratio by brood year and release group

Brood Year (by release group)	Age at Release	Target Size at Release	Mean % SAR[a]
2002	Yearling	8 fpp	.97
2003	Yearling	8 fpp	.26
2004	Yearling	8 fpp	.10
2005	Yearling	8 fpp	.12
2006	Yearling	8 fpp	.29
2007	Yearling	8 fpp	.07
2008	Yearling	8 fpp	.24
2009	Yearling	8 fpp	.06
2010	Yearling	8 fpp	.06
2011	Yearling	8 fpp	.06
2012[b]	Yearling	8 fpp	.02
2013[b]	Subyearling	12 fpp	.13
2013[b]	Yearling	12 fpp	.25
2013[b]	Yearling	8 fpp	.11

Notes:

a. Mean of 2 to 5 release groups, depending on the year

b. Values are preliminary and do not include fish returning at age-5 or older

Percent survival based on CWT fish captured in all fisheries, spawning grounds, and hatcheries

Data sources are Regional Mark Information System (2018 expanded tag recoveries for BY 2002 to 2013. This report excludes recoveries in Fishery 70 series (juvenile recoveries).

References

Champely, S., C. Ekstrom, P. Dalgaard, J. Gill, S. Weibelzahl, A. Anandkumar, C. Ford, R. Volcic, H. De Rosario. Basic Functions for Power Analysis. Last updated March 3, 2018. Available at: Available at: https://CRAN.R-project.org/package=pwr.

Cohen, J., 1988. *Statistical Power Analysis for the Behavioral Sciences*. Second edition. Hillsdale, NJ: Lawrence Erlbaum.

Regional Mark Information System, 2018. Regional Mark Processing Center. Pacific States Marine Fish Commission. Accessed January 15, 2018. Available at: http://www.rmpc.org/.

APPENDIX E: Proposal to Evaluate Total Dissolved Gas and Water Temperature – Lewis River Hatchery, North Fork Lewis River

INTRODUCTION

In August of 2016, the utilities monitored basic water quality in the spring Chinook rearing raceways at North Fork Lewis River (Lewis River) Hatchery. Results from this initial monitoring showed that levels of total dissolved gas (TDG) in the rearing ponds intermittently exceed the TDG limit of 110% of saturation for water quality in surface waters that maintain aquatic life in the State of Washington (Ecology, 2017; Figure 1). Diurnal fluctuations observed for TDG were also found to be strongly correlated with water temperature (r^2=0.97).

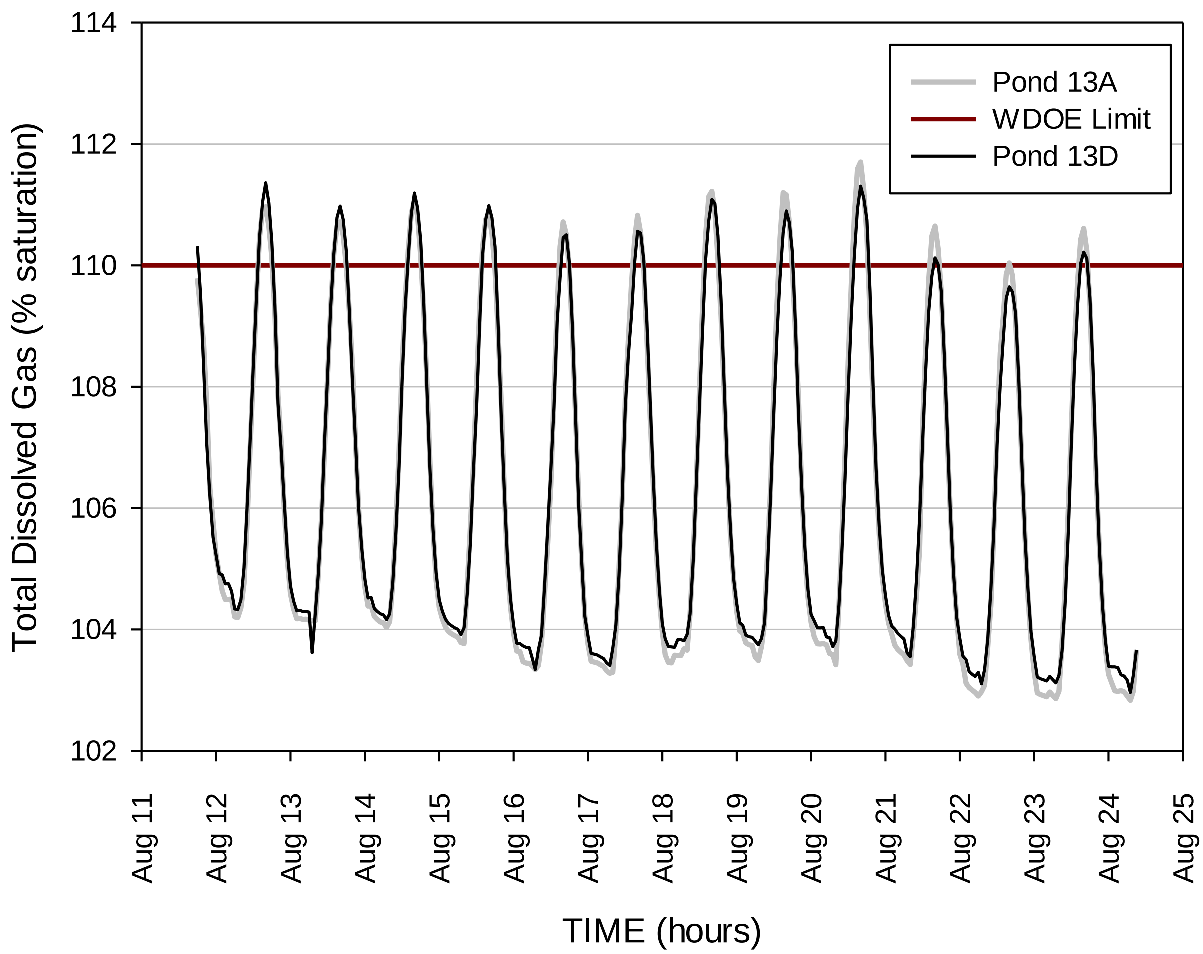

Figure 1. Hourly total dissolved gas monitoring in Rearing Pond Bank 13 at North Fork Lewis River Hatchery from August 11 through August 24, 2016

GENERAL APPROACH

Elevated TDG levels at Lewis River Hatchery have been a concern since at least 1988. In a memorandum from Mr. Robin Nicolay (hatchery manager at the time) to Mr. Wayne Daley of Fish Pro dated June 29, 1988, chronically high TDG levels and extreme temperature ranges were identified as potential contributors to disease outbreaks at the hatchery. The memorandum also states concerns regarding the efficacy of the aeration towers during periods of spill at Merwin Dam (Nicolay, 1988). The aeration towers were installed in the early 1980s as part of general upgrades at the facility.

The purpose of this study is to monitor TDG and water temperature over time to verify ambient river conditions compared to rearing conditions and also to identify potential sources of TDG in the water supply at Lewis River Hatchery. One potential source includes the upwelling system installed in 2011 to provide a more natural inflow into the rearing ponds. The upwelling system is closed (i.e., not open to atmosphere) and under pressure. Thus, any air entrainment into the system (e.g., pumps) becomes a potential source of TDG in the rearing ponds. Another potential source is the air burst system used to clean the screens at the upstream intake. The system uses compressed air through a network of underwater piping and may have developed leaks, creating a chronic source of TDG to the hatchery.

This evaluation will include specific testing of both the upwelling system and aeration tower. Additionally, routine monitoring of TDG and water temperature will occur during the summer months when both diel temperature fluctuations and potential for gas supersaturation are greatest. Routine data collection will compare ambient river conditions (control) with conditions in the rearing ponds to determine whether significant differences exist between the control and rearing areas. Lastly, past water temperature records will be collected and summarized for the Lewis River, Cowlitz, and Kalama hatcheries to compare and document differences between the three facilities.

FIELD METHODS

Testing and monitoring will focus on rearing ponds 13-1 and 14-1, which are located in Pond Banks 13 and 14 (Figure 2). Source water for Pond 13-1 will come directly from the pumps at the upstream intake and be delivered to Pond 13-1 via the upwelling system. Source water for Pond 14-1 will incorporate the installed reuse system from Pond 13-1. That is, Pond 13-1 will use first pass water and Pond 14-1 will use reuse water (from Pond 13-1). The comparison between the reuse system (Pond 14-1) and the upwelling system (Pond 13-1) is being used to evaluate whether the upwelling system is contributing to elevated TDG levels.

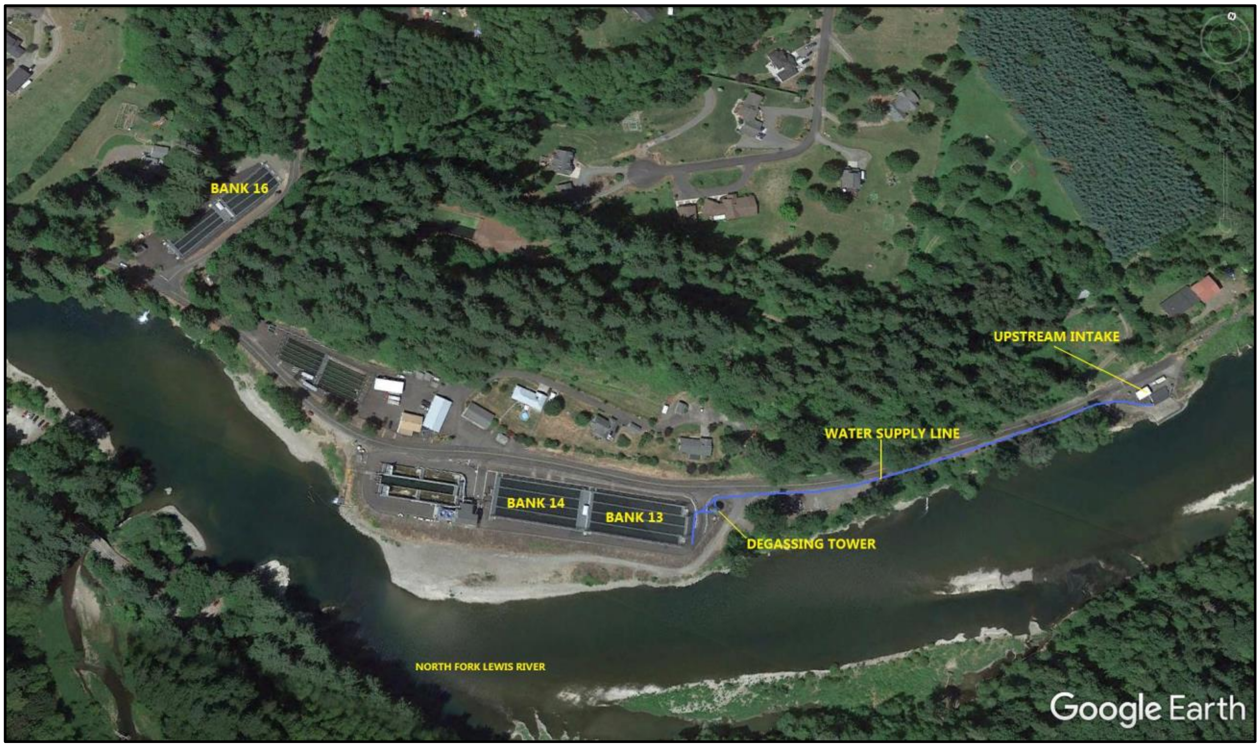

Figure 2. General site plan of Lewis River Hatchery, North Fork Lewis River

All monitoring will include the use of two control sites. One site will be located immediately upstream of the hatchery intake to measure ambient river temperature and dissolved gas levels prior to entering the hatchery intake. A second control datasonde will be placed inside the screened pump well at the intake to verify that the screen or air burst system are not contributing to elevated TDG inside the pump well. Air may be entrained at the screen from head differentials caused by clogged screens. Use of the air burst system may also elevate TDG not only because it forces compressed air through a network of underwater piping to backflush the screens, but also because undetected leaks in the system could be contributing to chronic elevation of background TDG levels that exceed those of ambient river conditions.

Hach® MS-5 and MS-4a datasondes will be used for all sites and factory calibrated for both TDG and temperature prior to deployment. In addition to the two datasondes at the selected control sites, three datasondes will be placed in the rearing ponds as depicted in Figure 3 for the duration of the study. The sites are denoted as 'A' through 'E' and are described in Table 1.

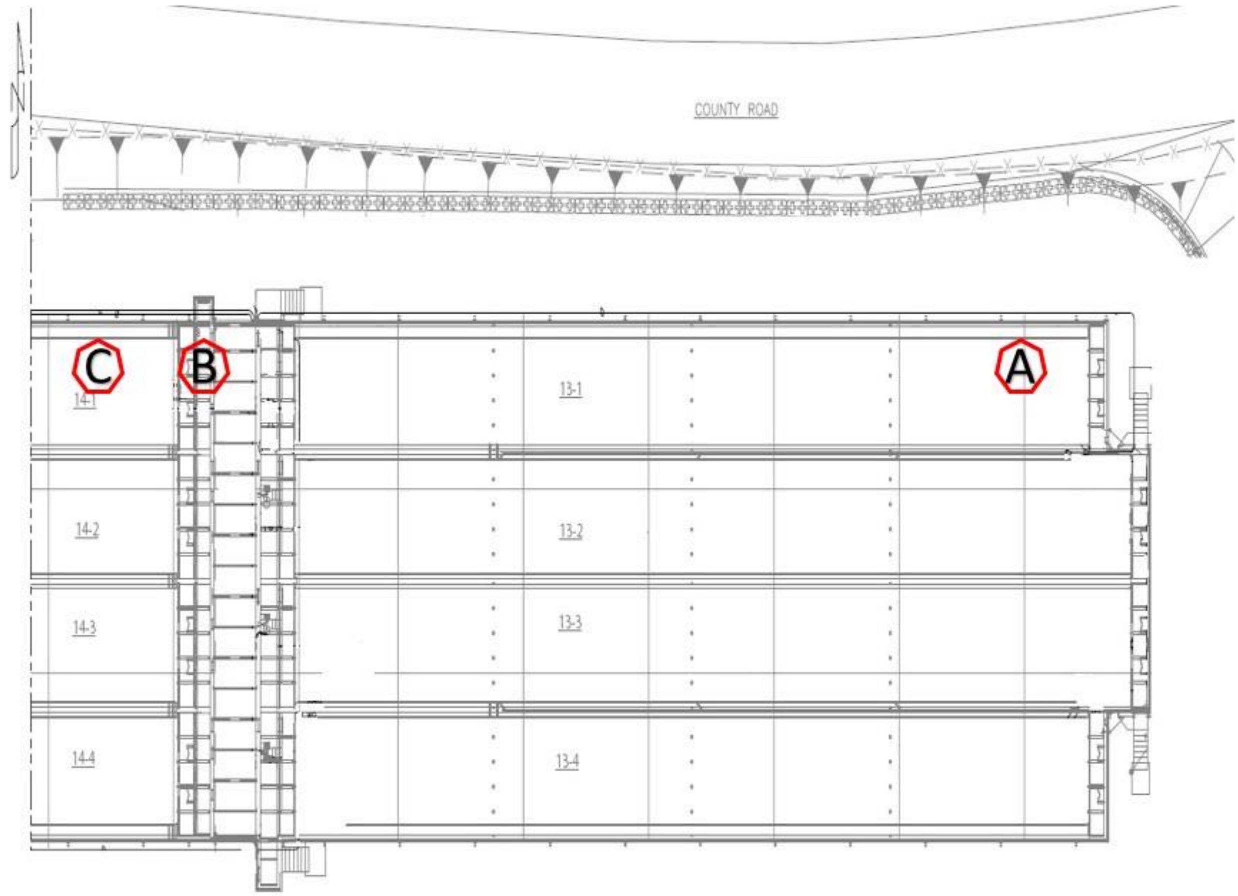

Figure 3. Layout of Pond Banks 13 and 14 (partial) denoting the proposed location of datasondes in the rearing ponds at the North Fork Lewis River Hatchery for testing and monitoring of total dissolved gas and water temperature

Table 1. Site descriptions, locations, and purpose of each datasonde placement for the duration of the study

Site	Location	Purpose
A	Near the inflow of the upwelling discharge into Pond 13-1	To measure TDG and water temperature exiting the upwelling system
B	In the water reuse channel between Pond Bank 13 and 14	To measure TDG and water temperature prior to overflowing the reuse wall into Pond 14-1
C	Near the inflow from the reuse wall overflow into Pond 14-1	To measure TDG and water temperature after overflowing the reuse wall in Pond 14-1
D	Inside the screened pump intake well (upstream intake)	To measure TDG and water temperature at the pump source and near the air burst system (secondary control)
E	Upstream of the intake in the Lewis River	To measure ambient in river conditions without influence from the hatchery (primary control)

Datasondes will be suspended to a depth of 10 feet or within 6 inches of the bottom of each location (whichever is deepest). Meters should be as deep as possible to reduce potential air bubble formation on the membranes. In rearing ponds, datasondes will be suspended above the floor 6 to 8 inches to prevent erroneous readings from decaying fish waste or uneaten food.

Routine Monitoring

The first information needed prior to any testing is to verify whether conditions in the rearing ponds are representative of conditions in the river. That is, that TDG levels and temperature ranges in the rearing ponds are not significantly different than levels occurring naturally. If conditions are representative, then testing of the upwelling system is not necessary as part of this study. However, testing of the aeration tower will need to occur regardless to determine if the tower is able to dissipate dissolved gases efficiently.

Datasondes will be placed at sites A through E (Table 1) for routine monitoring beginning in July 2017. Datasondes will be serviced every 2 weeks to download data, clean and grease seals, and replace batteries if necessary. The first two data sets representing 1 month of monitoring will be compared to determine whether TDG or temperature is influenced by the hatchery water delivery system (i.e., significant differences exist between the hatchery and control) and that TDG and temperature ranges are within state standards.

Upwelling Test

Beginning in July, water from the upstream intake will be directed to Pond 13-1. Water passing through Pond 13-1 will be routed to Pond 14-1 through the reuse water supply pipe (Figure 4). This pipe discharges into the reuse water supply channel for Pond Bank 14 (Figure 4). Water is supplied to Pond Bank 14 ponds via a weir wall that includes stop logs to regulate the flow into each of the four ponds (Figure 5). Reuse water flowing over the stop logs simulates a typical hatchery (open) inflow delivery system. This allows for both the submerged upwelling system (Pond Bank 13) and open overflow system (Pond Bank 14) to be evaluated simultaneously. Also, if water is found to be supersaturated in Pond 13-1, use of the overflow reuse wall should help reduce this oversaturation by reducing hydrostatic pressure from the water as it flows over the wall.

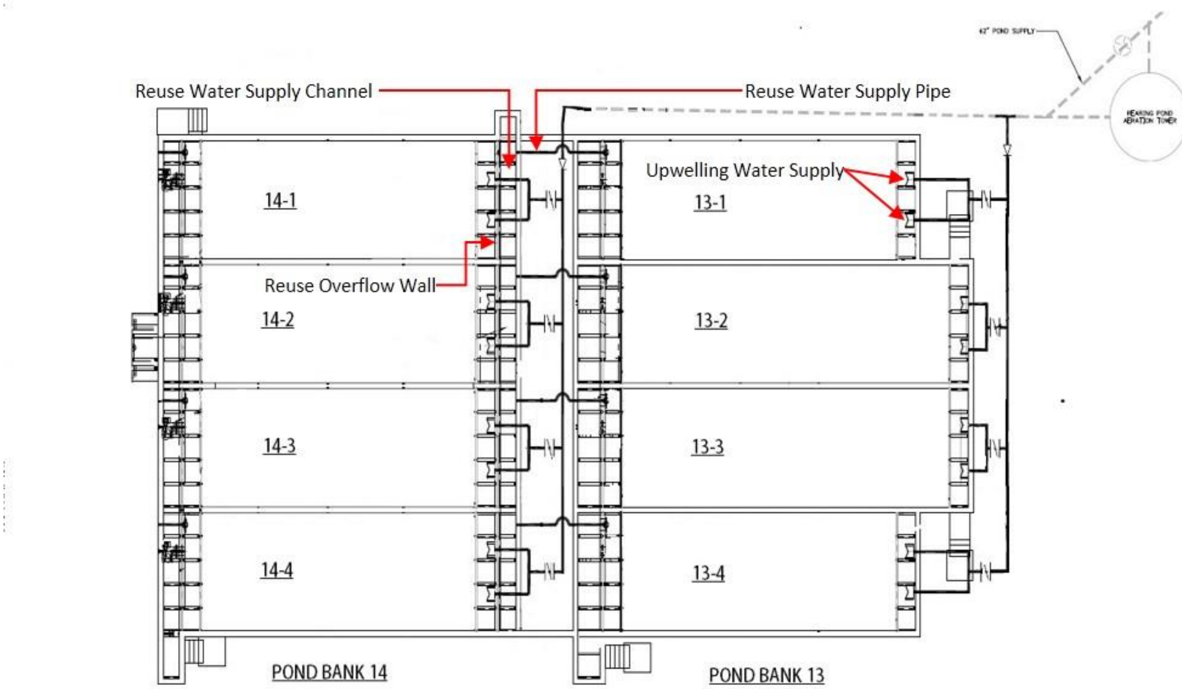

Figure 4. Piping diagram for Pond Banks 13 and 14

Figure 5. Location of the upwelling pipes and reuse water weir wall

Aeration Tower Test

The aeration tower(s) was installed as a precautionary measure to protect fish rearing at the facility from supersaturation caused by spill at Merwin Dam. During each spill event, hatchery personnel are notified and water is routed through the tower(s) to remove dissolved gas that *may* be present in the water supply. However, the effectiveness of the aeration tower has not been scrutinized by past hatchery managers (Nicolay, 1988).

After testing of the upwelling system is complete, a test of the aeration tower will be initiated whereby source water will be directed through the tower and supplied to Pond Bank 13-1. Datasondes in Pond Bank 13-1 will continuously monitor TDG and temperature for a period of 1 week while source water is directed through the tower. After the 1-week period, water will be directed to bypass the tower (as per normal operating protocol) and normal monitoring will resume.

Additional testing of the aeration tower will be necessary during spill events at Merwin Dam in 2018. This testing is necessary to determine if the towers are effectively protecting fish rearing at the facility from oversaturation caused by spill at Merwin Dam. The timing of this testing will of course depend on when a spill event occurs and the magnitude of that spill event. To achieve this, the utilities will monitor water conditions during the winter and spring of 2018 and deploy meters at the facility once the likelihood of spill at Merwin Dam is predicted by PacifiCorp's resource scheduling department.

FREQUENCY AND DURATION

Table 2. Frequency and duration of data collection

Task Description	Data Collection		Parameters Measured
	Duration	Frequency	
Routine Monitoring	July 1 to October 31	Hourly*	TDG (mm Hg), Barometric Pressure (mm Hg), Water Temp (°C), Air Temp (°C)
Upwelling Testing	August 15 – 30	20 minutes	
Aeration Tower Testing	September 1 – 15**	20 minutes	

Notes:
** Routine monitoring is hourly except during testing when data collection frequency is increased to every 20 minutes*
*** Aeration tower testing will also include monitoring during any spill event at Merwin Dam occurring during 2017/2018 runoff season*

ANALYTICAL METHODS

Analysis of collected data will focus on identifying sources of TDG at the facility. Principal sources include the following:

- The screens or air burst system at the upstream intake
- The upwelling inflow configuration
- Air entrainment from the pumps or vents in the water supply line

The first determination to be made is whether water temperature and gas saturation in the rearing ponds is significantly different than that of the river (control). If significant differences are observed, specific analysis will be done to evaluate different portions of the water delivery system. That is, each datasonde will be evaluated against the in-river control to focus on specific areas as mentioned above.

The term *significant,* for purposes of this study, is not intended as purely a statistical difference, but also a biological one. That is, in addition to testing whether there is a statistical difference between the control and treatment areas, the analysis will evaluate whether collected data meet generally accepted levels to support fish health or whether they are considered potential stressors. A determination will also be made as to whether the water quality parameters are temporary, chronic, or acute in nature. For example, exceedances in TDG may only occur for an hour each day, or only exceed acceptable limits during extremely hot days or remain at chronically elevated levels for long periods.

In instances where values exceed or approach biological thresholds, options will be discussed to mitigate these stressors to fish rearing at the facility. Options will be discussed with state pathologists, fish culture staff, and fishery managers to develop recommendations and address any water quality concerns.

ASSUMPTIONS

1. The control location is representative of ambient river conditions.
2. The use of the reuse water supply for Pond 14-1 effectively simulates an open delivery system.
3. Water level elevations in the raceways are not subject to frequent or random water elevation changes that may interfere with monitoring TDG accurately.
4. The datasondes will remain within calibration standards for the duration of the study.

DELIVERABLES (TO BE COMPLETED BY DECEMBER 2018)

1. A summary of monthly temperature profiles including maximum, minimum, and average water temperatures for the Lewis River, Kalama, and Cowlitz hatcheries
2. Analysis and results of the influence of the aeration tower on raceway water quality (including during spill events if applicable)
3. Analysis and results of daily monitoring of the rearing ponds compared to in-river conditions
4. Analysis and results of the influence of the upwelling system on rearing pond TDG levels
5. Discussion of results with documented input from the Washington Department of Fish and Wildlife fish pathologist along with recommended actions to mitigate any water quality concerns

LIMITATIONS AND SPECIFIC CONCERNS

This study addresses only TDG and temperature and is not intended to be a comprehensive evaluation of overall water quality conditions at Lewis River Hatchery. There may be other water quality characteristics that are having a more significant influence on fish health at Lewis

River Hatchery (e.g., pathogen loading). Also, the ability to link elevated dissolved gas or temperature to fish health, smolt performance, or premature mortality may be difficult to prove, especially if these variables are chronic or temporary in nature. That is, to prove causality given an intermittent observation of elevated temperatures or TDG is difficult to determine and most likely outside the scope of this study. However, results from this study may support the development of new fish health monitoring objectives to detect biological effects of impaired water quality. For example, a portion of dead fish could be evaluated for gas bubble disease or other indications as recommended by state pathologists.

REFERENCES

Ecology (Washington State Department of Ecology), 2017. *Water Quality Standards for Surface Waters of the State of Washington*, Chapter 173-201A WAC. Publication no. 06-10-091. Olympia, Washington: Adopted August 1, 2016, Revised March 2017.

Nicolay, R., 1988. Temperature and flow data (Lewis River Hatchery), Memorandum to Wayne Daley (Fish Pro), June 29, 1988.

APPENDIX F: Volitional Release Literature Review

Introduction

The North Fork Lewis River (Lewis River) Hatchery and Supplementation Subgroup discusses release strategies and monitoring efforts for Lewis River Hatchery programs, to be documented in the Annual Operating Plan. In particular, implementation and monitoring of volitional or forced release methods should be informed by regionally accepted guidelines and best available science. This memorandum summarizes guidelines developed for the Columbia Basin by the Hatchery Scientific Review Group, draft Hatchery and Genetic Management Plans (HGMPs) for Lewis River programs, HGMPs for nearby hatchery systems, and relevant literature on the topic. Though not an exhaustive research effort, this memorandum is intended to inform Hatchery and Supplementation Subgroup discussions. Details for the Lewis River program release methods are included in the Annual Operating Plan.

Hatchery Scientific Review Group

Hatchery Scientific Review Group (HSRG) guidelines recommend volitional release and removal of residuals to minimize adverse ecological impacts, but the guidelines do not include details on the timing or duration of volitional period. The following are the relevant HSRG guidelines on volitional release:

- Minimize adverse ecological interactions by making reared and released fish as similar biologically to their natural counterparts, or, segregate hatchery fish in time and space (HSRG, 2014).
- Maximize survival of hatchery fish so that unnecessary releases are minimized (HSRG, 2014).
- Recommends volitional release of smolts, in particular for steelhead, to reduce interactions with natural-origin juveniles (see Snow et al., 2013, per HSRG, 2014).
- Adoption of volitional release with removal of residuals (fish that become residents rather than go to sea) may increase the long-term survival of released fish while decreasing negative ecological interactions (HSRG, 2009).

Hatchery and Genetic Management Plans for the North Fork Lewis River

There are five HGMPs pertaining to the Lewis River programs: spring Chinook, coho type N (late), coho type S (early), winter-late (endemic) steelhead (integrated), winter steelhead (segregated), and summer steelhead. In each HGMP, volitional release strategies for each species are discussed. The HGMPs are similar in that they all state the fish should be released at a fully-smolted stage to reduce negative ecological interactions. When volitional release periods are specified (for spring Chinook salmon and coho salmon), they are 6 weeks long with the remainder of fish being forced out. Details about volitional releases for each HGMP are included in the following six sub-sections:

Lewis River Type-N Coho Salmon – July 2014

- Fish are released at a time, size, and the system and life history stage to foster rapid migration to marine waters, and to allow juvenile listed fish to grow to a size that reduces potential for fish predation (see Sections 2.2.3 and 10.11 in WDFW and PacifiCorp, 2014a).

- Juveniles are released at fully-smolted stage to benefit juvenile to adult survival rates and reduce the likelihood for residualism and negative ecological interactions (Section 3.5.5 in WDFW and PacifiCorp, 2014a).
- Lewis River Hatchery on-station releases: This program is released on a volitional basis over a 6-week period beginning on or after April 1; approximately 80% of the stock volitionally migrate during that time period. The remaining 20% are forced out prior to May 20 (Section 10.4 in WDFW and PacifiCorp, 2014a). The spring Chinook and winter-late steelhead HGMPs contain additional details about timing, duration, and location of releases.

Lewis River Type-S Coho Salmon – July 2014

- Same as Type-N, (WDFW and PacifiCorp, 2014d).

Lewis River Winter-Late (Endemic) Steelhead (Integrated) – July 2014

- Program steelhead are released fully-smolted to foster rapid outmigration from the basin and to minimize predation and residualism risks (WDFW and PacifiCorp, 2014b).
- This HGMP cites other studies showing that forced releases meeting size, time, and coefficient of variation parameters have resulted in similar smolt-to-adult return rates compared to volitional releases (Wagner, 1968, Everson and Ewing, 1992 as cited in WDFW and PacifiCorp, 2014b).
- Actively migrating steelhead are released in a different location than forced release fish. Fish that actively migrate will be trucked to the Merwin Boat Ramp for release (river kilometer 30.8). Once the volitional release window has ended, remaining fish will be hauled to the at the Pekins Ferry site and released (WDFW and PacifiCorp, 2014b).

Lewis River Winter (Segregated) and Summer Steelhead (Segregated) – July 2014

- The HGMP for the segregated winter Steelhead program is similar to that for the integrated program HGMP; however, does not contain the same details about release locations and timing. The same details about volitional releases are given in the summer steelhead (segregated) HGMP (WDFW and PacifiCorp, 2014e).

Lewis River Spring Chinook Salmon (Segregated and Integrated) – July 2014

- Lewis River program juvenile Chinook salmon are released fully-smolted to foster rapid outmigration from the basin and to minimize negative ecological interactions (WDFW and PacifiCorp, 2014c).
- Fish from this program are released on a volitional basis over a 6-week period, with approximately 80% of the stock volitionally migrating during that period. The remaining 20% are forced out prior to March 20 and November 20 for the earlier fall release (Section 9.2.8 in WDFW and PacifiCorp, 2014c).

Steelhead Hatchery and Genetic Management Plans for Nearby Systems

Kalama River Wild Summer Steelhead (Integrated)

- This program implements volitional release starting May 1, followed by a forced-release. All fish are forced out by May 15 (WDFW, 2017).

Hood River Production Program: Winter Steelhead (Integrated)

- Smolts are released from acclimation ponds over a 7-day period.
- In some past years, non-emigrating winter steelhead were trucked near the mouth of the Hood River to reduce interactions with native populations in Hood River (ODFW and Confederated Tribes of Warm Springs Reservation of Oregon, 2017).
- Sampling of non-migrants has occurred, but in low numbers that did not reveal statistically significant differences from the total population.
- Per Gerstenberger (2017), in past years, many PIT-tagged fish that did volitionally emigrate from acclimation ponds were observed a year later in the Hood River system, indicating that volitional release was not synonymous with full smolting and low residual rates. In recent years, delaying releases until after May 1 has allowed for growth to an optimal size for full-smolting, has increased the number of fish that leave acclimation sites volitionally, and reduced the number of residuals observed in the Hood River system. The emigration period now coincides more closely with the wild-type emigration for the native stock. The program no longer trucks non-migratory fish to the mouth of the river and now forces the small number of non-migratory smolts from acclimation sites into the river after a 3-day volitional release period (Gerstenberger, 2017). A study of physiological indicators of smolting and precocious maturation found that that residualism and precocity rates were very low (estimated 3 to 4% residualism rate and 1 to 12% rate of maturation after 1 year at sea; Larsen et al., 2017).

Clackamas River Winter Steelhead

- Oregon Department of Fish and Wildlife "will investigate the option of 'holding back' juvenile steelhead that do not migrate during the volitional release period after necessary facility improvements are completed as part of the intake upgrade project at Clackamas Hatchery. Under this option, all fish remaining after the volitional release period would be transferred to trout fisheries in standing waterbodies after reaching legal size … This option will also be investigated at Eagle Creek NFH *[National Fish Hatchery]*, but we are unsure of how non-emigrants can be removed from the ponds" (ODFW 2017)
- Smolts are force released from Clackamas Hatchery into the Clackamas River, Foster Acclimation Pond into Foster Creek, and Eagle Creek NFH into Eagle Creek (after 24-hour volitional release period).

Cowlitz River Hatchery Production (all species)

Per Hoffnagle and Shoblom (2017), program details were as follows:

- The Cowlitz River programs use forced releases after volitional release to the river for all species.
- There are concerns that steelhead may be residualizing, but no study is planned.
- Volitional release periods are based on logistical concerns more than physiological state of fish.

Literature Review – Steelhead

Willamette Basin – Tinus and Friesen (2010) summarized current knowledge, data needs, and recommendations for summer and winter steelhead in the upper Willamette Basin. They conclude that among the few studies that have examined performance indicators between volitional and forced-release steelhead, no significant differences among release strategies have been identified. The 2008 NMFS Biological Opinion cited in this report includes reasonable and prudent alternative 6.1.6 stating that steelhead smolts should be volitionally released over an extended period of time (e.g., 2 to 4 weeks) with any non-migrants being removed and not released into free-flowing waters below (hydropower) projects (NMFS, 2008; Tinus and Friesen, 2010). NOTE: It is not confirmed whether upper Willamette River facilities are actually removing non-migrant fish.

Methow Basin – Snow et al. (2013) compared volitionally released versus forced-release juvenile hatchery summer steelhead for survival, smolt-to-adult return, and contribution to stream-resident populations of juvenile hatchery summer steelhead in the Twisp River for 3 brood years (2002 to 2004). Volitionally released steelhead had higher survival, greater smolt-to-adult return rates, and less residualism. They estimated that 82% of stream-resident hatchery juvenile summer steelhead originated from forced-release fish. Results suggest managers should employ volitional release strategies and not release non-migratory juveniles into waters inhabited by anadromous fishes. This reduces negative ecological interactions at little cost to adult returns.

Also in the Methow Basin, Gale et al. (2009) compared volitional release, forced-release, and volitional non-migrant steelhead from Winthrop NFH for the following metrics: Gill Na+, K+-ATPase (NKA) activity, body size, condition factor (K), travel time, and apparent survival. There was little evidence for a survival-, size-, or physiology-related advantage of volitionally released fish over forced-released fish.

Tatara et al. (2017) explored the differences in out-migration and travel rates between S1 and S2 smolts released over 5 years from Winthrop NFH. Nonvolitional migrants had lower survival rates than volitional migrant steelhead in both S1s and S2s. The S2 rearing cycle produced larger smolts with more uniform size distribution, resulting in higher survival and faster travel times during out-migration in most years. Body size at release explained most of the differences in survival within and between the rearing groups. 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.

Tucannon River – Viola and Schuck (2011) tested a release strategy designed to reduce the number of hatchery-reared steelhead failing to migrate out of the Tucannon River, and described the physical characteristics of those failing to migrate. After volitional emigration ceased, fish remaining were held in an acclimation pond. They had a male:female ratio of 4:1, and mostly were a combination of transitional, parr, and precocious male stages. These fish were harvested by sport anglers.

Hood River – In a study of physiological indicators of smolting and precocious maturation in Hood River steelhead, Larsen et al. (2017) found that for steelhead, size was a strong driver of successful smolting, with an optimal size around 200 millimeters. Fish that tended to exhibit a parr-like phenotype characteristic of residuals were smaller than fully-smolted fish, and male fish that showed signs of precocity tended to be larger than immature smolts.

Literature Review – Spring Chinook

Wenatchee Basin – Johnson et al. (2015) compared the adult survival of hatchery-reared spring Chinook released volitionally versus forcibly from a facility in the upper Wenatchee River for brood years 2003 to 2005. Smolt-to-adult survival rates were higher for forced releases. They recommend accounting for variability in survival within the migration corridor (i.e., flow in the Federal Columbia River Power System at time of release might be a bigger factor in survival than whether fish were volitionally or forcibly released). Night releases also increased survival.

Suggestions

- Consider detaining non-migrating steelhead; they may be more likely contribute to stream-resident populations than improve adult returns (Snow et al., 2013).
- Monitor indices of smolt development (e.g., size distribution and smolt index) to ensure fish are released at the peak of smolt development. Compare indices of smolt development between non-migratory fish and the total population.
- Enumerate non-migrating fish.
- For steelhead, release fish of an optimal size that reduces the number of fish exhibiting either a small, parr-like residual phenotype or the large, precocious male phenotype.
- Consider matching release timing to the emigration timing of natural origin stocks (though it could increase competition with natural origin fish).
- Consider night releases for spring Chinook if using forced release strategy (Johnson et al., 2015).
- Clarify language about volitional release in plans and reports. If a forced release follows a volitional period, describe both strategies.
- Monitor smolt emigration rate and duration from the Lewis River.
- Coordinate with other programs about latest science regarding volitional releases and National Oceanic and Atmospheric Administration recommendations.

References

Gale, W.L., C.R. Pasley, B.M. Kennedy, and K.G. Ostrand, 2009. "Juvenile Steelhead Release Strategies: A Comparison of Volitional- and Forced-Release Practices." *North American Journal of Aquaculture* 71(2): 97-106.

Gerstenberger, Ryan (Confederated Tribes of Warm Springs), 2017. Personal communication with Larissa Rohrbach (Anchor QEA, LLC). November 21, 2017.

Hoffnagle, Tim, and Eric Shoblom (Tacoma Power), 2017. Personal communication with Erik Lesko (PacifiCorp).

HSRG (Hatchery Scientific Review Group), 2009. *Columbia River Hatchery Reform System-Wide Report.* February 2009.

HSRG, 2014. On the Science of Hatcheries: An updated perspective on the role of hatcheries in salmon and steelhead management in the Pacific Northwest. A. Appleby, H.L. Blankenship, D. Campton, K. Currens, T. Evelyn, D. Fast, T. Flagg, J. Gislason, P. Kline, C. Mahnken, B. Missildine, L. Mobrand, G. Nandor, P. Paquet, S. Patterson, L. Seed, S. Smith, and K. Warheit. June 2014; revised October 2014.

Johnson, M.S., A.R. Murdoch, and C.P. Moran, 2015. "Adult Survival of Hatchery Spring Chinook Salmon Released Volitionally or Forcibly as Juveniles." *North American Journal of Aquaculture* 77(4) 547-550.

Larsen, D.A., M.A. Middleton, J.T. Dickey, R.S. Gerstenberger, C.V. Brun, and P. Swanson, 2017. "Use of Morphological and Physiological Indices to Characterize Life History Diversity in Juvenile Hatchery Winter-Run Steelhead." *Transactions of the American Fisheries Society* 146:663-679.

NMFS (National Marine Fisheries Service), 2008. *2008-2023 Willamette River Basin Project Biological Opinion.* NMFS Northwest Region, Seattle, Washington. F/NWR/2000/02117.

ODFW (Oregon Department of Fish and Wildlife), 2017. *Hatchery and Genetic Management Plan (HGMP) for Clackamas River Winter Steelhead Program*. Clackamas River Basin. January 2017.

ODFW and Confederated Tribes of Warm Springs Reservation of Oregon, 2017. *Hatchery and Genetic Management Plan (HGMP) Winter Steelhead (stock 50)*. Hood River Production Program. May 2017.

Snow, C.G., A.R. Murdoch, and T.H. Kahler, 2013. "Ecological and demographic costs of releasing nonmigratory juvenile hatchery steelhead in the Methow River, Washington." *North American Journal of Fisheries Management* 33:100-1112.

Tatara, C.R., M.R. Cooper, W.L. Gale, B.M. Kennedy, C.R. Pasley, and B.A. Berejikian, 2017. "Age and Method of Release Affect Migratory Performance of Hatchery Steelhead." *North American Journal of Fisheries Management* 37(4): 700-713.

Tinus, C.A., and T.A. Friesen, 2010. *Summer and Winter Steelhead in the Upper Willamette Basin: Current Knowledge, Data Needs, and Recommendations.* Final Report to: U.S. Army Corps of Engineers, Task Order NWPPM-09-FH-05. Oregon Department of Fish and Wildlife, Corvallis Research Laboratory.

Viola, A.E., and M.L. Schuck, 2011. "A method to reduce the abundance of residual hatchery steelhead in rivers." *North American Journal of Fisheries Management* 15(2) 488-493.

WDFW (Washington Department of Fish and Wildlife), 2017. *Hatchery and Genetic Management Plan (HGMP) for Kalama River Wild Summer Steelhead (Integrated)*. Kalama River/Lower Columbia. February 2017.

WDFW and PacifiCorp, 2014a. *Draft Hatchery and Genetic Management Plan (HGMP) for Lewis River Type-N Coho.* Lewis Subbasin/Lower Columbia Province. July 2014.

WDFW and PacifiCorp, 2014b. *Draft Hatchery and Genetic Management Plan (HGMP) for Lewis River Winter-late Steelhead.* Lewis Subbasin/Lower Columbia Province. July 2014.

WDFW and PacifiCorp. 2014c. *Draft Hatchery and Genetic Management Plan (HGMP) for Lewis River Spring Chinook.* Lewis Subbasin/Lower Columbia Province. July 2014.

WDFW and PacifiCorp, 2014d. *Draft Hatchery and Genetic Management Plan (HGMP) for Lewis River Type-S Coho.* Lewis Subbasin/Lower Columbia Province. July 2014.

WDFW and PacifiCorp, 2014e. *Draft Hatchery and Genetic Management Plan (HGMP) for Lewis River Winter Steelhead (Segregated).* Lewis Subbasin/Lower Columbia Province. July 2014.