Endangered Species Act (ESA) Section 7(a)(2) Biological Opinion and Magnuson-Stevens Fishery Conservation and Management Act Essential Fish Habitat (EFH) Consultation

Evaluation of Hatchery Programs for Spring Chinook Salmon, Summer Steelhead, and Rainbow Trout in the Upper Willamette River Basin

NMFS Consultation Number: WCR-2018-9781

Action Agencies: National Marine Fisheries Service
U.S. Army Corps of Engineers

Affected Species and Determinations:

ESA-Listed Species	**Status**	**Is Action Likely to Adversely Affect Species or Critical Habitat?**	**Is Action Likely To Jeopardize the Species?**	**Is Action Likely To Destroy or Adversely Modify Critical Habitat?**
Upper Willamette Spring Chinook Salmon (*Oncorhynchus tshawytscha*)	T	Yes	No	No
Upper Willamette Winter Steelhead (*O. mykiss*)	T	Yes	No	No
Lower Columbia River coho salmon (*O. kisutch*)	T	Yes	No	No
Lower Columbia River steelhead	T	Yes	No	No
Lower Columbia River Chinook salmon	T	Yes	No	No
Columbia River chum salmon (*O. keta*)	T	Yes	No	No
Upper Columbia River spring-run Chinook salmon	E	No	No	No
Snake River spring/summer run Chinook salmon	T	Yes	No	No
Snake River fall-run Chinook salmon	T	No	No	No
Middle Columbia River steelhead	T	No	No	No
Upper Columbia River steelhead	T	No	No	No
Snake River Basin steelhead	T	No	No	No
Snake River sockeye salmon (*O. nerka*)	E	No	No	No
Eulachon (*Thaleichthys pacificus*)	T	No	No	No
Southern green sturgeon (*Acipenser medirostris*)	T	No	No	No
Southern Resident killer whale(*Orcinus orca*)	E	No	No	No

Fishery Management Plan That Describes Essential Fish Habitat (EFH) in the Project Area	Does the Action Have an Adverse Effect on EFH?	Are EFH Conservation Recommendations Provided?
Pacific Coast Salmon	No	No
Pacific Coast Groundfish	No	No
Coastal Pelagic Species	No	No

Consultation Conducted By: National Marine Fisheries Service, West Coast Region, Sustainable Fisheries Division

Issued By:

for Sustainable Fisheries

Date: **May 17, 2019**

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1 INTRODUCTION

This introduction section provides information relevant to the other sections of the document and is incorporated by reference into Sections 2 and 3 below. The underlying activities that drive the proposed actions are the operation and maintenance of six hatchery programs in the Upper Willamette River Basin, Oregon. The hatchery programs are funded and operated by the U.S. Army Corps of Engineers (Corps) and Oregon Department of Fish and Wildlife (ODFW). Each program is described in detail in a Hatchery and Genetic Management Plan (HGMP), which were submitted to the National Marine Fisheries Service (NMFS) for review. NMFS is evaluating these programs here under section 7 of the ESA. A subsequent evaluation under limit 5 of the 4(d) Rule will occur for the spring Chinook salmon programs because these programs propose to take natural-origin fish for broodstock purposes (direct take).

The operation and management of every hatchery program is unique in time, and specific to an identifiable stock and its native habitat (Flagg et al. 2004). NMFS defines integrated hatchery programs as those that are reproductively connected or “integrated” with a natural population, promote natural selection over hatchery-influenced selection, contain genetic resources that represent the ecological and genetic diversity of a species, and are included in a salmon ESU or steelhead DPS. When a hatchery program actively maintains distinctions or promotes differentiation between hatchery fish and fish from a native population, then NMFS refers to the program as “isolated” (also referred to as segregated). Isolated programs promote domestication or selection in the hatchery over selection in the wild and may culture a stock of fish with phenotypes (e.g., different ocean migrations and spatial and temporal spawning distribution) different from the natural population.

1.1 Background

NMFS prepared the biological opinion (opinion) and incidental take statement portions of this document in accordance with section 7(b) of the ESA of 1973, as amended (16 U.S.C. 1531, et seq.), and implementing regulations at 50 CFR 402.

NMFS also completed an Essential Fish Habitat (EFH) consultation. It was prepared in accordance with section 305(b)(2) of the Magnuson-Stevens Fishery Conservation and Management Act (MSA) (16 U.S.C. 1801, *et seq*.) and implementing regulations at 50 CFR 600.

We completed pre-dissemination review of this document using standards for utility, integrity, and objectivity in compliance with applicable guidelines issued under the Data Quality Act (DQA) (section 515 of the Treasury and General Government Appropriations Act for Fiscal Year 2001, Public Law 106-554). The document will be available through NMFS’ Public Consultation Tracking System [*https://pcts.nmfs.noaa.gov/pcts-web/homepage.pcts*]. A complete record of this consultation is on file at the Sustainable Fisheries Division, Roseburg, Oregon.

1.2 Consultation History

Since the listing of Upper Willamette River spring Chinook salmon and winter steelhead under the ESA, hatchery programs in the Willamette Basin have needed ESA authorization. The first section 7 consultation on the Willamette hatchery programs occurred with a biological opinion issued in 2000 to the co-managers. This opinion authorized the programs for three years. Subsequent section 7 consultation on the Willamette Project (all of the Corps dams and associated hatchery programs) was completed in 2008 with the issuance of a new opinion to the co-managers. One of the Reasonable and Prudent Alternatives (RPA) of this opinion was to develop criteria and protocols for the spring Chinook salmon programs that incorporates natural-origin salmon into the hatchery broodstocks. Allowing natural-origin Chinook salmon to be taken for broodstock requires a separate authorization under the ESA that was not included in the Incidental Take Statement (ITS) of the 2008 opinion (NMFS 2008). This new action to allow the co-managers to take natural-origin salmon for broodstock can only be authorized under the ESA's limit 5 of the 4(d) Rule for direct take of natural-origin salmon. New HGMPs were developed by the co-managers for these Chinook salmon hatchery programs and submitted to NMFS for review. After several drafts of these HGMPs were reviewed by NMFS, we issued a sufficiency letter for all of the spring Chinook salmon HGMPs to the co-managers on October 14, 2016. After this, NMFS began evaluation of the new Chinook salmon HGMPs, as required under the ESA and the National Environmental Policy Act (NEPA).

On December 15, 2016, NMFS issued a Federal Register notice (81 FRN 241) requesting public review and comment of the four submitted spring Chinook salmon HGMPs in the Upper Willamette River basin as required under limit 5 of the 4(d) Rule. In the same FRN, we also stated our intent to develop an Environmental Impact Statement (EIS) and requested information necessary to prepare this evaluation from interested parties. The comment period for this notice closed on January 30, 2017 (81 FR 90787).

NMFS released the draft EIS (DEIS) for public review and comment on March 23, 2018. The DEIS addresses the potential effects of all the hatchery programs and facilities in the Upper Willamette River basin. After addressing public comments on the DEIS, NMFS will proceed with the final EIS and issue the Record of Decision (ROD) at the time when this ESA consultation is completed.

In addition, NMFS is also evaluating the hatchery programs for summer steelhead and rainbow trout in the Upper Willamette River as part of this consultation. New information on the effects of these hatchery programs has become available since the 2008 opinion (NMFS 2008). However, the summer steelhead and rainbow trout hatchery programs only involve incidental take of listed salmon and steelhead (no take of listed winter steelhead for broodstock purposes) and will be authorized through this opinion (including the ITS and Terms and Conditions). There is no requirement for public review and comment for these two hatchery programs since they are being consulted upon under section 7 of the ESA (unlike the Chinook salmon programs above that will be approved for direct take under limit 5 of the 4(d) Rule).

1.3 The Proposed Federal Action

"Action" means all activities, of any kind, authorized, funded, or carried out, in whole or in part, by federal agencies. The proposed action involves two federal actions by NMFS and the Corps. NMFS' federal action is the evaluation of whether the Chinook salmon HGMPs submitted by the co-managers meet the specified criteria in limit 5 of the ESA 4(d) rule for listed Upper Willamette River spring Chinook salmon and winter steelhead (50 CFR § 223.203(b)(6)). Before NMFS can potentially approve the Chinook salmon HGMPs, we must undertake intra-agency consultation under section 7 of the ESA. The federal action of the Corps is its funding and operation of the hatchery programs for Chinook salmon, summer steelhead, and rainbow trout in the Upper Willamette River Basin, of which the Corps is required to consult with NMFS under section 7 of the ESA. Both of the federal actions specified above are included in this opinion.

1.3.1 Describing the Proposed Action

The HGMPs for the spring Chinook salmon, summer steelhead, and rainbow trout programs as described in Corps (2016a), (2016b), (2016c), (2016d), (2018a), and (2018b) is the proposed action. The specific hatchery facilities and associated hatchery programs are listed in Table 1. The hatchery facilities located in the UWR are shown in Figure 1. Activities included in the HGMPs are as follows:

- Collection of spring Chinook salmon, summer steelhead, and winter steelhead for hatchery broodstock.
- Holding adult broodstock at the specific hatchery facilities if appropriate.
- Spawning, incubation, and juvenile rearing at the specific hatchery facilities.
- Release of approximately six million juvenile hatchery fish (10% exceedance of the program goal) from the various hatchery release facilities in the Upper Willamette River basin (Table 1). Release of up to 437,000 pounds of hatchery rainbow trout of various sizes. Release size (+/- 10% variation) are specified in the specific HGMPs.
- Research, monitoring, and evaluation activities associated with the hatchery programs.

Table 2 provides further details for the proposed activities of the UWR hatchery programs.

Table 1. List of the primary hatchery facilities and associated programs with HGMPs included in the proposed action.

Hatchery Facility (primary)	Hatchery Program	HGMP Reference[1]	Production Goal (millions)
Willamette Hatchery	Middle Fork Willamette spring Chinook salmon	Corps 2016a	1.7
McKenzie Hatchery	McKenzie spring Chinook salmon	Corps 2016b	0.61
Roaring River, Willamette, and Leaburg hatcheries	Rainbow trout	Corps 2018b	437,000 pounds
South Santiam Hatchery	South Santiam spring Chinook salmon	Corps 2016c	1.1
	Upper Willamette summer steelhead	Corps 2018a	0.6
Marion Forks Hatchery	North Santiam spring Chinook salmon	Corps 2016d	0.71

[1]HGMPs are available online at: https://www.dfw.state.or.us/fish/hgmp/final.asp#6 (accessed March 12, 2019).

Figure 1. Map of the Willamette River basin showing fish facilities and dams.

Table 2. Operations of the fish collection facilities and hatchery facilities associated with the HGMPs and reintroductions above federal dams in the Upper Willamette River Basin.

Activity	Facility	Location
1) Trap and haul for reintroduction above federal dams, and/or 2) Broodstock collection	Minto Fish Collection Facility	North Santiam; RM 42
	Foster Fish Collection Facility	South Santiam River; RM 38.5
	Dexter Fish Collection Facility	Middle Fork Willamette River; RM 17
	Fall Creek Fish Collection Facility	Fall Creek (MF Willamette); RM 7.2
	Cougar Fish Collection Facility	South Fork McKenzie River; RM 4.5
	McKenzie Hatchery	McKenzie River; RM 37
	Leaburg Hatchery	McKenzie River; RM 38.5
3) Incubation and rearing of juvenile hatchery salmon, steelhead, and rainbow trout	Marion Forks Hatchery	North Santiam River; RM 73
	South Santiam Hatchery	South Santiam River; RM 38.5
	McKenzie Hatchery	McKenzie River; RM 37
	Leaburg Hatchery	McKenzie River; RM 38.5
	Oak Springs Hatchery	Deschutes River; RM 47
	Roaring River Hatchery	Crabtree Creek; RM 1.2
	Willamette Hatchery	Middle Fork Willamette River; RM 42
4) Release of juvenile hatchery salmon, steelhead, and rainbow trout	Minto Fish Collection Facility	North Santiam; RM 42
	South Santiam Hatchery	South Santiam River; RM 38.5
	McKenzie Hatchery	McKenzie River; RM 37
	Leaburg Hatchery	McKenzie River; RM 38.5

Activity	Facility	Location
	Dexter Fish Collection Facility	Middle Fork Willamette River; RM 17
	Willamette River	Eugene area
	SAFE	Lower Columbia River (Chinook salmon)
	Willamette River basin	Throughout basin in ponds, reservoirs, rivers, and streams (rainbow trout)
5) Research, Monitoring, and Evaluation	RME specified in HGMPs	Varies
	Watershed areas accessible to hatchery and natural salmon migration, spawning, and rearing	

For the spring Chinook salmon hatchery programs, the proposed action includes the use of natural-origin salmon for broodstock purposes. NMFS (2008) identified this action in the Reasonable and Prudent Alternative (# 6.2.2) because of the biological benefits for an integrated broodstock (e.g. Waters et al. 2015; Ford et al. 2016; Waters et al. 2016). The salmon HGMPs specify criteria for the use of natural-origin salmon depending upon the abundance of the natural population annually. Returns must exceed the minimum abundance thresholds before any natural fish can be used for broodstock. If this threshold is exceeded in any given year, then natural-origin fish can be used for broodstock according to a "sliding scale" where as natural fish abundance increases, then more natural-origin fish can be potentially taken for broodstock.

For the hatchery summer steelhead program, the proposed action includes several management changes that have been implemented recently (NMFS 2008; Tinus and Friesen 2012; Johnson et al. 2018), or will be implemented under Corps (2018a). In particular, these include:

- Advancing the spawn timing of hatchery summer steelhead by spawning broodstock earlier (primarily in December compared to later timing in previous years). The purpose of this action is to segregate spawning of summer and winter steelhead to minimize overlap in space and time.
- Reduce the release of hatchery summer steelhead smolts in the South Santiam River to 121,000 fish annually (25% reduction from previous years; section 1.11.2 of Corps 2018a). The purpose of this action is to reduce the number of surplus hatchery steelhead returning to the South Santiam River and potentially interacting with winter steelhead in the wild, while still providing fish for harvest.

- Terminate the "recycling" of hatchery summer steelhead in the North Santiam River and South Santiam River collected at fish collection facilities back downstream (page 15 of Corps 2018a). Recycling has occurred in some years in accordance with NMFS (2008) to provide hatchery steelhead for fisheries. The purpose of terminating recycling of hatchery steelhead is to minimize the number of hatchery steelhead potentially spawning in the wild (Erdman et al. 2018).
- Managing gene flow (introgression) from hatchery summer steelhead into ESA-listed winter steelhead populations in the North Santiam, South Santiam, Molalla, Calapooia, and westside tributaries to less than 2% (standard 3.4 of Corps 2018a). The purpose of this action is to minimize genetic effects of hatchery summer steelhead on winter steelhead populations to very low levels.

1.3.2 Interrelated and Interdependent Actions

"Interrelated actions" are those that are part of a larger action and depend on the larger action for their justification. "Interdependent actions" are those that have no independent utility apart from the action under consideration. In determining whether there are interrelated or interdependent actions that should be considered in this consultation, NMFS has considered whether fisheries impacting spring Chinook salmon and winter steelhead produced by the Upper Willamette River basin hatchery programs are interrelated or interdependent actions that are subject to analysis in this opinion.

Recreational and commercial fisheries for salmon and steelhead produced by the proposed hatchery programs occur in the ocean and freshwater and may incidentally take ESA-listed spring Chinook salmon and winter steelhead. Fisheries in the ocean would occur regardless of hatchery production from the Upper Willamette River basin, and are not therefore considered here as an interrelated or interdependent action. The winter steelhead fisheries would still occur if the proposed hatchery programs did not occur because this fishery is entirely catch and release with no hatchery winter steelhead being produced. However, the spring Chinook fisheries target hatchery fish produced by these hatchery programs and these fisheries would not exist if the proposed hatchery programs did not occur. Therefore, the Chinook salmon fisheries is an interrelated action with the salmon hatchery programs.

All freshwater fishery impacts on listed, natural-origin spring Chinook salmon and winter steelhead are governed by ESA-approved Fisheries Management and Evaluations Plans (FMEPs) reviewed regularly by ODFW, NMFS, and the Pacific Fishery Management Council (PFMC). NMFS approved these two FMEPs in 2001 and management continues to be implemented annually in accordance with NMFS authorizations. NMFS determined the FMEPs would not likely jeopardize the continued existence of Upper Willamette River spring Chinook salmon and winter steelhead or adversely modify designated critical habitat for these listed species (NMFS 2001a; NMFS 2001b). The fisheries continue to be evaluated annually with regular reporting submitted to NMFS to ensure the fisheries are conducted in accordance with the approved plans. To date there has never been an exceedance of authorized impacts. Future fisheries will continue to be implemented under permanent fishing regulations adopted by ODFW that have demonstrated harvest impacts below authorized levels.

2 ENDANGERED SPECIES ACT: BIOLOGICAL OPINION AND INCIDENTAL TAKE STATEMENT

The ESA establishes a national program for conserving threatened and endangered species of fish, wildlife, plants, and the habitat upon which they depend. As required by section 7(a)(2) of the ESA, each Federal agency must ensure that its actions are not likely to jeopardize the continued existence of endangered or threatened species, or adversely modify or destroy their designated critical habitat. Per the requirements of the ESA, Federal action agencies consult with NMFS and section 7(b)(3) requires that, at the conclusion of consultation, NMFS provides an opinion stating how the agency's actions would affect listed species and their critical habitats. If incidental take is reasonably certain to occur, section 7(b)(4) requires NMFS to provide an ITS that specifies the impact of any incidental taking and includes non-discretionary reasonable and prudent measures (RPMs) and terms and conditions to minimize such impacts.

2.1 Analytical Approach

This opinion includes both a jeopardy analysis and an adverse modification of designated critical habitat analysis. The jeopardy analysis relies upon the regulatory definition of "to jeopardize the continued existence of" a listed species, which is "to engage in an action that would be expected, directly or indirectly, to reduce appreciably the likelihood of both the survival and recovery of a listed species in the wild by reducing the reproduction, numbers, or distribution of that species" (50 CFR 402.02). Therefore, the jeopardy analysis considers both survival and recovery of the species.

This opinion relies on the definition of "destruction or adverse modification," which "means a direct or indirect alteration that appreciably diminishes the value of critical habitat for the conservation of a listed species. Such alterations may include, but are not limited to, those that alter the physical or biological features essential to the conservation of a species or that preclude or significantly delay development of such features" (81 FR 7214).

The designation of critical habitat for Upper Willamette River (UWR) spring Chinook salmon and winter steelhead uses the term primary constituent element (PCE) or essential features. The new critical habitat regulations (81 FR 7414) replace this term with physical or biological features (PBFs). The shift in terminology does not change the approach used in conducting a ''destruction or adverse modification'' analysis, which is the same regardless of whether the original designation identified PCEs, PBFs, or essential features. In this opinion, we use the term PBF to mean PCE or essential feature, as appropriate for the specific critical habitat.

We use the following approach to determine whether a proposed action is likely to jeopardize listed species or destroy or adversely modify critical habitat.

Identify the range-wide status of the species and critical habitat

This section describes the status of species and critical habitat that are the subject of this opinion. The status review starts with a description of the general life history characteristics and the population structure of the ESU/DPS, including the strata or major population groups (MPG) where they occur. NMFS has developed specific guidance for analyzing the status of salmon and steelhead populations in a "viable salmonid populations" (VSP) paper (McElhany et al. 2000). The VSP approach considers four attributes, the abundance, productivity, spatial structure, and diversity of each population (natural-origin fish only), as part of the overall review of a species' status. For salmon and steelhead protected under the ESA, the VSP criteria therefore encompass the species' "reproduction, numbers, or distribution" (50 CFR 402.02). In describing the range-wide status of listed species, NMFS reviews available information on the VSP parameters including abundance, productivity trends (information on trends, supplements the assessment of abundance and productivity parameters), spatial structure and diversity. We also summarize available estimates of extinction risk that are used to characterize the viability of the populations and ESU/DPS, and the limiting factors and threats. To source this information, NMFS relies on viability assessments and criteria in technical recovery team documents, ESA Status Review updates, and recovery plans. We determine the status of critical habitat by examining its PBFs. Status of the species and critical habitat are discussed in Section 2.2.

Describe the environmental baseline in the action area

The environmental baseline includes the past and present impacts of federal, state, or private actions and other human activities *in the action area* on ESA-listed species. It includes the anticipated impacts of proposed federal projects that have already undergone formal or early section 7 consultation and the impacts of state or private actions that are contemporaneous with the consultation in process. The environmental baseline is discussed in Section 2.3 of this opinion.

Analyze the effects of the proposed action on both the species and their habitat

Section 2.51 first describes the various pathways by which hatchery operations can affect ESA-listed salmon and steelhead, then applies that concept to the specific programs considered here.

Cumulative effects

Cumulative effects, as defined in NMFS' implementing regulations (50 CFR 402.02), are the effects of future state or private activities, not involving Federal activities, that are reasonably certain to occur within the action area. Future Federal actions that are unrelated to the proposed action are not considered because they require separate section 7 consultation. Cumulative effects are considered in Section 2.6 of this opinion.

Integration and synthesis

Integration and synthesis occurs in Section 2.7 of this opinion. In this step, NMFS adds the effects of the proposed action (Section 1.3) to the status of ESA protected populations in the Action Area under the environmental baseline (Section 2.4) and to cumulative effects (Section 2.6). Impacts on individuals within the affected populations are analyzed to determine their effects on the VSP parameters for the affected populations. These impacts are combined with the overall status of the ESU/DPS to determine the effects on the ESA-listed species, which will be used to formulate the agency's opinion as to whether the hatchery action is likely to: (1) result in appreciable reductions in the likelihood of both survival and recovery of the species in the wild by reducing its numbers, reproduction, or distribution; or (2) reduce the value of designated or proposed critical habitat.

Jeopardy and adverse modification

Based on the Integration and Synthesis analysis in Section 2.7, the opinion determines whether the proposed action is likely to jeopardize ESA protected species or destroy or adversely modify designated critical habitat in Section 3.7.3.

Reasonable and prudent alternative(s) to the proposed action

If NMFS determines that the action under consultation is likely to jeopardize the continued existence of listed species or destroy or adversely modify designated critical habitat, NMFS must identify a RPA or RPAs to the proposed action.

In addition, NMFS has further determined that the proposed action would not likely have any adverse effects on other ESA-listed species in the action area (e.g. other ESA-listed salmon ESUs in the Columbia River, Pacific eulachon, southern resident killer whales, and southern green sturgeon). These determinations are based on the absence of any adverse effects on these ESA-listed species in the action area where hatchery fish are present. These species may potentially interact in the Lower Columbia River estuary and/or have no adverse effects of the proposed action. Based on these determinations, these species will not be addressed further in this opinion. See section 2.12 “Not Likely to Adversely Affect Determinations” below for the assessment of these findings.

2.2 Rangewide Status of the Species and Critical Habitat

The species and the designated critical habitat that are likely to be adversely affected by the proposed action, and any existing protective regulations, include Upper Willamette River (UWR) spring Chinook salmon and winter steelhead, Lower Columbia River Chinook salmon, coho salmon, and steelhead, Columbia River chum salmon, and Snake River spring/summer Chinook salmon. Status of the species is the level of risk that the listed species face based on parameters considered in documents such as recovery plans, status reviews, and ESA listing determinations. The species status section helps to inform the description of the species’ current “reproduction, numbers, or distribution” as described in 50 CFR 402.02. The opinion also examines the status and conservation value of critical habitat in the action area and discusses the current function of the essential physical and biological features that help to form that conservation value.

2.2.1 Rangewide Status of the Species

“Species” Definition: The ESA of 1973, as amended, 16 U.S.C. 1531 *et seq*. defines “species” to include any “distinct population segment (DPS) of any species of vertebrate fish or wildlife which interbreeds when mature.” To identify DPSs of salmon species, NMFS follows the “Policy on Applying the Definition of Species under the ESA to Pacific Salmon” (56 FR 58612, November 20, 1991). Under this policy, a group of Pacific salmon is considered a DPS and hence a “species” under the ESA if it represents an evolutionarily significant unit (ESU) of the biological species. The group must satisfy two criteria to be considered an ESU: (1) It must be substantially reproductively isolated from other con-specific population units; and (2) It must represent an important component in the evolutionary legacy of the species. For the action area of this opinion, UWR spring Chinook salmon and winter steelhead, Lower Columbia River Chinook salmon, coho salmon, and steelhead, Columbia River chum salmon,

and Snake River spring/summer Chinook salmon of the taxonomic species *Oncorhynchus tshawytschas and O. mykiss,* respectively, and as such each are considered a "species" under the ESA.

The rangewide status of Pacific salmon ESU (i.e., a "species" under the ESA) depends on the health or viability of its constituent populations. NMFS commonly uses four parameters to assess population viability: abundance, productivity, spatial structure, and diversity (McElhany et al. 2000). These "viable salmonid population" (VSP) criteria therefore encompass the species' "reproduction, numbers, or distribution" as described in 50 CFR 402.02. When these parameters are collectively at appropriate levels, they maintain a population's capacity to adapt to various environmental conditions and allow it to sustain itself in the natural environment. These parameters or attributes are substantially influenced by habitat and other environmental conditions.

"Abundance" generally refers to the number of naturally produced adults (i.e., the progeny of naturally spawning parents) in the natural environment.

"Productivity," as applied to viability factors, refers to the entire life cycle of Pacific salmon; i.e., the number of naturally spawning adults (i.e., progeny) produced per naturally spawning parental pair. When progeny replace or exceed the number of parents, a population is stable or increasing. When progeny fail to replace the number of parents, the population is declining. McElhany et al. (2000) use the terms "population growth rate" and "productivity" interchangeably when referring to production over the entire life cycle. They also refer to "trend in abundance," which is the manifestation of long-term population growth rate.

"Spatial structure" refers both to the spatial distributions of individuals in the population and the processes that generate that distribution. A population's spatial structure depends fundamentally on accessibility to the habitat, on habitat quality and spatial configuration, and on the dynamics and dispersal characteristics of individuals in the population.

"Diversity" refers to the distribution of traits within and among populations. These range in scale from DNA sequence variation at single genes to complex life history traits (McElhany et al. 2000).

In describing the range-wide status of ESA-listed species, we rely on viability assessments and criteria in NMFS Technical Recovery Team (TRT) documents and NMFS recovery plans, when available, that describe VSP parameters at the population, major population group (MPG), and species scales (i.e., salmon ESUs and steelhead DPSs). For species with multiple populations, once the biological status of a species' populations and MPGs have been determined, NMFS assesses the status of the entire species. Considerations for species viability include having multiple populations that are viable, ensuring that populations with unique life histories and phenotypes are viable, and that some viable populations are both widespread to avoid concurrent extinctions from mass catastrophes and spatially close to allow functioning as meta-populations (McElhany et al. 2000).

2.2.1.1 Upper Willamette Spring Chinook Salmon ESU

The UWR Chinook salmon ESU was listed as threatened under the ESA on March 24, 1999 (64 FR 14308) and reaffirmed on June 28, 2005 (70 FR 37160) and April 14, 2014 (79 FR 20802). The UWR Chinook salmon ESU includes all naturally spawned populations of spring Chinook salmon in the Clackamas River and in the Willamette River and its tributaries above Willamette Falls, Oregon. Also included are the existing hatchery salmon programs that are also part of the ESU and included in the listing (Table 3) (NMFS 2005). The hatchery programs considered part of the ESU are the McKenzie River salmon program (McKenzie Hatchery), North Santiam salmon program (Marion Forks Hatchery), South Santiam salmon program (South Santiam Hatchery), and Middle Fork Willamette salmon program (Willamette Hatchery)(Table 3), and Clackamas salmon program (Clackamas Hatchery). The Willamette/Lower Columbia Technical Recovery Team (WLCTRT) identified seven independent populations within this ESU, as shown in Table 3 and Figure 2, below (Myers et al. 2006). All populations are part of the same stratum, or major population group (WLCTRT 2003).

Table 3. Independent populations and artificial propagation programs that are part of the UWR spring Chinook salmon ESU.

Independent population	**Artificial Propagation Component**
Clackamas River	Clackamas Hatchery
Molalla River	Marion Forks Hatchery
North Santiam River	Marion Forks Hatchery
South Santiam River	South Santiam Hatchery
Calapooia River	None
McKenzie River	McKenzie Hatchery
Middle Fork Willamette River	Willamette Hatchery

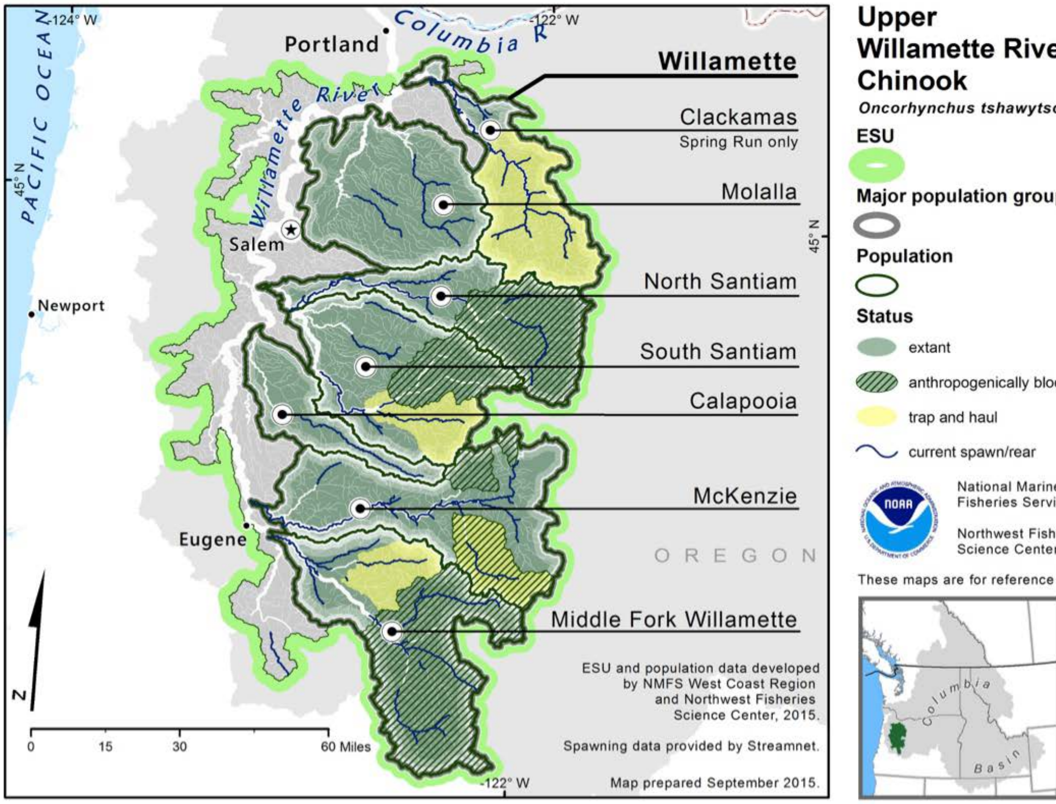


Figure 2. Map of Upper Willamette River Chinook salmon ESU, showing independent populations and major population groups. Figure taken from NWFSC (2015).

Life History

UWR Chinook salmon are one of the most genetically distinct groups of Chinook salmon in the Columbia River Basin. Historically (before the laddering of Willamette Falls), passage by returning adult salmonids over Willamette Falls (Rkm 37) was possible only during the winter and spring high-flow periods. The early run timing of Willamette River spring-run Chinook salmon relative to other lower Columbia River spring-run populations is viewed as an adaptation to flow conditions at the falls. Since the Willamette Valley was not glaciated during the last epoch, the reproductive isolation provided by the falls was probably uninterrupted for a considerable time and provided the potential for significant local adaptation relative to other Columbia River populations (Myers et al. 2006). Upper Willamette River Chinook salmon still contain a unique set of genetic resources compared to other Chinook stocks in the W/LC Domain (Figure 3; also see Myers et al. 1998 and Myers et al. 2006).

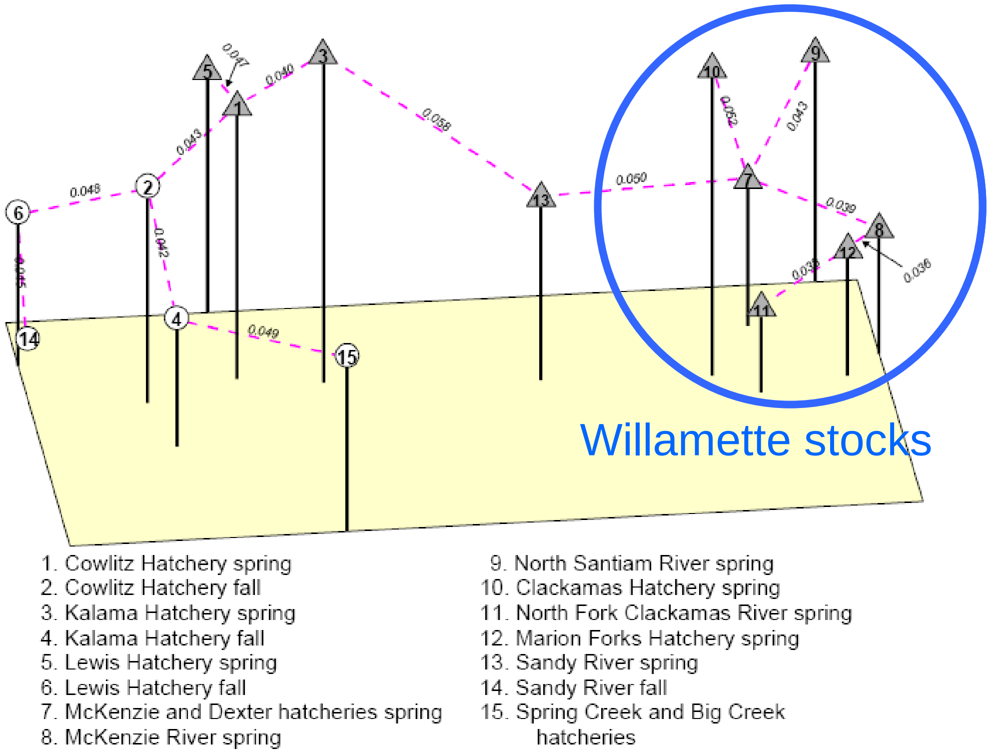


Figure 3. Three-dimensional representation of genetic difference, showing similarity of UWR Chinook stocks (indicated by proximity in the diagram) and their distinctness from Lower Columbia Chinook stocks (indicated by distance in the diagram). Figure adapted from Myers et al. 2006.

While adult UWR Chinook salmon begin appearing in the lower Willamette River in January, the majority of the run ascends the falls in April through May (Myers et al. 2006). Mattson (1963) discusses the existence of a late spring-run Chinook salmon that ascended the falls in June. These fish were apparently much larger and older (presumably 6 year-olds) than the earlier part of the run. Mattson (1963) speculated that this portion of the run intermingled with the earlier-run fish on the spawning grounds and did not represent a distinct run. The disappearance of the June run in the Willamette River in the 1920s and 1930s was associated with a dramatic decline in water quality from pollution discharge in the mainstem Willamette River.

Juvenile emigration patterns of the UWR Chinook salmon are complicated, and include traits from both ocean- and stream-type life histories (Figure 4). Smolt emigrations occur both as subyearlings, consistent with ocean-type life histories, and as yearlings, consistent with stream-type life histories, in the fall and spring (Figure 4) (Schroeder et al. 2016). While data are not available for all populations, available data indicate that the Clackamas, McKenzie, and the North Santiam River populations have the greatest percentage of yearling migrants (Figure 5).

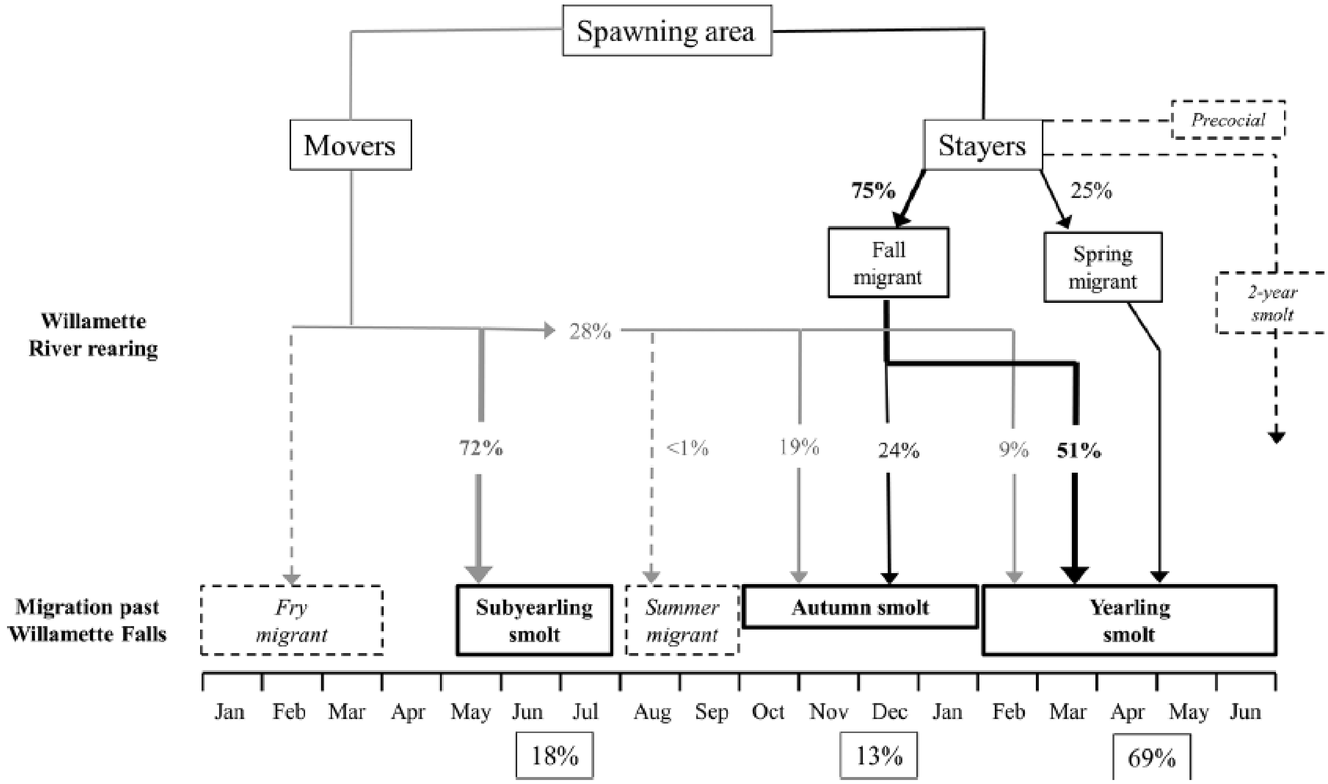


Figure 4. Juvenile spring Chinook salmon life history types in the Willamette River. Figure taken from Schroeder et al. (2016).

Ocean distribution of this ESU is consistent with an ocean-type life history, with the majority of spring Chinook caught off the coasts of British Columbia and Alaska. Spring Chinook from the Willamette River have the earliest return timing of all Chinook stocks in the Columbia Basin, with freshwater entry beginning in February. At present, adults return to the Willamette River primarily at ages 3 through 5, with age 4 fish being most abundant (Johnson and Friesen 2013). Historically, age 5 fish were most abundant, and spawning occurred between mid-July and late October. The current spawn timing of both hatchery and natural-origin UWR Chinook is September and early October (Schroeder and Kenaston 2004). Table 4 shows generalized life history timing for UWR Chinook salmon.

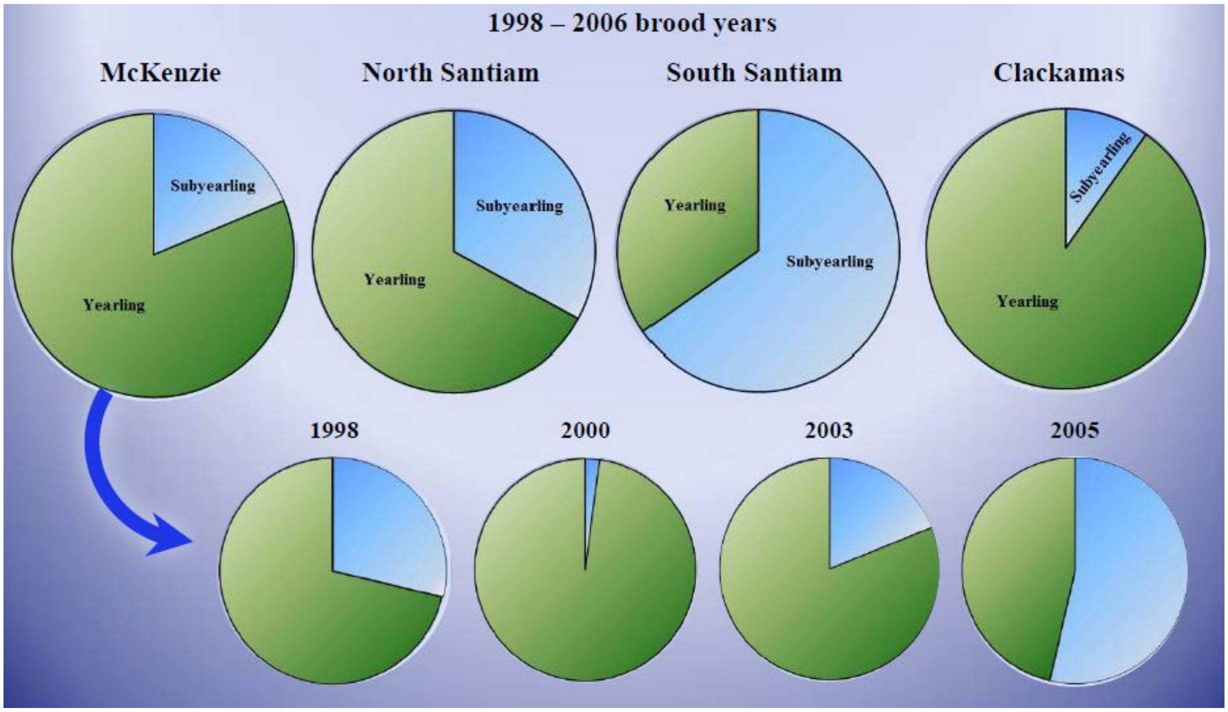


Figure 5. Proportion of returning natural-origin Chinook salmon in Willamette populations that migrated as sub-yearling or yearling smolts. Figure taken from Schroeder et al. (2013).

Table 4. Chinook salmon life history timing. Light shading represents low-level abundance and dark shading represents higher abundance. Upstream migration in this table refers to adult presence in the mainstem Willamette and tributaries.

Month:	J	F	M	A	M	J	J	A	S	O	N	D
Upstream Migration												
Spawning in Tributaries												
Intragravel Development												
Juvenile Rearing												
Juvenile Out-migration												

Abundance and Productivity

Chinook salmon counts at Willamette Falls have been undertaken since 1946, when 53,000 Chinook salmon were counted; however, not until 2002 with the return of nearly 100% marked hatchery-reared fish was it possible to inventory naturally-produced spring Chinook salmon with any accuracy. Fish returning in 2002 benefitted from very good ocean conditions and the calculated trend since then (nearly 10 percent annually) is influenced by that peak; in any event, from the last status review (NWFSC

2015), the last five years that were reviewed (2010-2014) have seen a downward trend in natural-origin adult returns, with an overall geometric mean of 9,269 fish (Figure 6, Table 5).

Adult natural-origin returns (NOR) of spring Chinook salmon to the North Santiam River, as measured at Bennett Dam and through redd and carcass surveys, have exhibited an increase in abundance in contrast to many of the other populations in the ESU and the combined count at Willamette Falls (Figure 6). Estimates of NORs at Bennett Dam from 2001-2005 ranged from 217 to 721, with a geometric mean of 514. The current 5-year geometric mean of spring-run Chinook salmon ascending Bennett Dam is 1,372 (2010-2014; Table 5).[1] Spawner abundance, based on redd count, is noticeably less than the Bennett Dam counts, 412 (2010-2014),[2] but exhibits a similar recent positive trend.

Genetic analysis of returning adults suggests that there is some contribution to escapement by the progeny of hatchery-origin spawners transported above Detroit Dam. Presently, natural-origin fish that reach the fish handling facilities at Minto are transported above the fish barrier to spawn in the North Santiam reach between Minto and Big Cliff Dam. While this "sanctuary" reach is solely populated with unmarked adult Chinook salmon, temperature and dissolved gas conditions may contribute to elevated pre-spawning mortality levels.

Spring-run Chinook salmon adults returning to the South Santiam River are monitored via redd counts and carcass recoveries in the mainstem South Santiam. Carcass recoveries are used to estimate the proportion of NOR and hatchery-origin return (HOR) spawners. In addition, direct counts of returning adults are made at the Foster fish collection facility at Foster Dam, where only NORs (unmarked fish) are passed above the dam. Foster Dam counts may be biased by conditions at the adult trap below Foster Dam, because not all fish produced upstream of the dam are attracted to the trap. Additionally, some of the NORs that enter the trap may be the offspring of spawners from reaches below the dam.

[1] Table data reflects Bennett Dam counts to 2013.
[2] Differences between the Bennett Dam counts and redd-based spawner estimates suggest that pre-spawning mortality counts and redd counts and expansions contain considerable uncertainty.

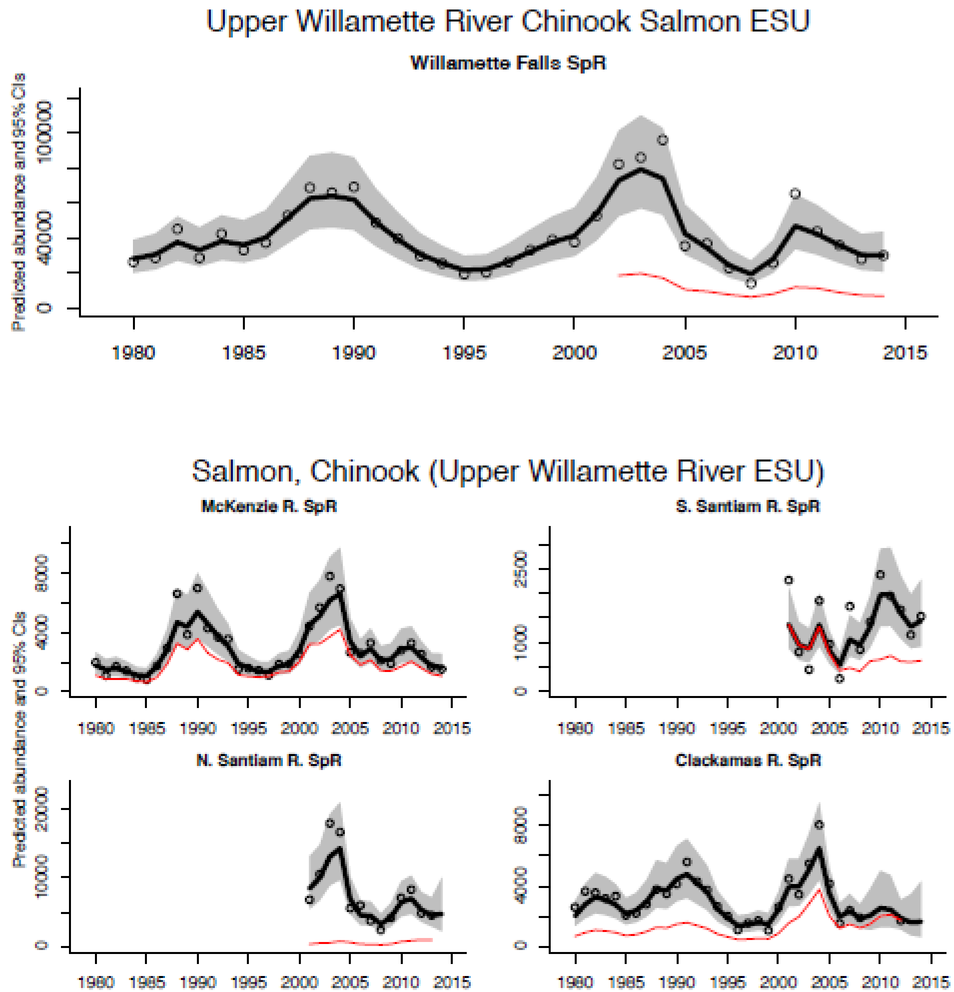


Figure 6. Estimated total (thick black line) and natural (thin red line) of spring Chinook salmon. Figure taken from NWFSC (2015).

Table 5. Five-year geometric mean of raw natural-origin spawner (NOS) counts. This is the raw total spawner count times the fraction NOS estimate, if available. In parentheses, 5-year geometric mean of raw total spawner counts is shown. NA indicates no estimates are available. Please see Table 50 in NWFSC (2015) for additional details.

Population	1990-94	1995-99	2000-04	2005-09	2010-14	% Change (2005-09 to 2010-14)
Willamette Falls Spring Chinook	(39,891)	(26,608)	20,900 (66,906)	7,567 (25,547)	9,269 (38,630)	22 (51)
McKenzie	2,134 (3,583)	1,118 (1,539)	3,241 (5,100)	1793 (2,457)	1,446 (2,254)	-19 (-8)
N. Santiam	NA	NA	408 (12,064)	290 (4,136)	852 (5,963)	194 (44)
S. Santiam	NA	NA	1,108 (1,108)	450 (883)	575 (1,686)	28 (91)

For the available Foster Dam time series from the most recent status review (2007-2014; Figure 6), the abundance of NOR spawners has exhibited a positive trend. Additional detailed information (Figure 7), shows the trend is more obvious and encouraging. It appears that juvenile passage through Foster Dam is sufficiently high to sustain a naturally-spawning aggregation above the Dam, although total abundance is still quite low. Genetic analysis indicates that the replacement rates for the 2007 and 2008 brood years were 0.96 and 1.16, respectively (O'Malley et al. 2014). Efforts are currently underway to improve both adult collection and juvenile downstream passage at Foster Dam.

The status of spring-run Chinook salmon in the McKenzie River is monitored through both dam counts at Leaburg Dam, and through extensive spawner surveys (redd and carcass counts) throughout the basin. Genetic pedigree analysis of transported adults provides further information on the productivity of stream reaches above Cougar Dam, where fish are trapped and hauled above the dam to historic spawning areas. Numerous long-term abundance and life-history data sets exist for this population.

Overall, McKenzie River spring-run Chinook salmon natural-origin abundance has declined to levels not seen since the time of listing. Genetic pedigree based estimates of cohort replacement rate for the 2007 and 2008 brood years from hatchery adults released above the Cougar Dam were both below replacement, 0.41 and 0.31, respectively (Banks et al. 2014). Juvenile tagging studies suggest that total survival through Cougar Reservoir and Dam project has been poor (Beeman et al. 2013). Overall, redd counts for the entire McKenzie River have declined over the last five years, suggesting a systematic limiting factor. Both short-term and long-term trends for the entire population are negative (Figure 6, Table 5).

Chinook salmon in the Middle Fork Willamette River are monitored through redd and carcass surveys throughout much of the basin. In addition, fish are enumerated at both the Dexter Trap and at the Fall Creek trap below Fall Creek Dam. Presently, unmarked fish (presumed naturally produced) are transported above Fall Creek Dam. From 2006-2014, the pHOS for fish transported above Fall Creek Dam has averaged 4.6 percent (±1.5%), while predominately marked hatchery fish are transported above

Dexter Dam to the North Fork Middle Fork Willamette River and Hills Creek (above Hills Creek Dam reservoir). Fish transported above Dexter Dam are part of an experimental program to assess the potential for a sustained trap and haul process around the dams.[3] Although the transported hatchery-origin adults successfully reproduce, in the absence of adequate downstream juvenile fish passage facilities it is unlikely that this program currently provides any substantial direct benefit to population abundance or productivity. Alternatively, the progeny of fish passed above Fall Creek Dam have a much higher likelihood of successful downstream passage via the complete drawdown of Fall Creek Reservoir every fall. Based on returns to Fall Creek Dam, adult-to-adult return rates[4] have averaged 0.97 from 2010-2014.

With the exception of spawning reaches above Fall Creek Dam, the remainder of the currently accessible portion of the Middle Fork Willamette Basin, below Dexter Dam and Fall Creek Dam, is subject to conditions that result in a very high pre-spawning mortality and very poor incubation and juvenile survival. Natural-origin spawners above Fall Creek averaged 138 ±40 fish from 2002-2014, with a slightly positive long-term trend. Estimates of pre-spawning mortality can be quite high in some years for the fish transported above Fall Creek Dam.[5] Of the hatchery-origin adults transported above Dexter Dam, pre-spawning mortalities have been high for fish transported to Hills Creek above Hills Creek Dam (49.3% 2012-14) compared to the North Fork Middle Fork Willamette River (39.0%, 2012-2014). Longer transportation times to Hills Creek are thought to be partially responsible for these differences (Naughton et al. 2015).

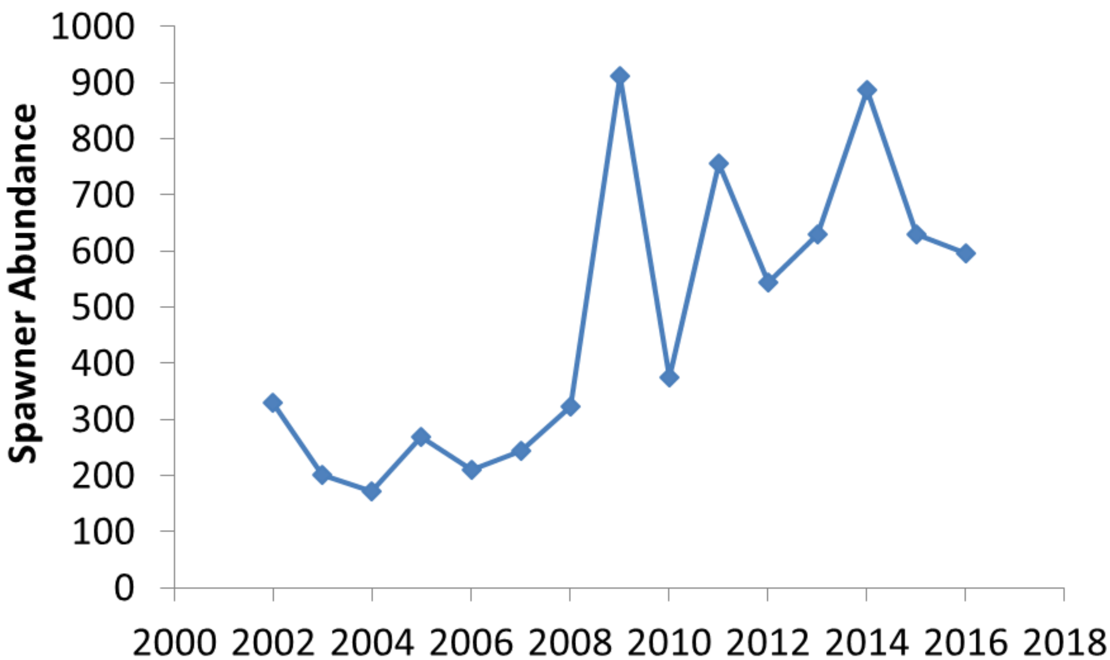


Figure 7. South Santiam natural-origin spawner escapement (basinwide). Figure taken from Sharpe (2017).

[3]As a secondary benefit, the progeny of transported fish provide forage for Bull Trout.
[4]Adult-to-adult rates calculated as NOR adults returning to Fall Creek Dam divided by the average number of adults (NOR and HOR) passed above Fall Creek Dam four and five years previously.
[5]Pre-spawning mortality is estimated from recovered carcasses and may be biased depending on the number and timing of surveys, the number of carcasses recovered, and the seasonal river conditions.

Spatial Structure

For the Upper Willamette Spring Chinook ESU, most of the historic habitat is not accessible because of large dams (with the exception of the Clackamas River basin). In some basins (e.g., North Santiam, South Santiam, and Middle Fork Willamette), it is estimated that the inaccessible habitat produced most of the spring Chinook salmon (McElhany et al. 2007).

Based on the information above, the Clackamas River has the lowest spatial structure risk rating, followed by the McKenzie and Molalla rivers. The North Santiam, South Santiam and Middle Fork river basins are considered at high or very high risk based on spatial structure (NWFSC 2015).

Diversity

Diversity in the sense of the VSP parameters is discussed in terms of life history and genetic components. The risk of extinction based on spatial structure and diversity did not change in the latest status update (NWFSC 2015). All populations remain at medium to high risk (please see below).
As discussed above, UWR Chinook salmon show some of the most complicated juvenile migration patterns. Juvenile life-history tactics are characterized by patterns of holding, rearing and downstream movement from time of emergence in natal streams to saltwater entry of smolts. Billman et al. (2014) found that in the upper Willamette River, the expression of life-history tactics is associated with where juveniles rear in the basin with fish rearing in downstream locations generally completing seaward migrations earlier in life than fish rearing in upstream locations. They found morphological differences between autumn migrants and yearling smolts that were similar to differences between parr rearing in downstream and upstream reaches, indicating that body morphology is correlated with life-history tactics. Autumn migrants and parr from downstream sampling sites had deeper bodies, shorter heads and deeper caudal peduncles compared with yearling smolts and parr from the upstream sampling site.

The other major factor that is considered when assessing the diversity of a population is genetic diversity. One factor in understanding genetic diversity risk is the influence of hatchery fish on a natural population. Hatchery fish that spawn in the wild can interbreed with natural-origin fish and affect the genetic integrity of the natural population. Depending upon hatchery broodstock management, hatchery fish that interbreed with natural fish can reduce the productivity and long-term fitness of the wild population to varying degrees from inbreeding and outbreeding depression. Prior to release from the hatchery, hatchery fish experience different selection pressures than fish in the wild. This hatchery-influenced selection (often referred to as domestication) occurs in hatchery fish, which may alter the genetic make-up of the natural-origin population if there is substantial interbreeding. Consequently, when hatchery fish interbreed in the wild with naturally produced fish, genetic changes may occur to the wild population depending upon the demographic condition of the natural-origin population, and level of straying and interbreeding. Johnson and Friesen (2013) found weak, but significant genetic structure among Chinook salmon populations within the UWR and almost no evidence for genetic divergence between hatchery and natural-origin populations within subbasins.

Table 6. The future target and current estimate of the percentage of spring Chinook salmon hatchery-origin spawners (pHOS) in Upper Willamette River sub-basins where spring Chinook salmon are released. Information on targets and current estimate from HGMPs and ODFW and NMFS (2011).

Sub-basin	Percentage of hatchery-origin spawners in the wild (pHOS)		Comment
	Future Target	**Current estimate**	
North Santiam	< 10% pHOS upstream of Detroit Dam and ≤ 21% downstream of dam	100% upstream of Detroit; 66% downstream of dam	Current estimate is the 2002-2017 average from C. Sharpe, ODFW, personal communication
South Santiam	<30% in the natural population of the South Santiam River (0% above Foster, <80% below Foster)	65% (total basin); 0-32% upstream of Foster Dam; 76% downstream of Foster Dam	Current estimate is the 2007-2017 average from C. Sharpe, ODFW, personal communication. pHOS is much greater downstream of Foster Dam (76%) and much lower upstream of the dam (32%).
McKenzie	< 10% for total natural spawning population in the McKenzie River subbasin, excluding the South Fork McKenzie Basin above Cougar Dam and the McKenzie Basin above Trail Bridge Dam.	35% (total basin); 78% downstream of Leaburg Dam, and 26% upstream of dam	Current estimate is average from 2002-2017C. Sharpe, ODFW, personal communication
Middle Fork Willamette	<10% in Fall Creek Basin and upstream of Dexter and Lookout Point dams	81% downstream of Dexter Dam (2002-2017), 19% upstream of Fall Cr. Dam (2002-2017), 98% North Fork Middle Fork River (2002-2015), and 99% upstream of Hill Cr Dam (2012-2015)67%	Current pHOS estimate is average between 2002-2013 from Table 2.2.2-2 of the HGMP for the area between Dexter and Jasper, including Fall Creek.

Overall Status of ESU

In the latest status review of the UWR, the risk ratings stayed the same as the previous status review, but the measurements of the VSP scores showed that there is some decline in the scores (Figure 8). As stated by NWFSC (2015):

> *Although there has likely been an overall decrease in the VSP status of the ESU since the last review, the magnitude of this change in not sufficient to suggest a change in risk category. Given*

current climatic conditions and the prospect of long-term climatic change, the inability of many populations to access historical headwater spawning and rearing areas may put this ESU at greater risk in the near future.

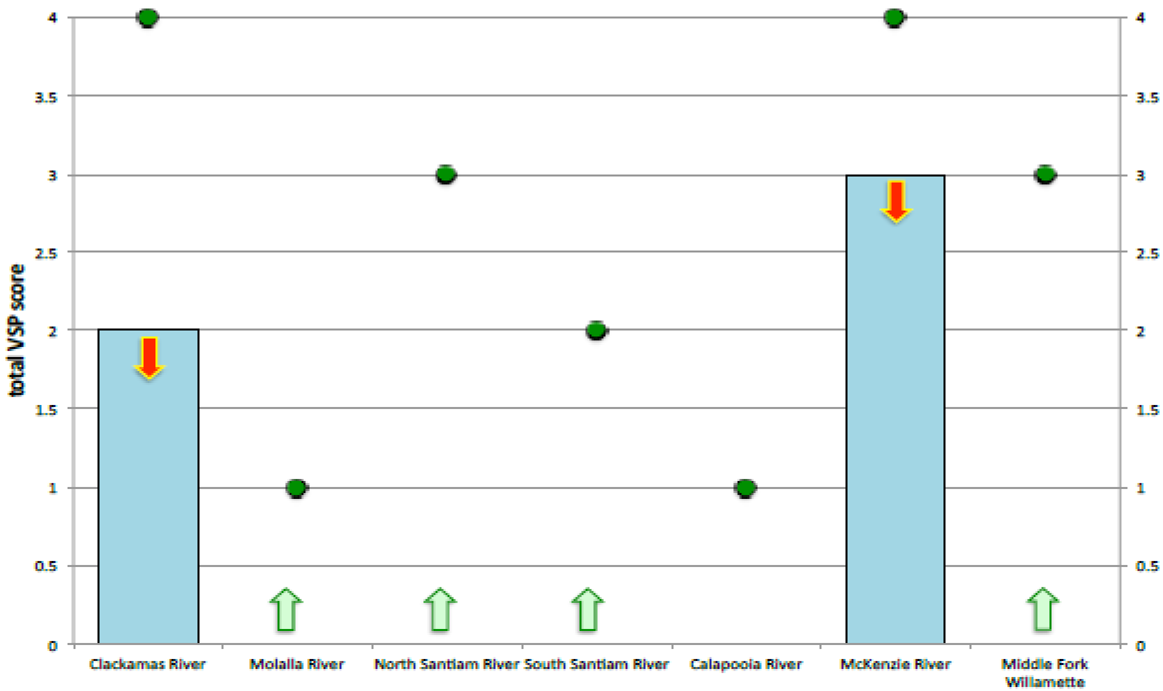


Figure 8. VSP status of spring Chinook populations in the Upper Willamette ESU. Green circles show recovery goal. Blue bars show previous VSP status. Red and green arrows show general direction of current status. Figure taken from NWFSC (2015).

Current Limiting Factors

The ESA recovery plan (ODFW and NMFS 2011) identifies the current limiting factors/threats for each of the populations in the Upper Willamette spring Chinook ESU. In summary, habitat loss and degradation associated with the Federal dams is currently limiting production in the North Santiam, South Santiam, McKenzie, and Middle Fork Willamette populations. For the Molalla and Calapooia populations, habitat loss and degradation associated with land management and urbanization is currently the most pressing threat limiting productivity. This habitat loss and degradation has long-term implications for genetics and the capability of the ESU to recover (Thompson et al. 2019).

Fishery harvest impacts have been substantially reduced since ESA listing and are no longer impeding the recovery of the ESU (ODFW and NMFS 2011). Hatchery programs pose risks and benefits to spring Chinook salmon from genetic introgression of hatchery fish in wild populations (risk) to increased abundance from reintroduction above the dams using hatchery fish (benefit). Predation in the reservoirs, mainstem Willamette River, Willamette Falls, lower Columbia River and estuary by non-native fish species, marine mammals, Caspian terns and cormorants prey upon both adult and juvenile Chinook salmon at high levels.

Table 7 describes the key limiting factors associated with habitat for spring Chinook and winter steelhead within the UWR that were described in ODFW and NMFS (2011). Secondary limiting factors and those key limiting factors that occur outside the UWR are not shown in Table 7.

Table 7. Limiting factors and threats for both Upper Willamette spring Chinook salmon and winter steelhead (unless specified for a species or population under threats). Based on tables 5-7, 5-8, and 5-9 of ODFW and NMFS (2011).

Limiting Factor	Threat
Habitat access (impaired downstream passage of juveniles at water control facilities, leading to direct and delayed mortality)	Subbasin dams
Habitat access (impaired adult access to holding and spawning habitat due to migration barriers)	Subbasin dams, road crossings, small dams, diversion structures
Predation (multiple sources)	For South Santiam winter steelhead: (by native and non-native fish species that are not associated with hatchery programs). Documented abundance of largemouth bass in Green Peter reservoir. Emerging concern of pikeminnow, centrarchid, and walleye impacts in other reservoirs and warm water reaches
Physical habitat quality (flood control/hydropower sources)	For Middle Fork Willamette spring Chinook salmon: impaired gravel and wood recruitment leading to lack of incubation gravel below Middle Fork Willamette flood control facilities
Physical habitat quality (impaired habitat complexity and diversity)	For spring Chinook salmon: Land use practices including stream cleaning, straightening and channelization, revetments, riparian area degradation, lack of large wood recruitment, and/or loss of floodplain connectivity and access to off-channel habitat; land use practices (non-hydro) resulting in loss of summer holding pools of sufficient depth and structure, aggravated by human harassment issues: contributing to high pre-spawn mortality, loss of off-channel and side channel areas for resting and feeding as a consequence of floodplain development and channelization and loss of seasonal and shallow rearing habitat due to dredging, filling and placement of culverts in streams.
Water quality/quantity (effects on temperature within subbasins)	For spring Chinook salmon: high summer water temperatures due to water and land use practices that impair riparian condition shading function, or practices that reduce summer streamflows (e.g., water withdrawals for agricultural, industrial, or municipal uses: leading to reduced growth and survival of juveniles; elevated fall water temperature below NS flood control facilities due to flow alterations: leading to premature hatching/emergence of CHS

Limiting Factor	Threat
	produced below dams; elevated water temperatures throughout the adult migration and holding window due to water land use practices that impair riparian condition shading function, or practices that reduce streamflows (e.g., water withdrawals for agricultural, industrial, or municipal uses, high temperatures and exposure to contaminants in urban areas such as the lower Willamette River.) contributing to poor adult condition and high pre-spawn mortality; elevated fall water temperature below MF Willamette flood control facilities due to flow alterations: leading to premature hatching/emergence of CHS produced below dams.
Water quality (input of toxins)	For spring Chinook salmon: Non-point sourcing of inputs of agricultural chemicals used throughout the Columbia and Willamette river basins; Point and non-point sourcing of runoff and lack of treatment from urban, industrial, rural and agricultural practices, including presence of legacy contaminants in sediments downstream of industrial and urban areas.
Hydrograph/water quantity (insufficient stream flows and floodplain storage from land use practices)	For winter steelhead: reduced mainstem Willamette flows due to spring reservoir filling at subbasin flood control facilities: leading to increased water temperature and subsequent disease vulnerability. For spring Chinook salmon and winter steelhead: reduced occurrence of peak flows that maintain and create habitat; resulting in decreased channel complexity and habitat diversity in lower subbasins and mainstem Willamette River.

To mitigate for the lack of passage at subbasin dams, reintroduction efforts have been implemented (NMFS 2008, Evans et al. 2015, Sard 2016, O'Malley et al. 2017a, O'Malley et al. 2017b). The Action Agencies in NMFS (2008) have been working with other agencies to investigate, design and construct juvenile fish passage facilities at many of the dams in the UWR. These efforts are on-going and are needed to increase the viability of the various populations within the UWR spring Chinook ESU.

Prespawning mortality of adult spring Chinook salmon has been a factor likely limiting productivity that has been a major focus of stakeholders in the UWR. Some populations have experienced over 80% loss of adults prior to spawning (Figure 9). Poor water conditions and disease outbreaks from overcrowding below the dams has been the primary cause of the excessive mortality rates of adult UWR spring Chinook salmon (Bowerman et al. 2018). When spring Chinook have natural access to headwater habitat areas where the fish can over-summer in natural habitat, mortality rates have been very low (see Upper McKenzie River in Figure 9).

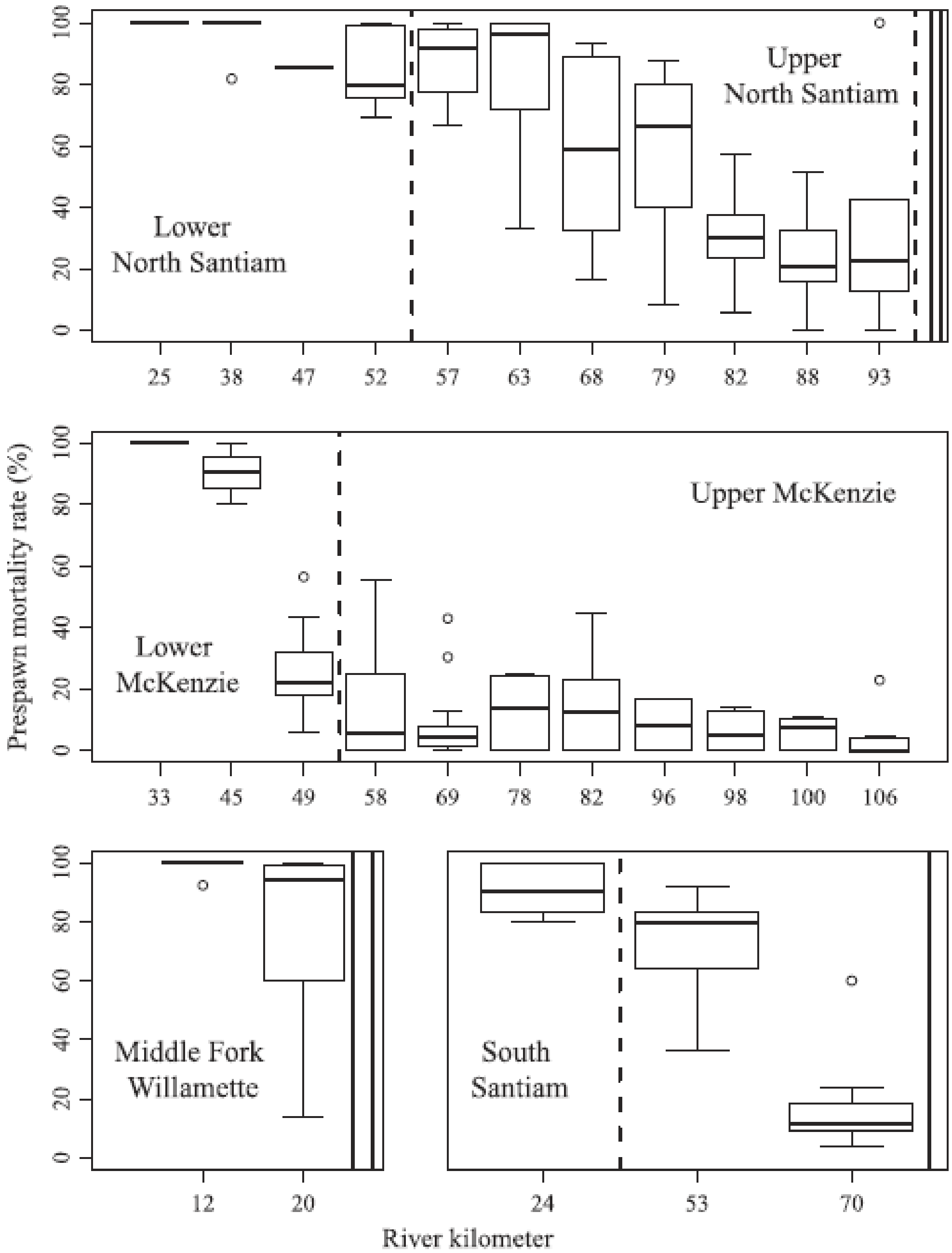


Figure 9. Observed site-specific female prespawn mortality rates (%) of spring Chinook salmon from 2002 through 2015 ordered by approximate river kilometer (proceeding upstream) from the main-stem Willamette River. Solid vertical lines represent the location of high-head (>20 m hydraulic head) dams and dashed vertical lines indicate low-head (<20 m) dams. Boxplots show medians, quartiles, 10th and 90th percentiles, and outliers. Distances are not to scale. Figure 4 from Bowerman et al. (2018).

2.2.1.2 Upper Willamette Winter Steelhead DPS

The UWR steelhead distinct population segment (DPS) includes all naturally spawned anadromous winter-run steelhead populations in the Willamette River, Oregon, and its tributaries upstream from Willamette Falls to the Calapooia River (inclusive). There are no hatchery programs included in this DPS (NMFS 2006). The hatchery summer-run steelhead that occur in the Willamette Basin are an out-of-basin stock and not considered part of the DPS.

The WLCTRT identified four historical independent populations within this DPS, all of which are part of one major population group, as shown in Figure 10 (Myers et al. 2006). Although spawning winter steelhead have been reported in the west-side tributaries to the Willamette River, these tributaries are not considered to have constituted an independent population historically (Myers et al. 2006). These tributaries may, however, serve as a population sink for the DPS, meaning that, although they do not sustain (and are not believed to have historically sustained) an independent population, winter steelhead are currently present and in some years may be relatively abundant (Jepsen et al. 2015).

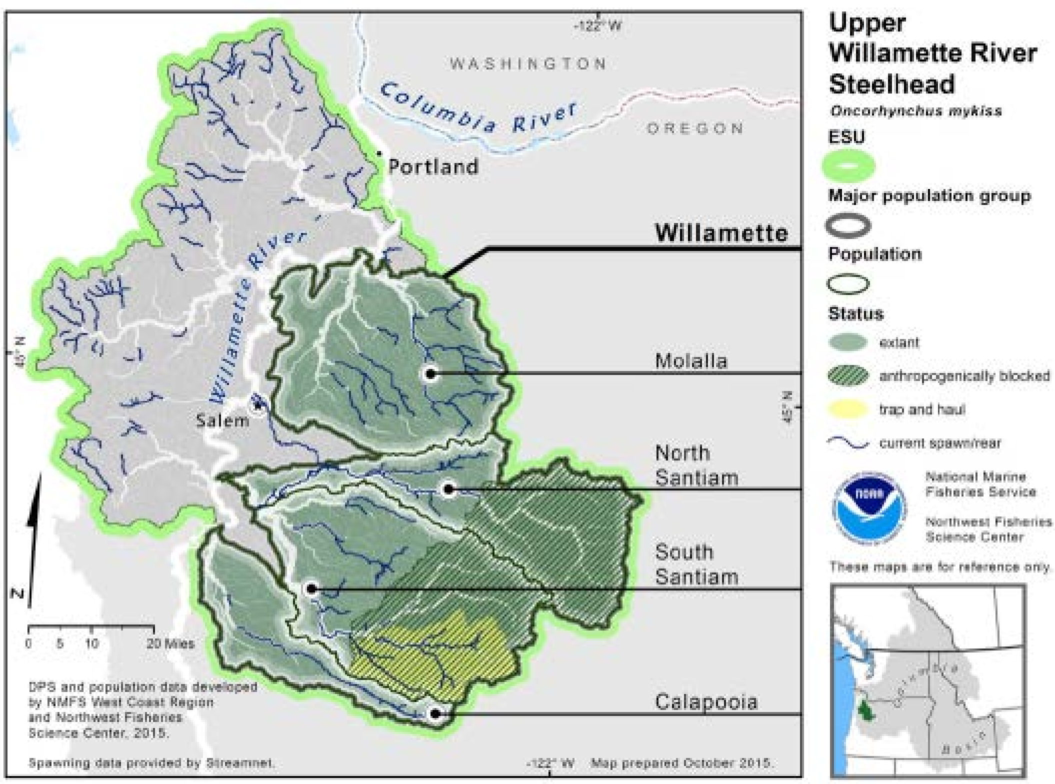


Figure 10. Map of Upper Willamette River Winter steelhead DPS, showing independent populations and major population groups Figure taken from NWFSC (2015).

Life History

The run timing of UWR steelhead is a legacy of the fact that before construction of a fish ladder at Willamette Falls in the early 1900s, flow conditions allowed steelhead to ascend Willamette Falls only during the late winter and spring. As a result, the majority of the UWR winter steelhead run return to freshwater in January through April, pass Willamette Falls from mid-February to mid-May, and spawn in March through June, with peak spawning in late April and early May. Compared to spring Chinook salmon, UWR steelhead can access more spawning habitats and typically spawn in smaller, higher gradient streams and side channels. Table 8 summarizes the generalized life history traits for UWR steelhead. UWR steelhead may spawn more than once, although the frequency of repeat spawning is relatively low. Repeat spawners are predominantly females and usually spend one-year post spawning in the ocean and spawn again the following spring.

Juvenile steelhead rear in headwater tributaries and upper portions of the subbasins for one to four years (most often two years), then as smoltification proceeds in April through May, migrate quickly downstream through the mainstem Willamette River and Columbia River estuary and into the ocean. UWR steelhead typically forage in the ocean for one to four years (most often two years) and during this time are thought to migrate north to Canada and Alaska and into the North Pacific including the Alaska Gyre (Myers et al. 2006).

Table 8. UWR steelhead life history timing. Light shading represents low-level abundance and dark shading represents higher abundance (after USACE 2007, Table 4-4).

MONTH:	J	F	M	A	M	J	J	A	S	O	N	D
Upstream Migration												
Spawning in Tributaries												
Intragravel Development												
Juvenile Rearing												
Juvenile Out-migration												

Abundance and Productivity

Populations in this DPS have experienced long-term declines in spawner abundance (Figure 11) and poor ocean survival (Kendall et al. 2017). Between 1985 and 2016, abundance for the DPS has ranged from 999 to 13,452, and averaged 4,707 (Figure 11). In the last 10 years (2007-2016), winter steelhead spawners upstream of Willamette Falls have ranged from 1,315 to 4,304 and averaged 3,140 (Figure 11). The long-term (1985 to 2016) abundance trend is negative for total winter-run steelhead counts (Figure 11).

In the Molalla River, between 1985 and 2016, the number of spawning winter-run steelhead have ranged from 353 to 5,115, averaging 1,664 (Figure 12). In the last ten years, (2007-2016), winter-run steelhead spawners in the Molalla River have ranged from 846 to 2,120, averaging 1,287 (Figure 12). The geometric mean of winter-run steelhead spawners in the Molalla River has ranged from 631 to 3,371 for the period between 1985 and 2016, and between 1,010 and 1,443 for the last ten years (Figure 12).

In the North Santiam River basin, winter-run spawners have ranged from 238 to 3,330, and averaged 1,129 from 1985 to 2016 (Figure 12). For the period between 2007 and 2016, winter-run steelhead spawners in the North Santiam River basin have ranged from 351 to 1,437, and have averaged 777 (Figure 12). The geometric mean of winter-run steelhead spawners in the North Santiam River basin has ranged from 543 to 2,182 between 1985 and 2016, and from 543 to 1,031 for the last ten years (Figure 12).

In the South Santiam River basin, winter-run steelhead spawners have ranged from 81 to 5,805, averaging 1,559 between 1985 and 2016, and from 81 to 1,314, averaging 870 in the last ten years (Figure 12). The geometric mean of winter-run steelhead spawners in the South Santiam River basin has ranged from 494 to 3,881 between 1985 and 2016, and from 518 to 1,306 for the last ten years (Figure 12).

In the Calapooia River basin, winter-run steelhead spawners have ranged from 36 to 1,125, averaging 354 between 1985 and 2016, and from 35 to 331, averaging 206 in the last ten years (Figure 12). The geometric mean of winter-run steelhead spawners in the Calapooia River basin has ranged from 105 to 774 between 1985 and 2016, and from 119 to 330 for the last ten years (Figure 12).

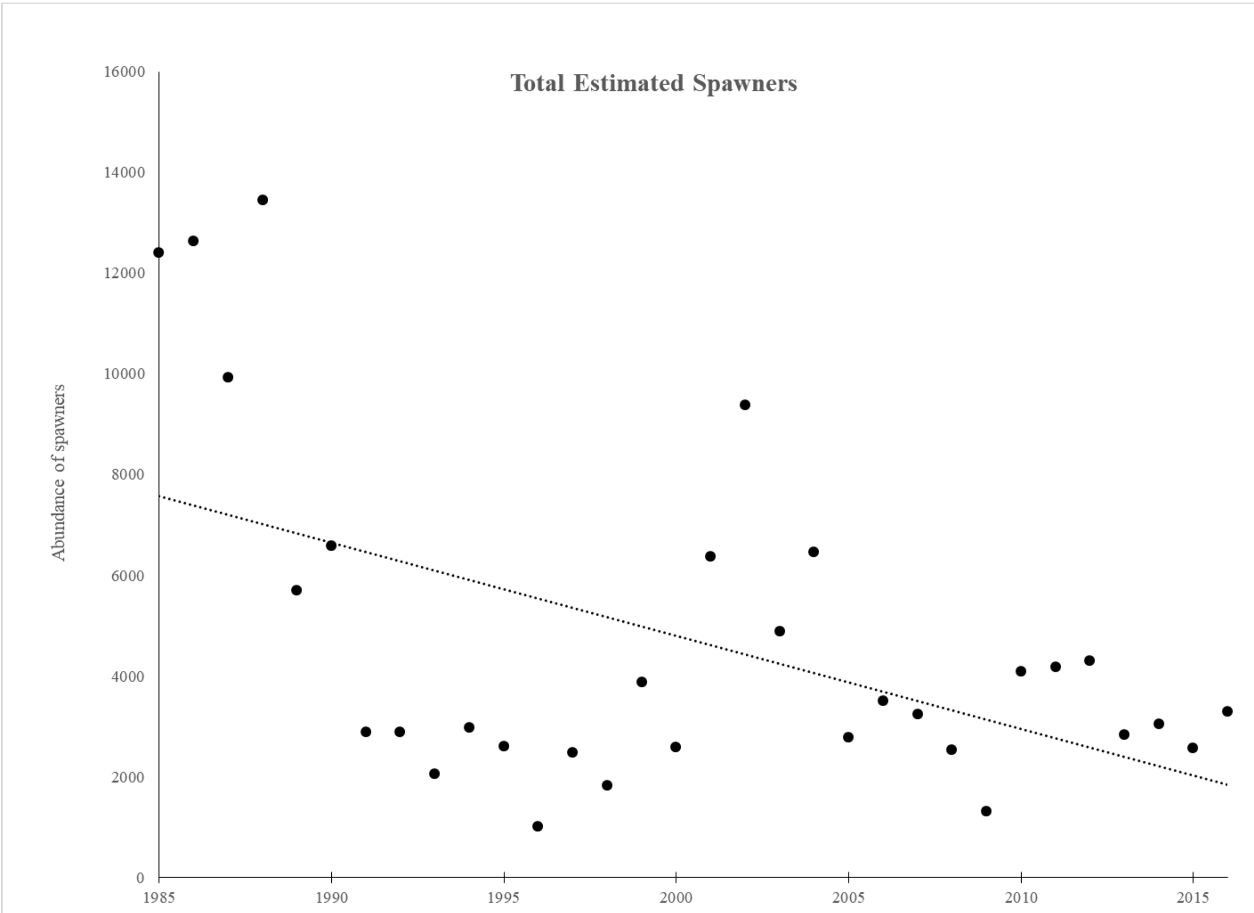


Figure 11. Estimated total number of UWR winter-run steelhead spawners from 1985-2016 (data from ODFW).

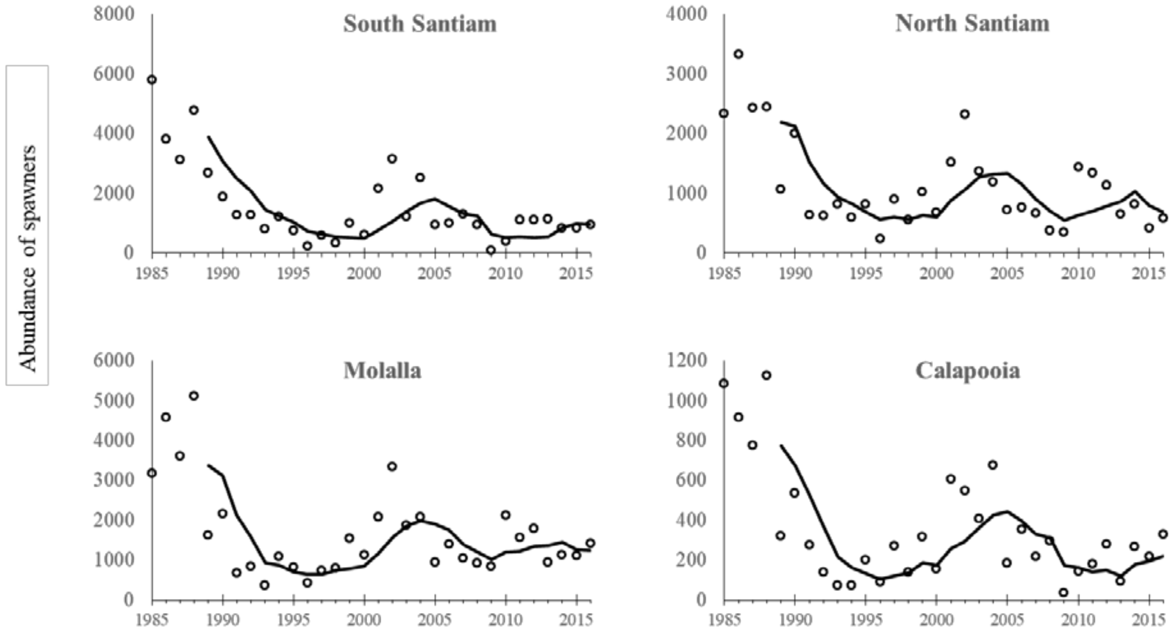


Figure 12. Estimated abundance of winter-run steelhead spawners, 1985-2016 in the Upper Willamette River. Open circles are the yearly estimates and the solid line is the five-year geometric mean (data from ODFW).

Spatial Structure

The largest factor affecting spatial structure is the lack of access to historically important spawning and rearing habitat that occurs upstream of dams on the North and South Santiam rivers. Currently, unmarked winter steelhead are transported upstream of Foster Dam on the South Santiam River, which assists in spatial structure and once juvenile passage is provided, should increase productivity. Spawning and rearing habitat downstream of the dams is not thought to have been the major spawning areas prior to their construction and is believed to be of lesser quality than the habitat upstream of the dams, in general (ODFW and NMFS 2011).

Diversity

Winter steelhead in the UWR exhibit diverse life histories typical of steelhead (Quinn 2005). Juvenile steelhead exhibit a range of residence time in freshwater from one to three years. Adult steelhead return after two years in saltwater. The genetic structure of steelhead populations in the UWR has been studied recently. Van Doornik et al. (2015) found genetic structure among *O. mykiss* species sampled throughout the UWR (Figure 13). Winter steelhead occupying the eastside rivers draining the Cascade mountains were distinct from steelhead occupying westside rivers in the Coast Range mountains (Figure 13). Resident rainbow trout occupying the McKenzie and Middle Fork Willamette rivers were distinct from steelhead.

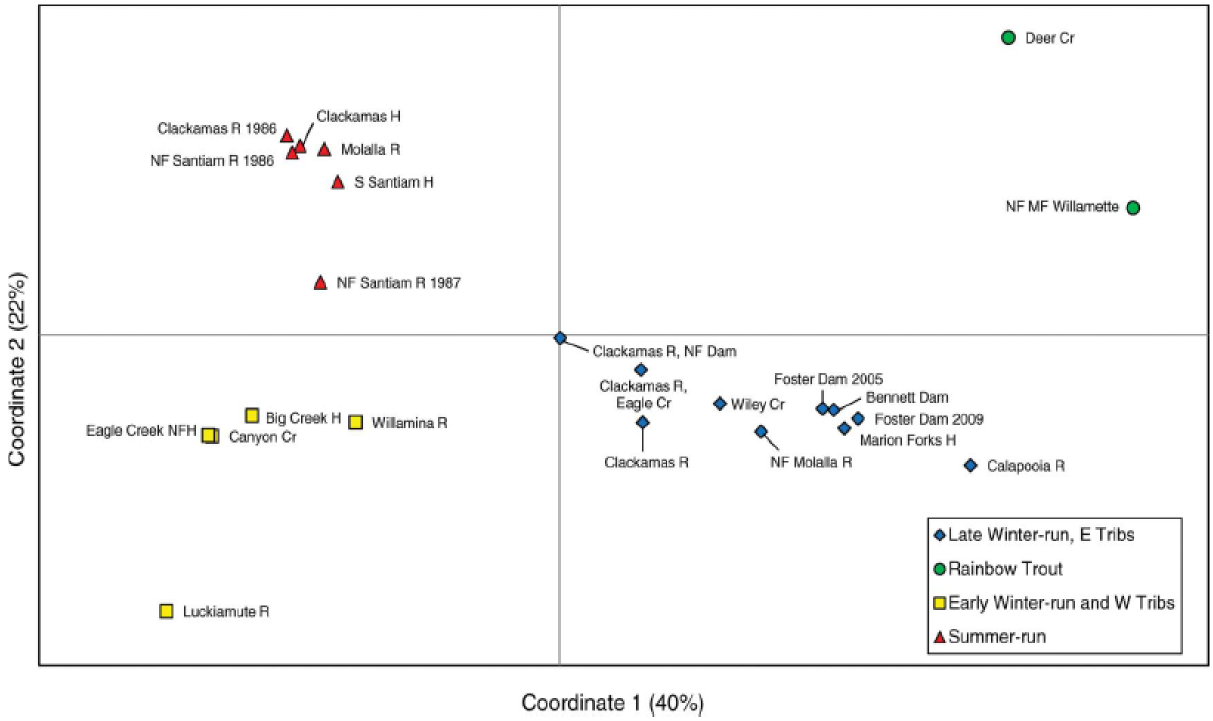


Figure 13. Principal components plot of genetic distances among Willamette River steelhead and rainbow trout samples. Figure taken from Van Doornik et al. (2015).

Releases of hatchery winter steelhead were terminated by 1998. Releases occurred throughout the UWR using hatchery stocks from a local, winter steelhead founded in the North Santiam and other stocks outside of the UWR (Big Creek, Alsea, Cedar, Siletz). Past releases of winter steelhead from UWR stocks outside the UWR are shown in Table 9. Currently, the only steelhead program in the UWR releases summer steelhead originally taken from Skamania Hatchery on the Washougal River from the Lower Columbia River DPS. Past releases of hatchery summer steelhead occurred in the Molalla River in 1972 and from 1980-1996 for an average annual release of 45,000 smolts. Hatchery summer steelhead have been released in the North Santiam and South Santiam rivers since 1966 and 1968, respectively. Summer steelhead and winter steelhead remain genetically distinct (Van Doornik et al. 2015; Johnson et al. 2018).

Table 9. Releases of hatchery winter steelhead from hatchery stocks originating from outside of the UWR. The majority of releases came from Big Creek hatchery stock, but other stocks included Alsea, Cedar, and Siletz hatchery stocks. These releases represent the entire period of record for winter steelhead releases from these stocks in the UWR (Buchanan et al. 1979; Busby et al. 1996).

Location	Time Span of Releases	Number of Years	Total Released	Average per year
Gales Creek	1978-1997	20	431,044	21,552
Tualatin	1970-1998	28	326,754	11,670
Willamina	1978-1982	5	108,691	21,738
Yamhill	1974-1982	9	419,308	46,590
Rickreal	1982-1983	2	64,800	32,400
Molalla	1970-1996	29	2,128,132	73,384
North Santiam	1966-1971	3	160,046	53,349
South Santiam	1965-1969	5	201,900	40,380
McKenzie	1967-1986	6	274,646	45,774
Fall Creek	NA	NA	439,638	NA

Overall Status of DPS

In the latest status review of the UWR winter steelhead DPS, the risk ratings stayed the same as the previous status review, but the measurements of the VSP scores showed that there is some decline in the scores (Figure 14). As stated by NWFSC (2015):

> *While the diversity goals are partially achieved through the closure of winter-run steelhead hatchery programs in the Upper Willamette River, there is some concern that the summer-run steelhead releases in the South Santiam River may be influencing the viability of native steelhead in the North and South Santiam rivers. Overall, none of the populations in the DPS are meeting their recovery goals . . .*

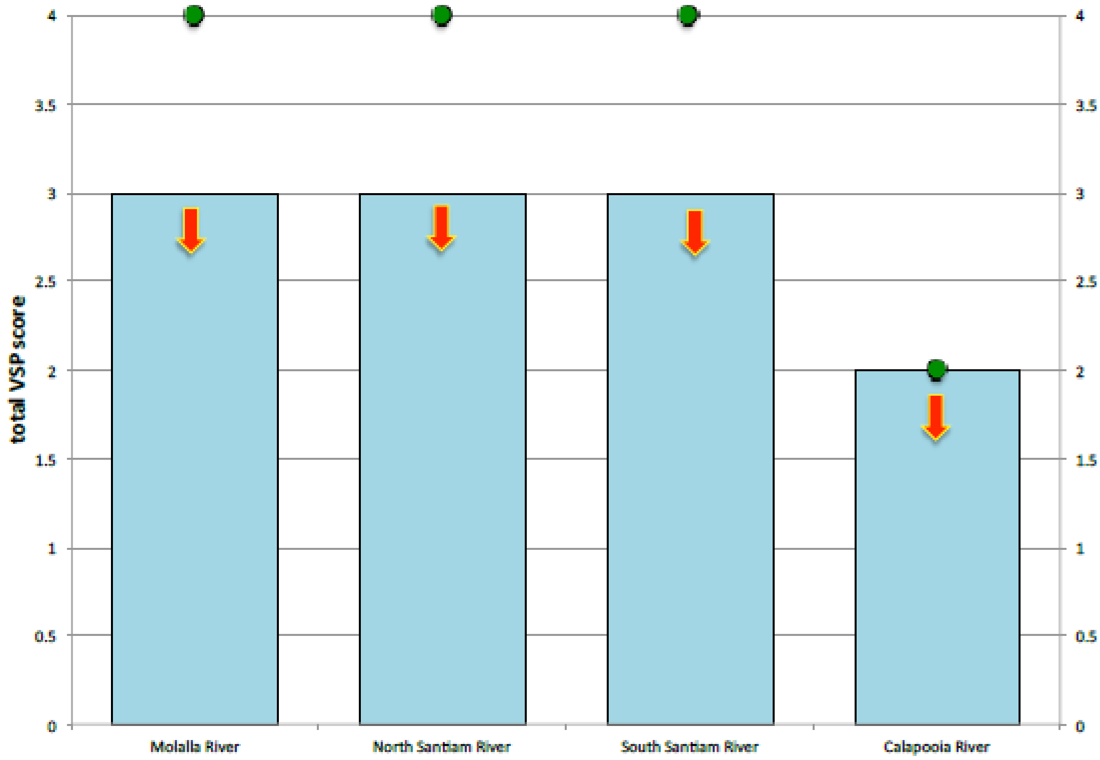


Figure 14. VSP status of demographically independent populations in the Upper Willamette winter-run steelhead DPS. Green circles show recovery goal. Blue bars show previous VSP status. Red and green arrows show general direction of current status. Figure taken from NWFSC (2015).

Current Limiting Factors

The ESA recovery plan (ODFW and NMFS 2011) identifies the current limiting factors/threats for each of the four populations in the Upper Willamette winter steelhead DPS. In summary, habitat loss and degradation associated with the Federal dams is currently limiting production in the North Santiam and South Santiam populations. For the Molalla and Calapooia populations, habitat loss and degradation associated with land management and urbanization is currently the most pressing limiting factors/threats. Fishery harvest impacts are not impeding the recovery of the DPS because all fisheries intercepting winter steelhead are entirely catch and release and overall impacts are less than 5% for each population. There are no hatchery programs for winter steelhead, but hatchery summer steelhead pose risks to listed winter steelhead from hybridization and ecological interactions. Predation in the reservoirs, mainstem Willamette River, Willamette Falls, lower Columbia River and estuary by non-native fish species, marine mammals, Caspian terns and cormorants predate upon both adult and juvenile steelhead at high levels. Table 7 describes the key limiting factors associated with habitat for spring Chinook and winter steelhead within the UWR that were described in ODFW and NMFS (2011). Secondary limiting factors and those key limiting factors that occur outside the UWR are not shown in Table 7.

Three marine mammal species (Steller sea lion, California sea lion, and harbor seal) forage on steelhead (and salmon) in the Willamette River. In recent years, there has been a large increase in the number of

California sea lions and Steller sea lions that are entering lower Columbia and feeding on adult salmon and steelhead.

Some of the sea lions that enter the Columbia River make their way up the Willamette River and feed on adult salmonids attempting to find passage over Willamette Falls. In the mid-1990s observations of California sea lions in the Willamette River began to increase where they often foraged for winter steelhead and spring Chinook salmon below the fishways at Willamette Falls (128 miles upstream from the ocean). ODFW began monitoring sea lion occurrence and predation on salmonids at the falls beginning spring 1995. Continuing through 2003, results from these observations showed that sea lions at Willamette Falls generally numbered a dozen or fewer animals each year, and predation losses were generally a few hundred fish or less. In addition, the trend in predation activity appeared to be flat or declining whereas winter steelhead runs were increasing. Anecdotal information and informal surveys conducted by Portland State University suggested that after ODFW surveys ended in 2003, predation of salmonids at Willamette Falls was continuing to increase (Wright et al. 2016). ODFW began monitoring sea lion predation again in 2014.

ODFW estimated that the number of winter steelhead killed by sea lions in 2014, 2015, and 2016 is 780, 557, and 915 respectively. Falcy (2017) used population viability analysis (PVA) to estimate the effects of sea lion predation on the four independent populations of winter-run steelhead upstream of Willamette Falls. He found that the probability of extinction (in a 100 year period that the model used) rose as the number of sea lions rises (Table 10).

Table 10. Probabilities of quasi-extinction over a 100-year period in four populations of Willamette River winter steelhead under four different scenarios. Scenarios with sea lions assume that the predation mortality estimated during that year will continue indefinitely. The lowest predation rate was observed in 2015 and the highest predation rate was observed in 2017 (Table 1 from Falcy (2017)).

Scenario	Population			
	N. Santiam	S. Santiam	Calapooia	Molalla
No Sea Lions	0.015	0.048	0.993	0.000
2015 Sea Lions	0.079	0.158	0.998	0.001
2016 Sea Lions	0.274	0.335	0.999	0.021
2017 Sea Lions (preliminary estimate)	0.644	0.599	0.999	0.209

2.2.1.3 Lower Columbia River Chinook Salmon, Coho Salmon, and Steelhead

These species are included in the rangewide species status section here because these fish are affected by the proposed action. Hatchery smolts released in the UWR emigrate through the Lower Columbia River and may affect these species through ecological interactions. The Lower Columbia River (LCR) is generally considered the area downstream of the former site of Celilo Falls including all the tributaries flowing into the Columbia River and the Columbia River estuary and plume. This is now considered the area downstream of the Dalles Dam. Here we review the species status affected by the proposed action in this geographical stretch of the Columbia River.

Life History

Chinook salmon have a wide variety of life-history patterns that include: variation in age at seaward migration; length of freshwater, estuarine, and oceanic residence; ocean distribution; ocean migratory patterns; and age and season of spawning migration. Two distinct races of Chinook salmon are generally recognized: "stream-type" and "ocean-type" (Healey 1991; Myers et al. 1998). Ocean-type Chinook salmon reside in coastal ocean waters for three to four years before returning to freshwater and exhibit extensive offshore ocean migrations, compared to stream-type Chinook salmon that spend two to three years in coastal ocean waters. The ocean-type also enter freshwater to return for spawning later (May and June) than the stream-type (February through April). Ocean-type Chinook salmon use different areas in the river – they spawn and rear in lower elevation mainstem rivers, and they typically reside in freshwater for no more than three months compared to stream-type Chinook salmon that spawn and rear high in the watershed and reside in freshwater for a year.

LCR Chinook salmon are classified into three life-history types including spring runs, early-fall runs ("tules", pronounced (too-lees)), and late-fall runs ("brights") based on when adults return to freshwater. LCR spring Chinook salmon are stream- and ocean-types, while LCR early-fall and late-fall Chinook salmon are ocean-type. Other life-history differences among run types include the timing of spawning, incubation, emergence in freshwater, migration to the ocean, maturation, and return to freshwater. This life-history diversity allows different runs of Chinook salmon to use streams as small as 10 feet wide and rivers as large as the mainstem Columbia. Stream characteristics determine the distribution of run types among LCR streams. Depending on run type, Chinook salmon may rear for a few months to a year or more in freshwater streams, rivers, or the estuary before migrating to the ocean in spring, summer, or fall. All runs migrate far into the north Pacific on a multi-year journey along the continental shelf to Alaska before circling back to their river of origin. The spawning run typically includes three or more age classes. Adult Chinook salmon are the largest of the salmon species, and LCR fish occasionally reach sizes up to 25 kilograms (55 lbs.). Chinook salmon require clean gravels for spawning and pool and side-channel habitats for rearing. All Chinook salmon die after spawning once.

Coho salmon in the LCR exhibit life history characteristics similar to stream type Chinook salmon, where juveniles rear in freshwater until one year of age. Smolts enter saltwater approximately one year after emergence. Although run time variation is considered inherent to overall coho salmon life- history, LCR coho salmon typically display one of two major life-history types, either early or late returning freshwater entry. Freshwater entry timing for this ESU is also associated with ocean migration patterns based on the recovery of CWT hatchery fish north or south of the Columbia River (Myers et al. 2006). Early returning (Type-S) coho salmon generally migrate south of the Columbia River once they reach the ocean, returning to freshwater in mid-August and to the spawning tributaries in early September. Spawning peaks from mid-October to early November. Late returning (Type-N) coho salmon have a northern distribution in the ocean, returning to the LCR from late September through December and enter the tributaries from October through January. Most of the spawning for Type-N occurs from November through January, but some spawning occurs in February and as late as March (NMFS 2013e). In general, early returning fish (Type-S) spawn further upstream than later migrating fish (Type-N), although Type-N fish enter rivers in a more advanced state of sexual maturity (Sandercock 1991).

For winter steelhead in the LCR, life history characteristics are similar as described above for UWR steelhead. For summer steelhead in the LCR, natural-origin fish return to freshwater typically from May through July and reside in natal rivers and streams until spawning in the fall and winter.

Abundance and Productivity

The recent status review (NWFSC 2015) concluded that there has been little change since the last status review (Ford 2011) in the abundance and productivity of natural populations in the LCR, though there are some positive trends. For example, increases in abundance were observed in about 70% of the fall-run populations, and decreases in the hatchery contribution were noted for several populations. The improved fall-run VSP scores reflect both changes in biological status and improved monitoring. However, the majority of the populations in this ESU remain at high risk, with low natural-origin abundance levels, especially the spring-run Chinook population in this ESU (NWFSC 2015). Hatchery contributions remain high for a number of populations, especially in the Coast Fall MPG, and it is likely that many returning unmarked adults are the progeny of hatchery-origin parents, which contributes to the high risk. Moreover, hatchery produced fish still represent a majority of fish returning to the ESU even though hatchery production has been reduced (NWFSC 2015). Because spring-run Chinook salmon populations have generally low abundance levels from hydroelectric dams cutting off access to essential spawning habitat, it is unlikely that there will be significant improvements in the status of the ESU until efforts to improve juvenile passage systems are in place and proven successful (NWFSC 2015).

Spatial Structure

Under baseline conditions, constrained spatial structure at the ESU and DPS levels for LCR salmon and steelhead (related to conversion, degradation, and inundation of habitat) contributes to very low abundance and low genetic diversity in most populations, increasing risk to the ESU from local disturbances.

Diversity

Diversity has been greatly reduced at the ESU level because of low abundance in the remaining populations and habitat degradation, which influences the survival and expression of a wider range of life history diversities.

Overall Status of DPS

The most recent status review (NWFSC 2015) concluded that few populations are at or near their recovery viability goals. The remaining populations generally require a higher level of viability and most require substantial improvements to reach their viability goals. Even with the improvements observed during the last five years, the majority of natural populations in the LCR remain at a high or very high risk category and considerable progress remains to be made to achieve the recovery goals (NWFSC 2015).

Current Limiting Factors

Understanding the limiting factors and threats that affect LCR salmon and steelhead provides important information and perspective regarding the status of a species. One of the necessary steps in recovery and consideration for delisting is to ensure that the underlying limiting factors and threats have been addressed. Lower Columbia River salmon and steelhead were historically abundant and were subject to extensive harvest until the 1950s. There are many factors that affect the abundance, productivity, spatial structure, and diversity of these stocks. Factors that limit the ESUs and DPS have been, and continue to be, loss and degradation of spawning and rearing habitat including the estuary, impacts of mainstem hydropower dams on upstream access and downstream habitats, hatchery-related risks, and the legacy effects of historical harvest; together, these factors have reduced the persistence probability of all population. Other threats to the species include climate change impacts.

2.2.1.4 Columbia River Chum Salmon

These species are included in the rangewide species status section here because these fish are affected by the proposed action. Hatchery smolts released in the UWR emigrate through the Lower Columbia River and may affect these species through ecological interactions.

The ESU includes all naturally spawning populations of chum salmon in the Columbia River and its tributaries in Washington and Oregon, along with select hatchery chum salmon stocks. This ESU is comprised of three MPGs that has 17 natural populations. Chum salmon are primarily limited to the tributaries downstream of Bonneville Dam and the majority of the fish spawn in Washington tributaries of the Columbia River. Further details can be found in NMFS (2018).

Life History

Columbia River chum salmon are classified as fall-run fish, entering freshwater from mid-October through November and spawning from early November to late December in the lower mainstems of tributaries and side channels. There is evidence that a summer-run chum salmon population returned historically to the Cowlitz River, and fish displaying this life history are occasionally observed there. Historically, in general chum salmon had the widest distribution of all Pacific salmon species, comprising up to 50% of annual biomass of the seven species, and may have spawned as far up the Columbia River drainage as the Walla Walla River (Nehlsen et al. 1991). Chum salmon fry emerge from March through May (LCFRB 2010), typically at night, and are believed to migrate promptly downstream to the estuary for rearing. Chum salmon fry are capable of adapting to seawater soon after emergence from gravel (LCFRB 2010). Their small size at emigration is thought to make chum salmon more susceptible to predation mortality during this life stage (LCFRB 2010).

Given the minimal time juvenile chum salmon spend in their natural streams, the period of estuarine residency appears to be a critical phase in their life history and may play a major role in determining the size of returning adults. Chum and ocean-type Chinook salmon usually spend more time in estuaries than do other anadromous salmonids—weeks or months, rather than days or weeks. Shallow, protected habitats, such as salt marshes, tidal creeks, and intertidal flats serve as significant rearing areas for juvenile chum salmon during estuarine residency (LCFRB 2010).

Juvenile chum salmon rear in the Columbia River estuary from February through June before beginning long-distance ocean migrations (LCFRB 2010). Chum salmon remain in the North Pacific and Bering Sea for 2 to 6 years, with most adults returning to the Columbia River as 4-year-olds. All chum salmon die after spawning once.

Abundance and Productivity

Over the last century, Columbia River chum salmon returns have collapsed from hundreds of thousands to just a few thousand per year (NMFS 2013). Of the 17 natural populations that historically made up this ESU, 15 of them (six in Oregon and nine in Washington) are so depleted that either their baseline probability of persistence is very low, extirpated, or nearly so (NMFS 2013; NWFSC 2015). The Grays River and Lower Gorge populations showed a sharp increase in 2002 for several years, but have since declined back to relatively low abundance levels in the range of variation observed over the last several decades. Currently almost all natural production occurs in just two populations: the Grays/Chinook Rivers and the Lower Gorge area. The most recent total abundance information for Columbia River chum salmon in Washington is provided in Table 11, including chum salmon counted passing Bonneville Dam. For the other Washington populations not listed, and all Oregon populations, there are only occasional reports of a few chum salmon in escapements (NWFSC 2015).

Table 11. Peak spawning ground counts for fall chum salmon in index reaches in the LCR, and Bonneville Dam counts 2001-2016 (from WDFW SCORE[1])*.

Return Year	Grays River				Hamilton Creek Total	Hardy Creek	Mainstem Columbia (area near I-205)	Bonneville Count
	Crazy Johnson Creek	Main stem	West Fork Grays	Grays River Total				
2001	1,234	811	2,201	4,246	617	835	n/a	29
2002	2,792	2,952	4,749	10,493	1,794	343	3,145	98
2003	4,876	5,026	5,657	15,559	821	413	2,932	411
2004	1,051	5,344	6,757	13,152	717	52	2,324	42
2005	1,337	1,292	1,166	3,795	257	71	902	139
2006	3,672	1,444	1,129	6,245	478	109	869	165
2007	837	1,176	1,803	3,816	180	12	576	142
2008	992	684	725	2,401	221	3	644	75
2009	968	724	1,084	2,776	216	46	1,118	109
2010	843	3,536	1,704	6,083	594	175	2,148	124
2011	2,133	2,317	5,603	10,053	867	157	4,801	50
2012	3,363	1,706	2,713	7,782	489	75	2,498	65
2013	1,786	1,292	1,754	4,832	647	56	1,364	167
2014	1,380	1,801	1,078	4,259	922	108	1,387	122
2015	3,856	992	6,009	10,857	1,662	350	4,757	176
2016	5,790	6,019	18,599	30,048	1,597	354	5,062	47

[1] online at https://fortress.wa.gov/dfw/score/score/species/chum.jsp?species=Chum
*Date Accessed: October 10, 2017.

Spatial Structure

Under baseline conditions, constrained spatial structure at the ESU level (related to conversion, degradation, and inundation of habitat) contributes to very low abundance and low genetic diversity in most populations, increasing risk to the ESU from local disturbances.

Diversity

Diversity has been greatly reduced at the ESU level because of presumed extirpations and low abundance in the remaining populations (LCFRB 2010).

Overall Status of DPS

The most recent status review (NWFSC 2015) concluded that only 3 of 17 populations are at or near their recovery viability goals, although under the recovery plan scenario these three populations are those that have very low recovery goals of zero. The remaining populations generally require a higher level of viability and most require substantial improvements to reach their viability goals. Even with the improvements observed during the last five years, the majority of natural populations in this ESU remain at a high or very high risk category and considerable progress remains to be made to achieve the recovery goals (NWFSC 2015).

Current Limiting Factors

Understanding the limiting factors and threats that affect the Columbia River Chum Salmon ESU provides important information and perspective regarding the status of a species. One of the necessary steps in recovery and consideration for delisting is to ensure that the underlying limiting factors and threats have been addressed. Columbia River chum salmon were historically abundant and were subject to extensive harvest until the 1950s. There are many factors that affect the abundance, productivity, spatial structure, and diversity of the Columbia River Chum Salmon ESU. Factors that limit the ESU have been, and continue to be, loss and degradation of spawning and rearing habitat including the estuary, impacts of mainstem hydropower dams on upstream access and downstream habitats, and the legacy effects of historical harvest; together, these factors have reduced the persistence probability of all population. Other threats to the species include climate change impacts.

The recovery plan provides a detailed discussion of limiting factors and threats and describes strategies for addressing each of them. Chapter 4 of the recovery plan (NMFS 2013) describes limiting factors on a regional scale and how they apply to the four listed species from the LCR considered in the plan, including the Columbia River Chum Salmon ESU (NMFS 2013). Chapter 4 (NMFS 2013) includes details on large scale issues including:

- Ecological interactions,
- Climate change, and
- Human population growth.

Chapter 8 of the recovery plan discusses the limiting factors that pertain to Columbia River chum salmon natural populations specifically and the MPGs in which they reside. The discussion in Chapter 8 (NMFS 2013) is organized to address:

- Tributary habitat,
- Estuary habitat,
- Hydropower,
- Hatcheries,
- Harvest, and
- Predation.

Rather than repeating this extensive discussion from the recovery plan, it is incorporated here by reference.

2.2.1.5 Snake River spring/summer Chinook Salmon

These species are included in the rangewide species status section here because these fish are affected by the proposed action. Hatchery smolts released in the UWR emigrate through the Lower Columbia River and may affect these species through ecological interactions.

The Snake River spring/summer-run Chinook Salmon ESU includes all naturally spawned populations of spring/summer-run Chinook salmon in the mainstem Snake River and the Tucannon River, Grande Ronde River, Imnaha River, and Salmon River subbasins, as well as 10 artificial propagation programs (NWFSC 2015). However, inside the geographic range of the ESU, there are a total of 19 hatchery spring/summer-run Chinook salmon programs currently operational (Jones 2015). As explained above, genetic resources can be housed in a hatchery program but for a detailed description of how NMFS evaluates and determines whether to include hatchery fish in an ESU or DPS, see NMFS (2005d).

Life History

Chinook salmon have a wide variety of life-history patterns that include: variation in age at seaward migration; length of freshwater, estuarine, and oceanic residence; ocean distribution; ocean migratory patterns; and age and season of spawning migration. The Snake River spring/summer-run Chinook Salmon ESU consists of “stream-type” Chinook salmon, which spend two to three years in ocean waters and exhibit extensive offshore ocean migrations (Myers et al. 1998). For a general review of stream-type Chinook salmon, see the UWR Chinook Salmon ESU life-history and status description. In general, Chinook salmon tend to occupy streams with lower gradients than steelhead, but there is considerable overlap between the distributions of the two species.

Abundance and Productivity

The majority of natural populations in the Snake River spring/summer-run Chinook Salmon ESU remain at high risk overall, with one population (Chamberlain Creek in the MF MPG) improving to an overall rating of maintained due to an increase in abundance. Natural-origin abundance has increased over the levels reported in the prior review (Ford 2011) for most populations in this ESU, although the increases were not substantial enough to change viability ratings. Relatively high ocean survivals in recent years were a major factor in recent abundance patterns. Ten natural populations increased in both abundance and productivity, seven increased in abundance while their updated productivity estimates decreased, and two populations decreased in abundance and increased in productivity. One population, Loon Creek in the MF MPG, decreased in both abundance and productivity. Overall, all but one population in this ESU remains at high risk for abundance and productivity and there is a considerable range in the relative improvements to life cycle survivals or limiting life stage capacities required to attain viable status. In general, populations within the South Fork grouping had the lowest gaps among MPGs. The other multiple population MPGs each have a range of relative gaps (NWFSC 2015).

Spatial Structure

Spatial structure ratings remain unchanged or stable with low or moderate risk levels for the majority of the populations in the extant ESU (NWFSC 2015). Four populations from three MPGs (Catherine Creek and Upper Grande Ronde of the Grande Ronde/Imnaha MPG, Lemhi River of the Upper Salmon River MPG, and Lower MF Mainstem of the MF MPG) remain at high risk for spatial structure loss.

Diversity

Diversity has been greatly reduced at the ESU level compared to historic patterns because of low abundances in extant populations (Myers et al. 1998).

Overall Status of DPS

Although the status of the ESU is improved relative to measures available at the time of listing, the ESU remains at threatened status.

Current Limiting Factors

Understanding the limiting factors and threats that affect the Snake River spring/summer-run Chinook Salmon ESU provides important information and perspective regarding the status of a species. One of the necessary steps in recovery and consideration for delisting is to ensure that the underlying limiting factors and threats have been addressed. The abundance of spring/summer-run Chinook salmon had already began to decline by the 1950s, and it continued declining through the 1970s. In 1995, only 1,797 spring/summer-run Chinook salmon total adults (both hatchery and natural-origins combined) returned to the Snake River (NMFS 2017n).

There are many factors that affect the abundance, productivity, spatial structure, and diversity of the Snake River spring/summer-run Chinook Salmon ESU. Factors that limit the ESU have been, and continue to be, survival through the Federal Columbia River Power System (FCRPS); the degradation and loss of estuarine areas that help the fish survive the transition between fresh and marine waters, spawning and rearing areas that have lost deep pools, cover, side-channel refuge areas, and high quality spawning gravels; and interbreeding and competition with hatchery fish that far outnumber fish of natural-origin.

2.2.2 Critical Habitat

For Upper Willamette spring Chinook salmon and winter steelhead, critical habitat is designated for specific geographic areas presently occupied by natural origin salmon and steelhead (September 2, 2005; 70 FR 52630). All of the major population areas have critical habitat designations. There are some exclusions to critical habitat based upon non-biological factors. These are specified in the Federal Register notice. For other species in the Columbia River included in this opinion (see section 2.2), critical habitat is also designated in the Columbia River and estuary where these species are affected by the proposed action.

For salmon and steelhead, NMFS ranked watersheds within designated critical habitat at the scale of the fifth-field hydrologic unit code (HUC_5) in terms of the conservation value they provide to each listed species they support.[6] The conservation rankings are high, medium, or low. To determine the conservation value of each watershed to species viability, NMFS' critical habitat analytical review teams (CHARTs) evaluated the quantity and quality of habitat features (for example, spawning gravels, large wood, water conditions, and side channels), the relationship of the area compared to other areas within the species' range, and the significance to the species of the population occupying that area (NOAA Fisheries 2005). Thus, even a location that has poor quality of habitat could be ranked with a high conservation value if it were essential due to factors such as limited availability (*e.g.*, one of a very few spawning areas), a unique contribution of the population it served (*e.g.*, a population with a different life history pattern), or if it serves another important role (*e.g.*, obligate area for migration to upstream spawning areas).

The physical or biological features (PBFs) of freshwater spawning and incubation sites include water flow, quality, and temperature; suitable substrate for spawning and incubation; and migratory access for adults (Table 12). These features are essential to conservation because without them the species cannot successfully spawn and produce offspring. The PBFs of freshwater rearing sites include floodplain connectivity, natural cover (like large wood), good water quality and quantity (Table 12). These features are essential for proper rearing and growth to occur. The PBFs of freshwater migration associated with adult sexual maturation, adult holding (while maturing), kelt seaward migration, and juvenile growth, development, and seaward migration, include water that is free of artificial obstructions, and provides natural cover, and good water quality and quantity (Table 12). These features are essential to conservation because they allow adult fish to swim upstream to reach spawning areas and they allow larval fish to proceed downstream and reach the ocean.

[6] The conservation value of a site depends upon "(1) the importance of the populations associated with a site to the ESU [or DPS] conservation, and (2) the contribution of that site to the conservation of the population through demonstrated or potential productivity of the area" (NOAA Fisheries 2005).

Table 12. Physical and biological features (PBFs) of critical habitats designated for ESA-listed salmon considered in this opinion, and corresponding species life history events.

Physical and biological Features		Species Life History Event
Site Type	**Site Attribute**	
Freshwater spawning	Substrate Water quality Water quantity	Adult spawning Embryo incubation Alevin growth and development
Freshwater rearing	Floodplain connectivity Forage Natural cover Water quality Water quantity	Fry emergence from gravel Fry/parr/smolt growth and development
Freshwater migration	Free of artificial obstruction Natural cover Water quality Water quantity	Adult sexual maturation Adult upstream migration and holding Kelt (steelhead) seaward migration Fry/parr/smolt growth, development, and seaward migration
Estuarine areas	Forage Free of artificial obstruction Natural cover Salinity Water quality Water quantity	Adult sexual maturation and "reverse smoltification" Adult upstream migration and holding Kelt (steelhead) seaward migration Fry/parr/smolt growth, development, and seaward migration
Nearshore marine areas	Forage Free of artificial obstruction Natural cover Water quantity Water quality	Adult growth and sexual maturation Adult spawning migration Nearshore juvenile rearing

2.2.3 Climate Change

Climate change is projected to have serious negative implications for Columbia River salmon and steelhead populations and their critical habitat (Climate Impacts Group 2004; Scheuerell and Williams 2005; Zabel et al. 2006; ISAB 2007, Jaeger et al. 2017). It is anticipated that there will be negative effects of climate change on the distribution, abundance, productivity, and diversity of ESA-listed species and their habitat in the Upper Willamette basin and mainstem lower Columbia River.

Doppelt et al. (2009) projected that conditions in the Upper Willamette River Basin are going to change substantially during the coming century due to changing global climate conditions. They found that:

Temperature:

- Annual average temperatures are likely to increase from 2 to 4º F (1 to 2º C) by around 2040 and an additional 6 to 8º F (3 to 4º C) by around 2080.
- Average summer temperatures are likely to increase 4 to 6º F (2 to 3º C) by 2040 and an additional 4 to 8º F (2 to 4.5º C) by 2080, while average winter temperatures may increase 1 to 2º F (0.5 to 1º C) by 2040 and an additional 2 to 4º F (1 to 2º C) by 2080.

Precipitation and Snowpack:

- One model showed a slight increase in mean annual precipitation while the other two models show no real change.
- By 2040, all three models predict slightly less precipitation during spring, summer and fall and two models predict slightly more precipitation in winter.
- By 2080, precipitation patterns could range from a slight year-round decline to larger shifts that include monsoon patterns in the spring coupled with increased seasonal drought in the summer.
- Snowpack across the Pacific Northwest is likely to decline by 60% by 2040 and 80-90% by 2095 from current levels.
- As snow melts earlier in the spring, stream flows will peak earlier but at lower levels than typical flows in recent years, depending on the geology of the particular stream reach.

Storms and Flooding

- With warmer oceans and more available moisture in the atmosphere, storm events could increase in intensity, resulting in more flooding in all rivers in the Basin.

Based on the projected changes in climate conditions, Doppelt et al. (2009) identified the following likely consequences for aquatic systems and species in the UWR:

Aquatic Systems and Species

- Increased winter storm intensity, changes in seasonal precipitation patterns, and increased temperatures are likely to be detrimental to the reproduction and survival of many native fish and amphibians.
- Increasing temperature is likely to benefit warm water native species and non-native fishes and amphibians while harming native species that rely on cooler water. This will likely result in the

decline of Chinook salmon, steelhead, and Oregon chub. Spring Chinook salmon are likely to have particular problems in the lower Middle Fork Willamette River due to higher temperatures.

- Spring-fed streams and riparian areas will be buffered somewhat from climate change due to mediated shifts in flow and temperature.
- The McKenzie River basin is likely to remain the best stronghold for fish in the Upper Willamette. The Middle Fork Willamette River also may see more moderate changes in flow.
- Because the McKenzie River watershed is vital to Eugene municipal water supply in the summer months, increased summer drought and evapotranspiration could lead to seasonal water shortage.

Given the above, the effects of climate change on salmon and steelhead in the Columbia River basin are now detrimental and contribute to worsening the key limiting factors and threats for these species (section 2.2.1.1 and 2.2.1.2). The key limiting factors for all populations are related to freshwater habitat, with summer time water quality issues and poor overwinter survival of fry being widespread issues throughout the region. The expected effects of climate change will only worsen these key limiting factors by reducing summer time streamflows with increasing water temperatures, thereby limiting production of juvenile salmon and steelhead. Increases in precipitation during the winter and more frequent and intense storms will reduce egg–to-fry survival of juvenile salmon and steelhead. In addition, the overwinter survival of age-1 salmon and steelhead will likely be reduced from more winter storms affecting streams and rivers where overwinter refuge habitat is limited. Since freshwater production of juvenile salmon is limiting recovery, the potential improvements to early marine survival of smolts in the ocean from increased upwelling may provide some population benefits, but will be limited by the absolute abundance of salmon produced in freshwater (Suring et al. 2015).

2.3 Action Area

The “action area” means all areas to be affected directly or indirectly by the proposed action, in which the effects of the action can be meaningfully detected, measured, and evaluated (50 CFR 402.02). The action area for this analysis includes all areas in freshwater and estuarine habitats where hatchery fish may occur and/or hatchery-related activities occur. The action area for this consultation is defined as the entire Willamette River basin, and the lower Columbia River and estuary downstream from the Willamette River (including Multnomah channel). The ocean is not included in the action area because of the lack of quantitative information on the ecological effects of hatchery fish in a mixed stock ocean environment, the inter-annual variability in density dependent effects, and changes in the abundance of natural- and hatchery-produced salmonids. This is an area of continuing scientific investigation and NMFS will watch closely and revisit this analysis in the event that new scientific information emerges that trigger reinitiation of consultation (section 2.11). The NMFS (2017a) opinion on Mitchell Act funding considered the effects of hatchery fish in the estuary and ocean, and found that subyearling Chinook salmon and coho salmon are the most likely hatchery fish to have effects in these areas due to their long residence times and relatively high predation rates, respectively. Together these reasons suggest that the likelihood of detecting effects from the releases of hatchery Chinook salmon and steelhead on natural-origin fish in the estuary have already been examined to the best of our ability.

2.4 Environmental Baseline

The "environmental baseline" includes the past and present impacts of all Federal, state, or private actions and other human activities in the action area, the anticipated impacts of all proposed Federal projects in the action area that have already undergone formal or early section 7 consultation, and the impact of state or private actions which are contemporaneous with the consultation in process (50 CFR 402.02).

2.4.1 Past Actions

There have been many actions in the past that have affected listed salmon and steelhead in the Upper Willamette Basin including habitat reduction, hatcheries, and fisheries. Below is a summary of the major actions of the past. The Willamette River basin was one of the first areas in Oregon to be settled by European immigrants from the east coast after the establishment of the Oregon Trail in 1841. Consequently, the Willamette basin has been significantly altered from its natural state from urban development, agricultural development, building of flood control dams, and timber harvest. The Willamette Valley supports more than 70% of Oregon's human population and is the primary producer of Oregon's agricultural crops. The Portland metropolitan area, Salem, Corvallis, and Eugene are major cities all within the Willamette Valley.

Included in the baseline are the effects of the Willamette River Basin Flood Control Project, an array of dams and other structures, including salmon traps and passage systems, analyzed as a reasonable and prudent alternative (RPA) in response to a finding that the flood control project jeopardized Upper Willamette River Chinook and steelhead. Only the RPA actions that have been implemented and are currently in effect, or are well into the planning and construction process, are included in the baseline. Construction of the 13 Federal dams included in the project throughout the Willamette River basin has had the most profound effect on salmon and steelhead and their habitats (NMFS 2008). The vast majority of historic salmon and steelhead habitat was blocked and lost from production in the major population areas of the Middle Fork Willamette, McKenzie, South Santiam, and North Santiam rivers (Figure 15). This loss of habitat has resulted in the loss of important genetic resources in the affected populations (Thompson et al. 2019). The dams substantially reduced the adverse effects of flooding on human development, but also reduced the amount and complexity of juvenile rearing habitat for salmon and steelhead below the Federal dams. The complex network of side channels, sloughs, and wetlands in the mainstem Willamette River have been substantially reduced from reduced flooding and human development of riparian areas (Figure 16). Large woody debris, which is essential to the creation and maintenance of habitat for salmon and steelhead has also been significantly reduced below the dams (Figure 17).

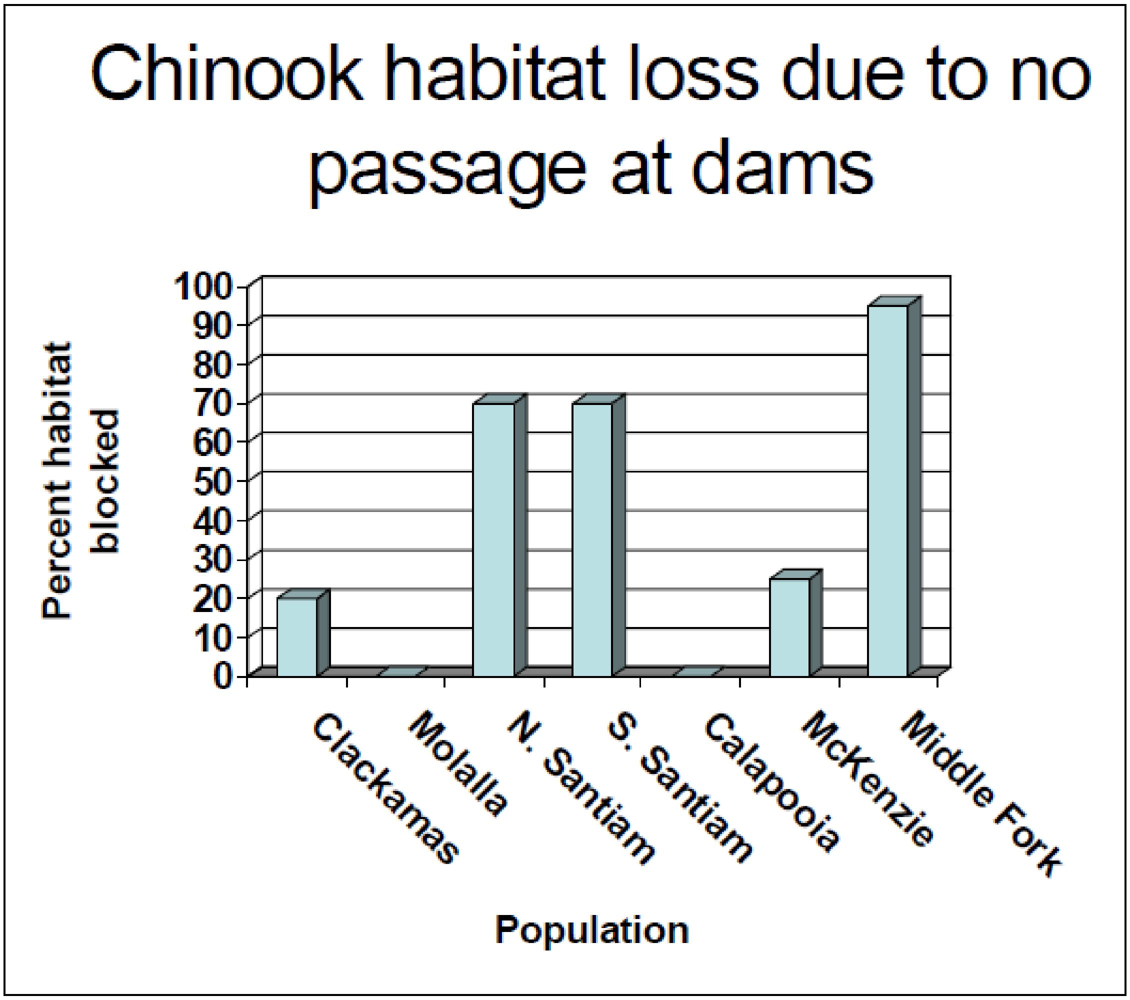


Figure 15. Percent of historic Chinook salmon spawning area in Upper Willamette Basin blocked by impassable Federal dams in each population area. Figure taken from NMFS (2008).

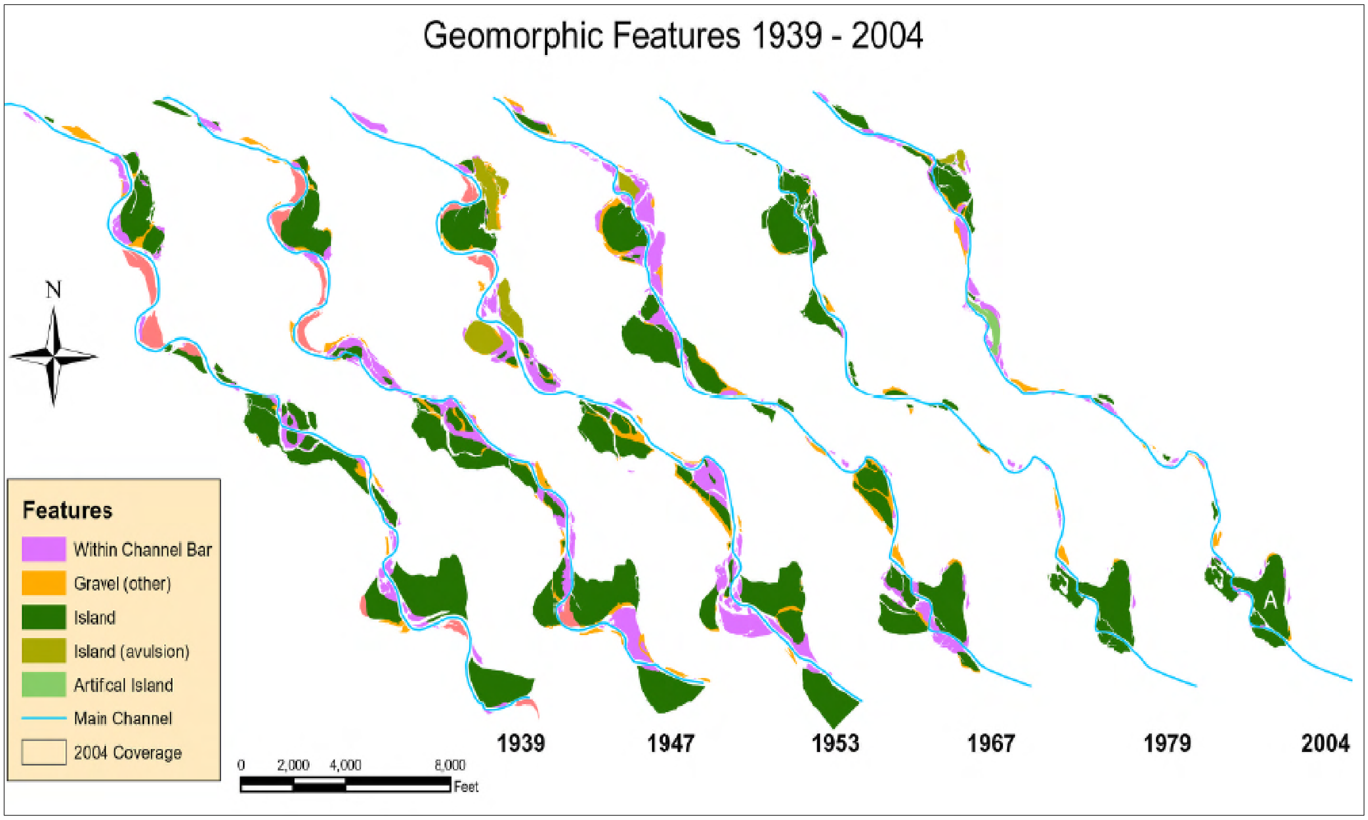


Figure 16. An example of mainstem river habitat simplification below Federal dams in the Upper Willamette River basin through time, 1939 to 2004 (Dykaar 2005).

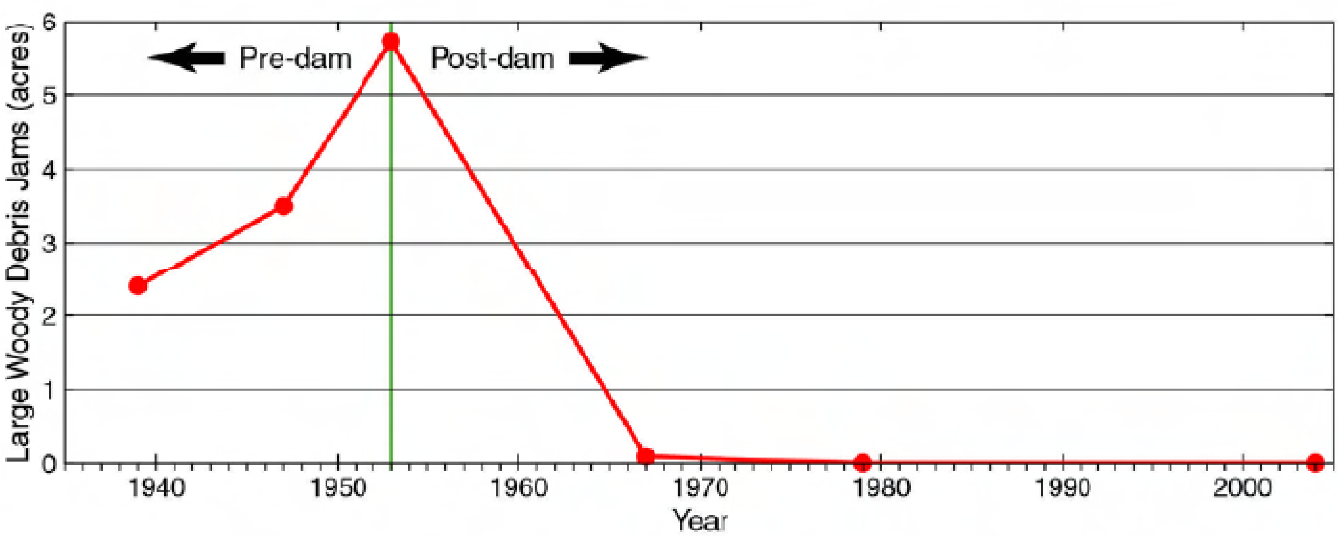


Figure 17. Reductions in large woody debris below Federal dams in the Upper Willamette River basin through time (Dykaar 2005).

The RPA for the 2008 Willamette Project Biological Opinion (NMFS 2008) also includes mitigation measures that have been implemented or are well into the planning and construction process, and which will serve to reduce the negative impacts to fish passage, such as the rebuilding of the fish collection facilities at Minto, Foster, and Fall Creek dams to improve the collection, transport, and survival of adult spring Chinook salmon and winter steelhead above the federal dams. These mitigation actions are currently in effect are part of the environmental baseline. Other RPA actions, such as downstream fish passage improvements at federal dams and reservoirs in the South Fork McKenzie, North Santiam, and Middle Fork Willamette population areas are still in the planning stages and not yet providing benefits under the environmental baseline. Actions included in the RPA which do not appear to be on track for completion by 2023 (the term of the 2008 Biological Opinion) are not included in the baseline here. These include: downstream passage improvement facilities in the North Santiam River, South Fork McKenzie River, Middle Fork Willamette River; improved adult fish collection facility at Dexter Dam; and prototype downstream passage collector in the Middle Fork Willamette River or South Santiam River.

Point source pollution was a major problem in the mainstem Willamette River until the early 1980's. Although pollution is still a concern, it is drastically improved now compared to decades ago. Most of the pollution issues now are from non-point sources. Legacy contaminants will remain in the basin for decades to come.

Harvest of salmon and steelhead in the past occurred at high levels that were unsustainable, especially after the substantial habitat loss from dam construction and continued operations that reduced the productivity of the populations. Significant harvest occurred on Willamette spring Chinook salmon and winter steelhead in the lower Columbia River gillnet fisheries from the mid- to late 1800's until the early 1990's. Additional sport harvest occurred primarily in the lower Columbia and lower Willamette rivers. Historically, cumulative harvest rates on spring Chinook salmon were commonly in excess of 40% annually, but have been reduced to near 10% since ESA listing in the late 1990s (Figure 18). For UWR winter steelhead, significant reforms were implemented in the early 1990's that required catch and release of all unmarked, wild winter steelhead. Hatchery programs were eliminated and changes to trout stocking and fishing regulations were made to reduce fishery exploitation rates. Whereas fishery harvest may have been a listing factor for winter steelhead, the reforms that have been implemented since ESA listing have reduced fishery harvest impacts such that it is no longer identified as a key or secondary limiting factor. The current exploitation rates on wild steelhead from sport fisheries are in the range of 0-3%. Steelhead are not intercepted in ocean fisheries to a measurable degree.

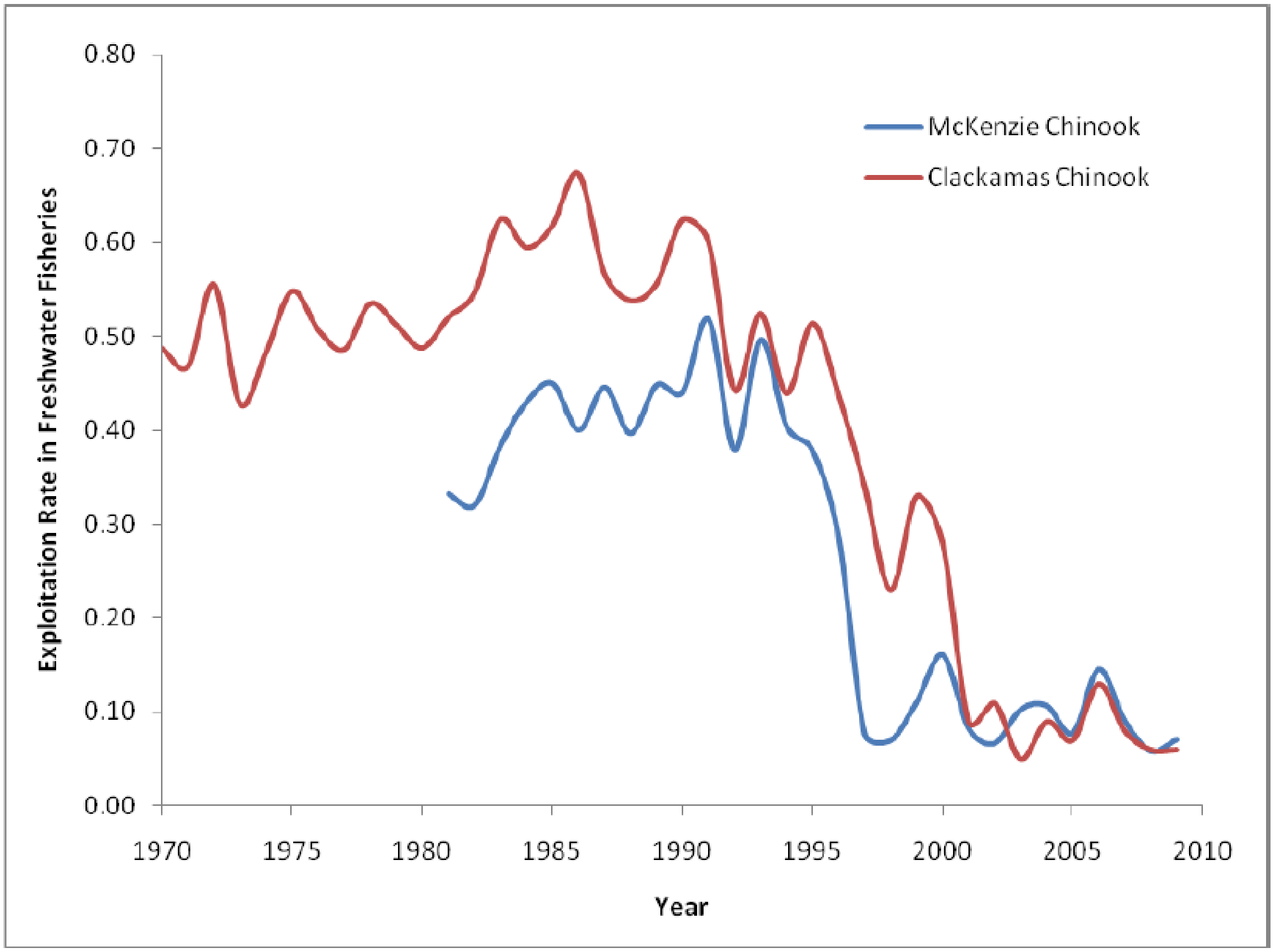


Figure 18. Freshwater fishery exploitation rates for McKenzie and Clackamas River spring Chinook salmon stocks. Rates include fisheries in the lower Columbia River, mainstem Willamette River, and Clackamas and McKenzie Rivers. Full implementation of selective fisheries, where only adipose fin-clipped Chinook salmon can be harvested, went into effect in 2002. Figure 5-2 from ODFW and NMFS (2011).

2.4.2 Present Conditions

Included in the environmental baseline are the effects of all past actions on the habitat conditions of Chinook salmon and winter steelhead. The present conditions for spring Chinook salmon and winter steelhead continue to be poor. The latest status review shows little overall improvement for both of these species (NWFSC 2015). Below is a summary of the present impacts of Federal, state, and private actions affecting spring Chinook salmon and winter steelhead in the action area. This section proceeds through the life cycle of salmon and steelhead beginning with eggs in the gravel.

2.4.2.1 Egg Incubation

The effects of present conditions on egg incubation greatly depends upon where the adults spawned. Eggs incubating in the rivers downstream from the Federal dams are exposed to threats that do not occur in habitats not affected by water management from the dams. If the eggs were laid in the tributaries where no dams occur or in areas upstream of the dams, water quality (e.g., temperatures and streamflow) conditions are more natural and eggs incubating in the gravel have relatively high survival compared to areas directly below the dams. Eggs incubating downstream of Federal dams in the North Santiam, South Santiam, McKenzie, and Middle Fork Willamette rivers are impacted by altered water temperatures, elevated total dissolved gases, and altered river flows affecting their survival (NMFS 2008). For spring Chinook salmon eggs incubating in the gravel below the Federal dams, water temperatures are typically much higher than natural conditions (see example from North Santiam; Figure 19) and can often reach lethal levels. River discharge is often greater than natural conditions during incubation as the reservoirs are drained in order to accommodate the next winter's storms (Figure 20). The combination of temperature, dissolved gas, and altered discharge impacts have reduced spring Chinook salmon egg survival (Figure 21). In addition, the warmer water temperatures result in earlier emergence of spring Chinook salmon fry (up to 3 months) below the dams compared to natural conditions (Figure 22), which also decreases survival from longer exposure to adverse winter conditions in the river (e.g. high flows from storm events).

For winter steelhead, the impacts on egg incubation are not as great because spawning is widespread throughout the entire population's range (mainstem rivers and all tributaries). Most of the incubating eggs are not exposed to unnatural conditions. Winter steelhead also spawn in late winter/early spring after the peak of winter storm events.

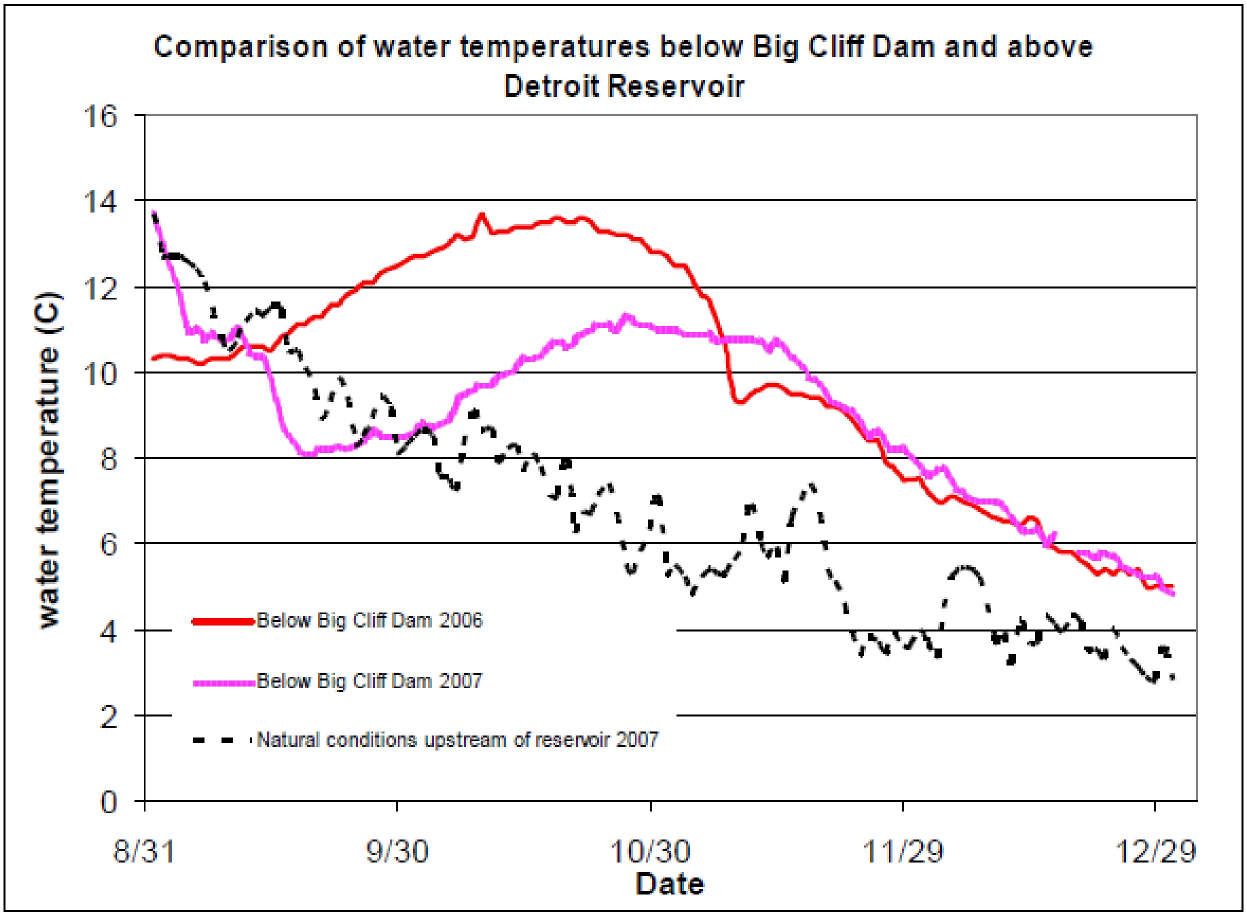


Figure 19. Water temperature below Big Cliff/Detroit dams on the North Santiam River compared to natural conditions during egg incubation of spring Chinook salmon.

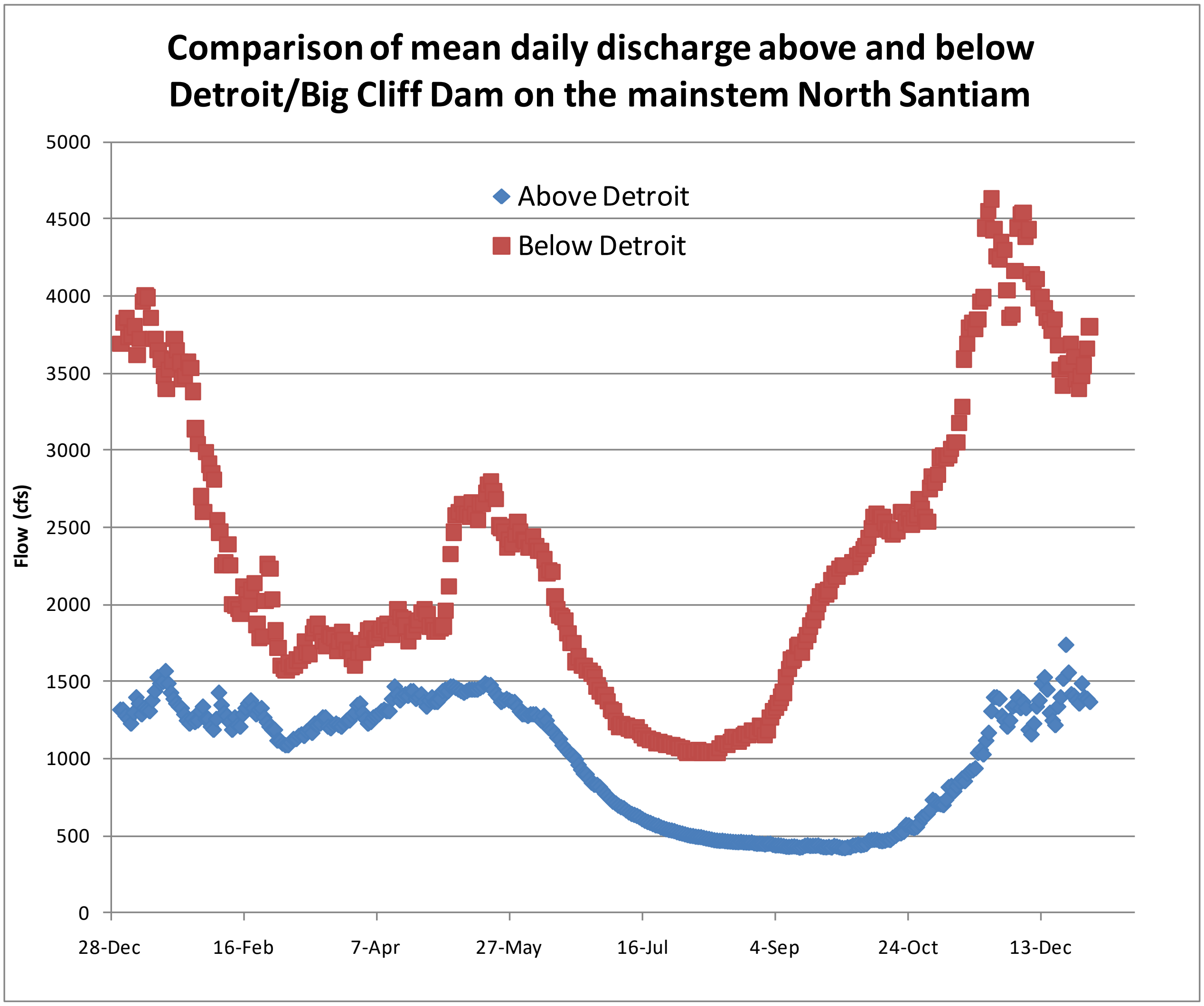


Figure 20. Comparison of streamflows above and below Big Cliff/Detroit dams in the North Santiam River. Data is the average daily flow for the period of record (60+ years) for each gage (Niagara and Boulder Cr).

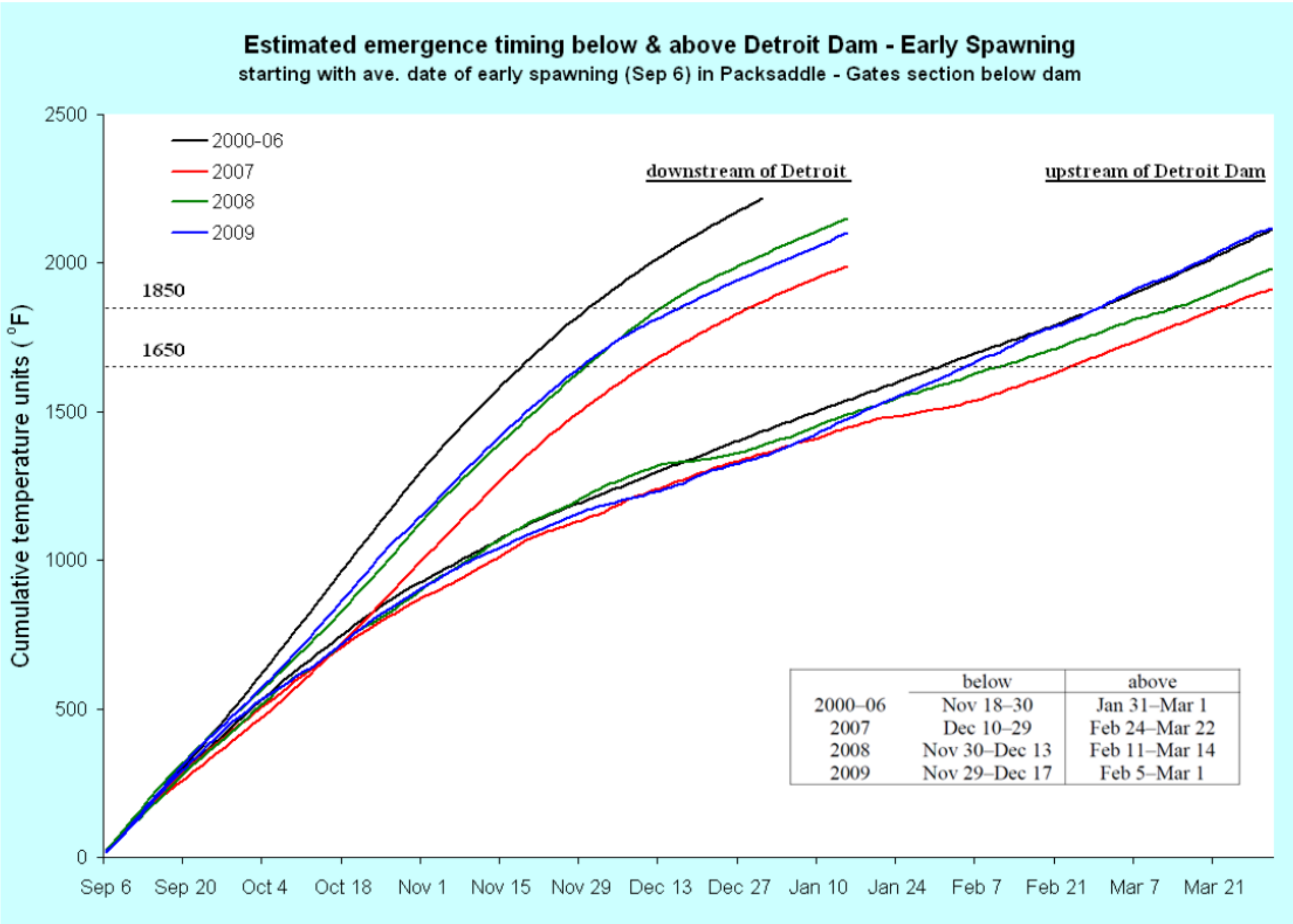
Impacts of warm water temperatures on spring Chinook egg survival

(data from Taylor and Garletts , USACE 2007)

Location	Survival
Willamette Hatchery (upstream, natural temperature)	81%
Below Dexter Dam (downstream; altered temperatures)	0%

- 3,200 eggs from the same 32 pairs
- incubated in different locations
- monitored survival, incidence of fungus

Figure 21. Survival of spring Chinook salmon eggs above and below Lookout Point/Dexter dams in the Middle Fork Willamette River.



	below	above
2000–06	Nov 18–30	Jan 31–Mar 1
2007	Dec 10–29	Feb 24–Mar 22
2008	Nov 30–Dec 13	Feb 11–Mar 14
2009	Nov 29–Dec 17	Feb 5–Mar 1

Figure 22. Emergence timing of spring Chinook salmon above and below Big Cliff/Detroit dams in the North Santiam River. Figure taken from NMFS (2008). Spring Chinook salmon emergence typically occurs as development accrues 1,650-1,850 cumulative temperature units.

2.4.2.2 Juvenile Rearing in Freshwater

Spring Chinook salmon exhibit a complex suite of juvenile life history types (Figure 4) throughout the Willamette river basin and thus are exposed to a variety of anthropogenic threats throughout the watershed. Juvenile salmon occupy habitats from the natal, headwater areas all the way downstream to the lower Columbia River and estuary during their first year of life. The rearing habitat upstream of the Federal dams is the least impacted by management or development. For juvenile Chinook salmon produced upstream of Federal dams that are emigrating downstream, most populations encounter reservoirs that are difficult to navigate due to slow moving waters, are exposed to high abundances of non-native and native predatory fishes, and suffer high mortality while passing through the dams (NMFS 2008). Table 13 shows the variety of fish species present in reservoirs throughout the Middle Fork Willamette population area.

Spring Chinook salmon emigrate through the federal dams using a variety of passage routes, with injury and mortality rates typically very high but variable depending upon the specific situation. For example, in a study of downstream passage at Detroit Dam on the North Santiam River, a minority of Chinook salmon passed the dam without injury or being killed (Figure 23; USACE 2018). The highest success rates occurred with salmon passing through the regulating outlets, which are typically only available for passage when the reservoir is at lower elevations in the fall and winter months. In most reservoirs, the majority of juvenile Chinook salmon do not emigrate downstream to complete their smolt emigration to the ocean because the fish cannot find adequately passage, as evidenced by the greater than smolt size Chinook salmon captured in the reservoirs (Figure 24). Population estimates of emigrating Chinook salmon fry entering Cougar reservoir typically exceeds >100,000's of fry, whereas the population estimates of salmon passing the dam downstream numbers in the tens of thousands per year (Hansen et al. 2017). In 2015, 18% of the juvenile Chinook salmon successfully passed and survived downstream of Cougar reservoir and dam (Hansen et al. 2017). Romer and Monzyk (2014) documented Chinook salmon that never emigrated out of Willamette reservoirs and completed their full life cycle without ever going to the ocean (residual Chinook life history).

Rearing in the reservoirs can provide growth benefits to juvenile Chinook salmon. However, dam passage mortality increases as fish size increases (USACE 2018). High growth rates coupled with reservoir drawdown in the fall (e.g. Fall Creek reservoir drawdown) has produced very healthy and very large smolts (USACE 2018). However, large-sized smolts tend to return back to freshwater from the ocean as adults at a younger age and be smaller on average (Ewing and Ewing 2002). This could have demographic consequences on population productivity (Quinn 2005). The historical template was to have a diversity of life history ages and sizes in order to survive variable environmental conditions in freshwater and in the ocean.

Throughout the year, juvenile Chinook salmon emigrate downstream to the mainstem Willamette River for rearing (Figure 4) (Schroder et al. 2015). However, most of the historic rearing habitat in side channels, backwater sloughs, and wetlands has been lost (Figure 25) (PNERC 2002). The development of the riparian area, streambank armoring, and disconnection of side channels has substantially reduced the rearing capacity of the mainstem Willamette River for juvenile Chinook salmon.

Juvenile winter steelhead rear in headwater tributaries and upper portions of the subbasins for one to four years (most often two years). While juvenile steelhead generally rear in the upper headwater areas, they are susceptible to the same threats and limiting factors that are affecting spring Chinook salmon juveniles.

Water quality deteriorates proceeding downstream, with warmer waters and accumulation of pollutants from run off and point source discharges. Portions of the lower Willamette River near Portland harbor is a "superfund" site that is highly contaminated. As such, most of the critical habitat that has been designated for spring Chinook salmon and winter steelhead in the UWR is listed under the 303d list of contaminated waters (Figure 26).

Table 13. Total numbers of native and non-native fishes captured in screw traps in Fall Creek, below Fall Creek dam, in the North Fork Willamette River, below Hills Creek dam and below Lookout Point Dam. Taken from Keefer et al. (2013).

Common name	Scientific name	Fall Creek	Fall Creek Dam	North Fork	Hills Creek Dam	Lookout Point Dam
Native species						
Largescale sucker	*Catostomus macrocheilus*	48	2	5	94	16
Sculpin	*Cottus* spp.	64	13	18	60	38
Western brook lamprey	*Lampetra richardsoni*	63	15	1	7	—
Coastal cutthroat trout[a]	*Oncorhynchus clarkii clarkii*	82	24	6	13	1
Rainbow trout	*Oncorhynchus mykiss*	659	70	17	33	6
Chinook salmon	*Oncorhynchus tshawytscha*	9259	1524[b]	1616	980	1997[c]
Salmonid fry	*Oncorhynchus* spp.	72	2	8	—	—
Mountain whitefish	*Prosopium williamsoni*	—	—	1	—	—
Northern pikeminnow	*Ptychocheilus oregonensis*	1	12	3	—	91
Longnose dace	*Rhinichthys cataractae*	367	10	55	7	—
Speckled dace	*Rhinichthys osculus*	1024	2	5	1	—
Dace	*Rhinichthys* spp.	337	—	31	16	—
Redside shiner	*Richardsonius balteatus*	1	49	—	13	34
Total		11 977	1723	1766	1224	2183
Non-native species						
Brown bullhead	*Ameiurus nebulosus*	—	132	—	119	2
Bluegill	*Lepomis macrochirus*	—	13 160	—	63	73
Largemouth bass	*Micropterus salmoides*	—	6179	—	11	43
White crappie	*Pomoxis annularis*	—	—	—	231	132 813
Black crappie	*Pomoxis nigromaculatus*	—	23 983	—	68	1
Walleye	*Sander vitreus*	—	—	—	—	10
Brook trout	*Salvelinus fontinalis*	—	—	1	—	—
Total		0	43 454	1	492	132 942

[a]Includes cutthroat trout × rainbow trout hybrids,
[b]492 had hatchery marks,
[c]1363 had hatchery marks.

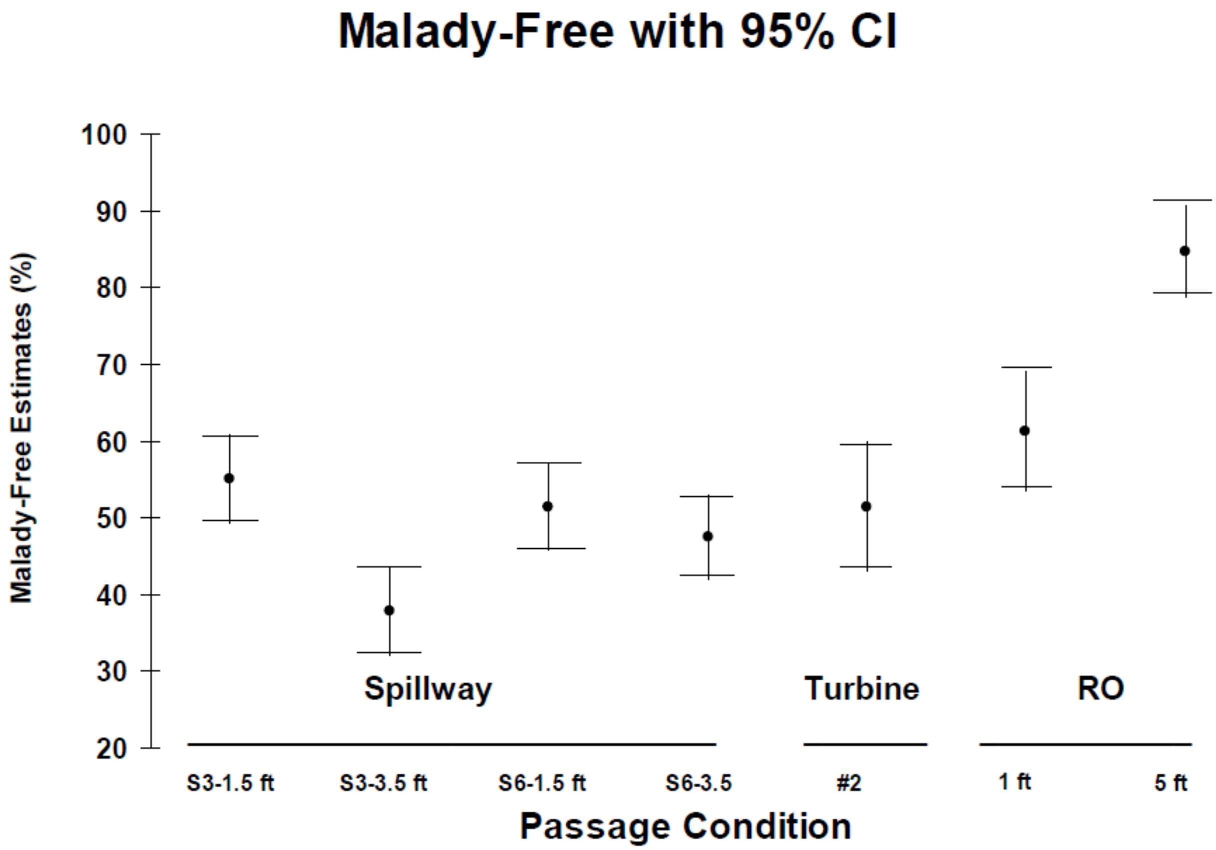


Figure 23. Rates of injury (malady-free and by inference percent injured (100% - malady-free %) for juvenile Chinook salmon passing through specific routes through Detroit Dam. Taken from USACE (2010).

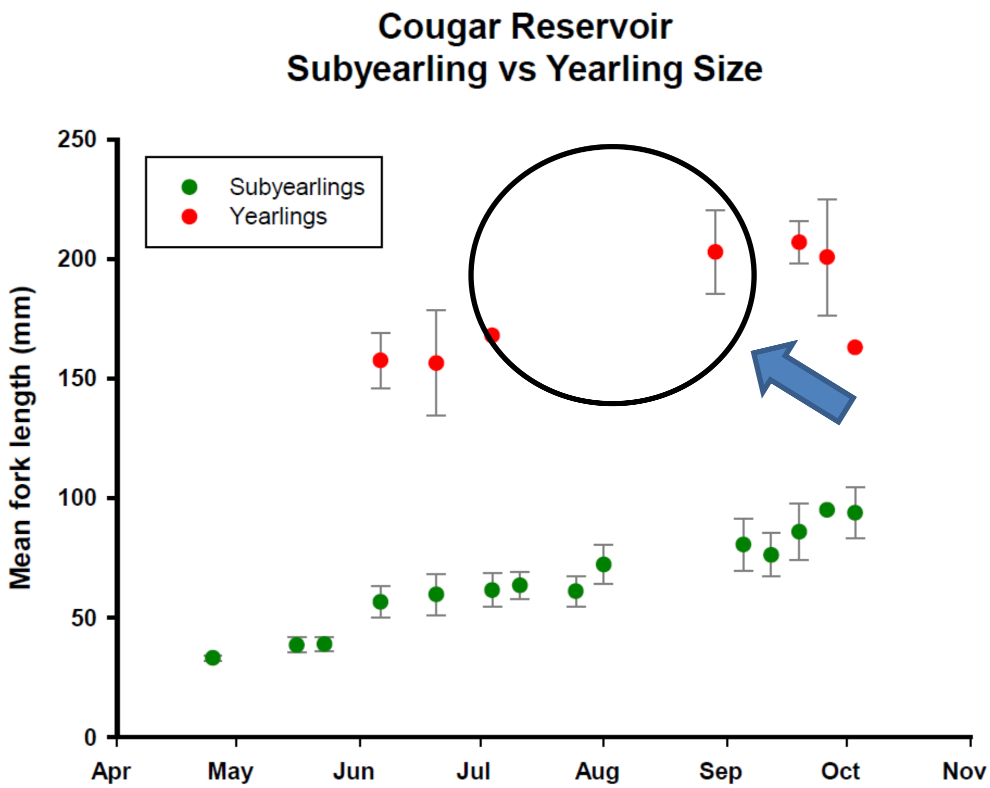


Figure 24. Mean length of juvenile spring Chinook salmon in Cougar Reservoir. In general, yearling smolts migrate downstream past the dam in the spring and the highlighted (circle and arrow) demonstrate that some juvenile salmon do not migrate and appear to rear in reservoirs. Figure modified from Monzyk et al. (2013).

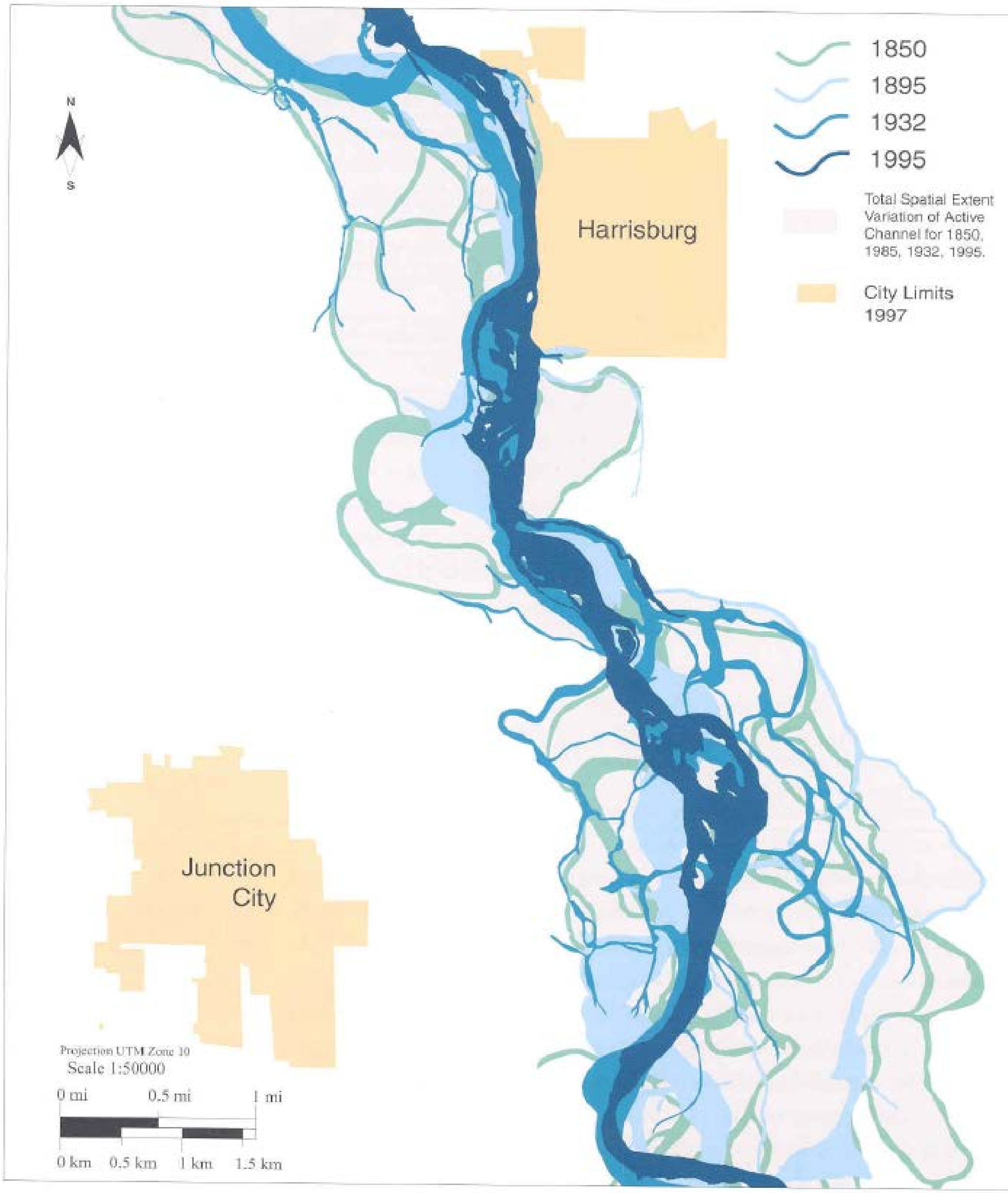


Figure 25. Mainstem Willamette River habitat loss from 1850 to 1995 (PNERC 2002)

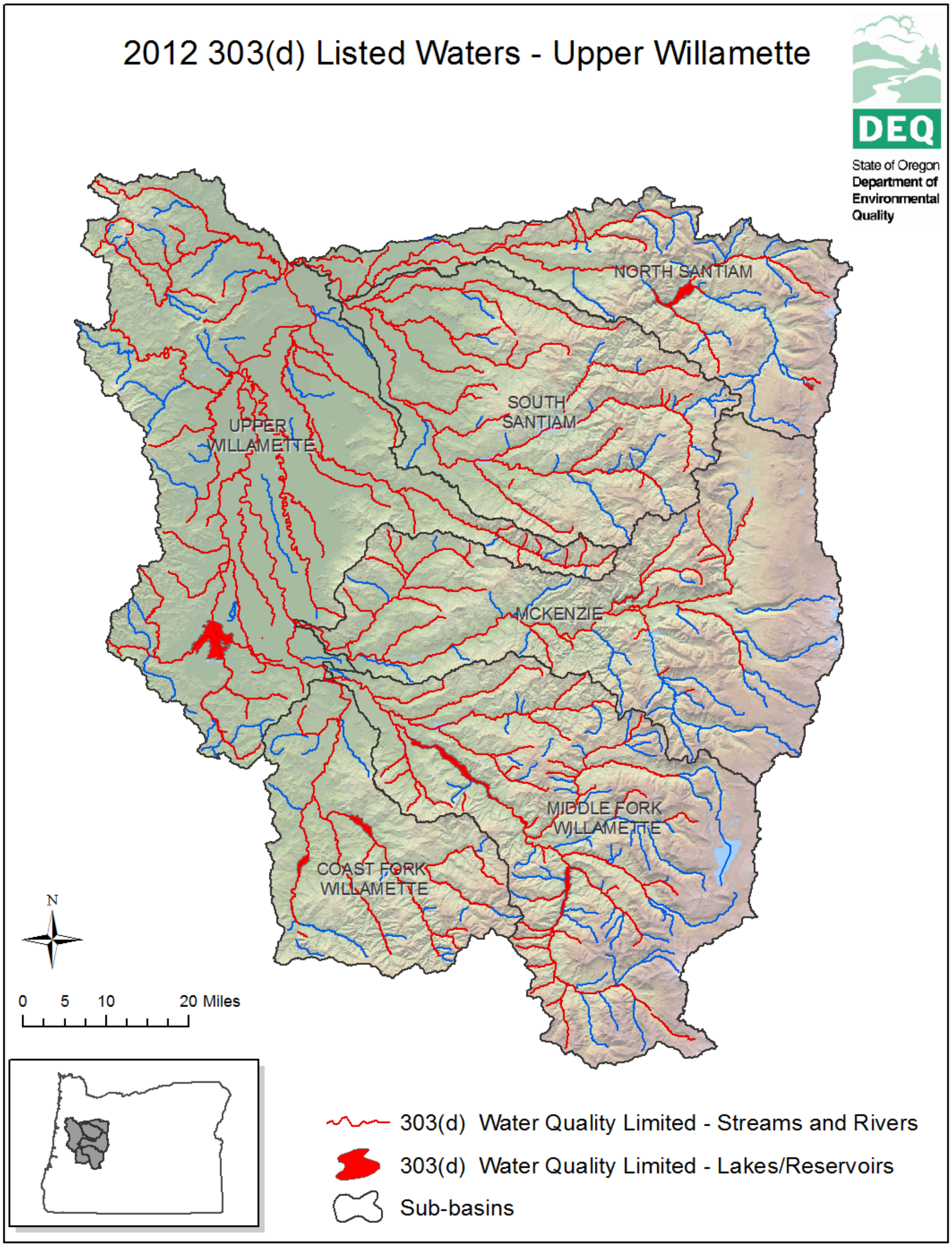


Figure 26. EPA 303(d) water-quality-impaired waters for the Upper Willamette River spring Chinook salmon ESU and winter steelhead DPS. Figure provided by ODEQ, P. Woolverton, personal communication, November, 2017.

The hatchery facilities in the North Santiam, South Santiam, McKenzie, and Middle Fork Willamette population areas use adjacent water sources to rear fish (Table 14). Most of the hatchery facilities use water directly piped from the federal dams and would not impact juvenile salmon and steelhead rearing near the hatchery facilities. However, there are other hatchery facilities not associated with the federal dams that divert water out of the tributaries between the intake and discharge location downstream from the hatchery. The maximum permitted water rights for surface and groundwater are also shown in Table 14. The actual water use by all facilities in each population area is specified in Table 15.

Table 14. Water source and use by hatchery facility.

Hatchery Facility	Maximum Surface Water Use Permitted by Water Right (cfs)	Maximum Groundwater Use Permitted by Water Right (cfs)	Surface Water Source	Minimum Mean Monthly Surface Water Flows during Facility Operation cfs (month)	Actual Surface Water Use (cfs) by Hatchery Facility During Minimum Mean Monthly Surface Flows (previous column)[1]	Maximum length of stream affected by hatchery water withdrawal (feet)[2]	Discharge Location
Marion Forks Hatchery	34	0	Marion Creek	438 (NF Santiam upstream of Detroit Dam; September)	18.5	4,840	Horn Creek
Marion Forks Hatchery	32	0	Horn Creek		3.01	790	Horn Creek
Minto Dam FF	60	0	North Santiam River	1,010 (August)	40.5	370	North Santiam River
Roaring River Hatchery	25	0	Roaring River	NA[3](October)	5.93	1,500	Roaring River
South Santiam Hatchery	NA[3]	0.11	South Santiam River	759 (August)	25.9	NA[3] (reservoir withdrawal)	South Santiam River
Foster Dam FF	NA[3]	0	South Santiam River	759 (August)	NA[3]	NA[3] (reservoir withdrawal)	South Santiam River
Leaburg Hatchery	0.33	NA[3]	Spring	NA[3]	0	NA[3]	McKenzie River

Hatchery Facility	Maximum Surface Water Use Permitted by Water Right (cfs)	Maximum Groundwater Use Permitted by Water Right (cfs)	Surface Water Source	Minimum Mean Monthly Surface Water Flows during Facility Operation cfs (month)	Actual Surface Water Use (cfs) by Hatchery Facility During Minimum Mean Monthly Surface Flows (previous column)[1]	Maximum length of stream affected by hatchery water withdrawal (feet)[2]	Discharge Location
	100	NA[3]	McKenzie River	2,200 (Vida gage) (September)	85.6	2,632	McKenzie River
McKenzie Hatchery	50	0	McKenzie River		50	NA[3] (canal withdrawal)	McKenzie River
	201	0	Cogswell Creek	NA (September)	2.2	1,892	McKenzie River
Willamette Hatchery	87.5	0.92	Salmon Creek	1,050 (MF Willamette near Oakridge; August)	80.6	7,339	Salmon Creek
Dexter dam FF	35	0	MF Willamette River	1,740 (July)	35	NA[3] (reservoir withdrawal)	Middle Fork Willamette

[1]Monthly hatchery facility water use data reported by ODFW for Water Year 2015-16.
[2]Reported values are the maximum distance from intake of water supply to discharge point at the outfall of the hatchery facility. Some hatchery facilities have two water intake sources and the farthest intake from the facility is reported here to represent the maximum stream reach affected. Lengths were estimated visually using Google Earth.
[3]Not available or applicable.

Table 15. Total water use (cfs up to permit rights for ground and surface water) for all of the hatchery facilities cumulatively within each salmonid population area.

Hatchery Facilities (by population area)	Actual Water Use at Facilities in Population Area	Maximum Percentage of Surface Water Diverted (percent)[1]
North Santiam (Marion Forks hatchery & Minto Dam FF)	126	< 5%
South Santiam (South Santiam hatchery, Roaring River hatchery, and Foster Dam FF[4])	31.94	< 4%
McKenzie (McKenzie hatchery & Leaburg hatchery)	170.33	< 4%
Middle Fork Willamette (Willamette hatchery & Dexter Dam FF)	122.5	< 8%

Source: HGMPs (see Appendix 1 for citations), United States Geological Survey data sets (http://waterdata.usgs.gov), http://streamflow.engr.oregonstate.edu/links/gages_mainx.htm

[1] This calculation is the actual surface water use by the hatchery facility (column 6 of Table 5 in Section 3.2, Water Quantity) divided by the minimum mean surface water flows during lowest annual streamflows (column 5 of Table 5 in Section 3.2, Water Quantity).

2.4.2.3 Smolt Emigration

The timing and duration of smolt emigration for UWR salmon and steelhead has been drastically altered by a variety of factors including construction and operation of federal dams and reservoirs, altered water temperatures and flow regimes in the migration corridors (Figure 27). Water temperatures below the federal dams are higher than natural conditions during the fall and winter prior to smolt emigration which contributes to earlier than natural emigration. Reduced flows during the late winter and early spring to refill the federal reservoirs cause slower emigration rates to the lower Columbia River and estuary, whereby increasing the risk of predation and disease. *Ceratomyxa shasta*, a parasite known to infect salmon and steelhead in the UWR, is problematic particularly during low flow conditions during smolt emigrations. Presently, natural-origin salmon and steelhead exhibit a reduced diversity of juvenile smolt life history types compared to historical times. There is a limited period in the spring when conditions are for successful emigration conditions that reduces diversity.

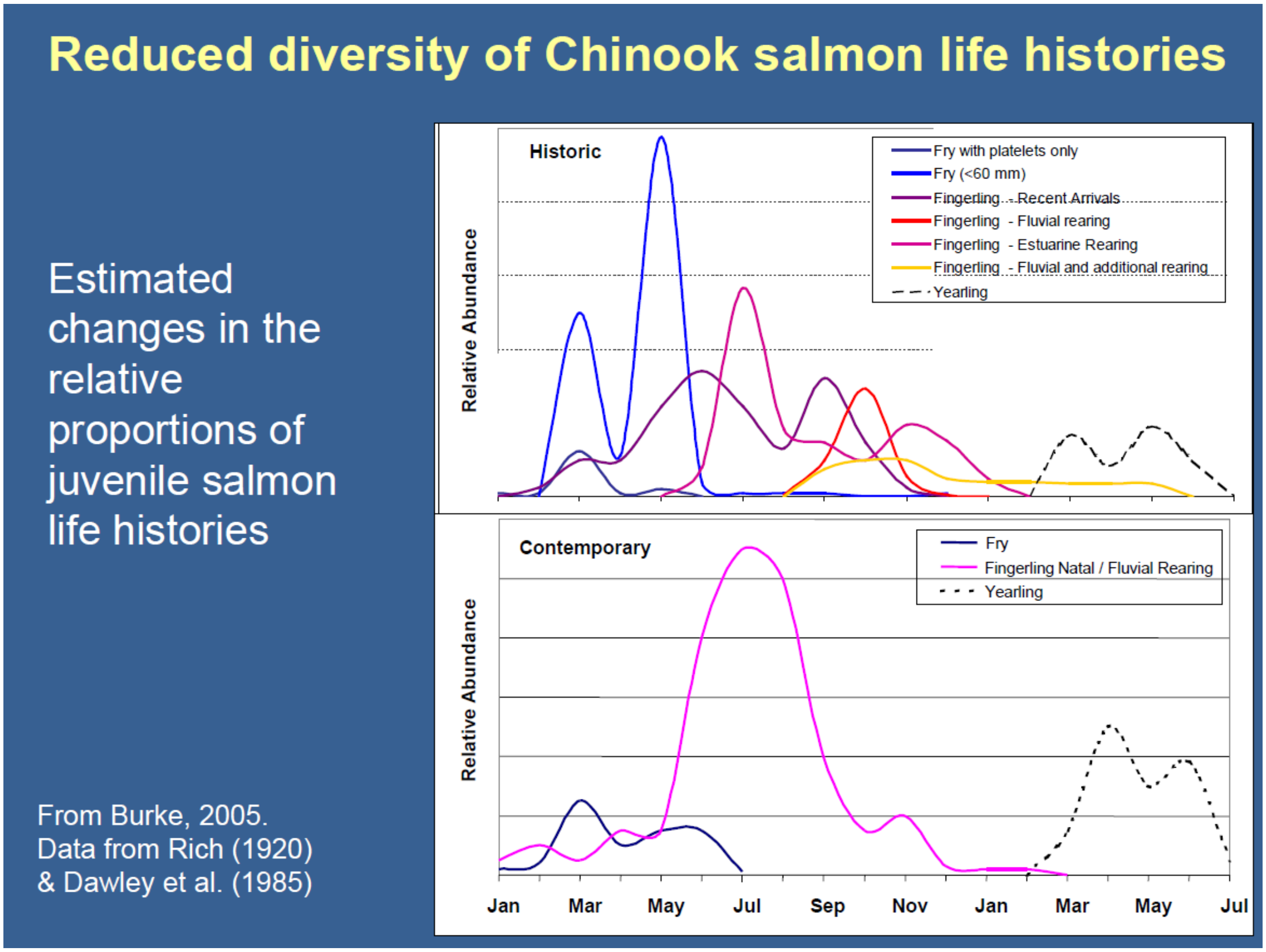


Figure 27. Changes in the life history expression of juvenile Chinook salmon in the lower Columbia estuary due to anthropogenic habitat alterations. Adapted from work in Bottom et al. (2005).

UWR Chinook salmon and steelhead are some of the first smolts to show up in the estuary during late winter and spring. The vast majority of the upriver stocks above Bonneville Dam are later timed in entering the estuary. Therefore, UWR salmon and steelhead are extremely vulnerable to avian predation due to the overlap in migration timings (Figure 28). In addition, the abundance and density of other fish species in the estuary, including millions of hatchery fish, increases the potential for adverse ecological interactions with UWR smolts (Figure 29). The ability of the lower Columbia estuary habitat to support a diversity of life history types of Chinook salmon is greatly reduced compared to historic types due to habitat degradation (Figure 27).

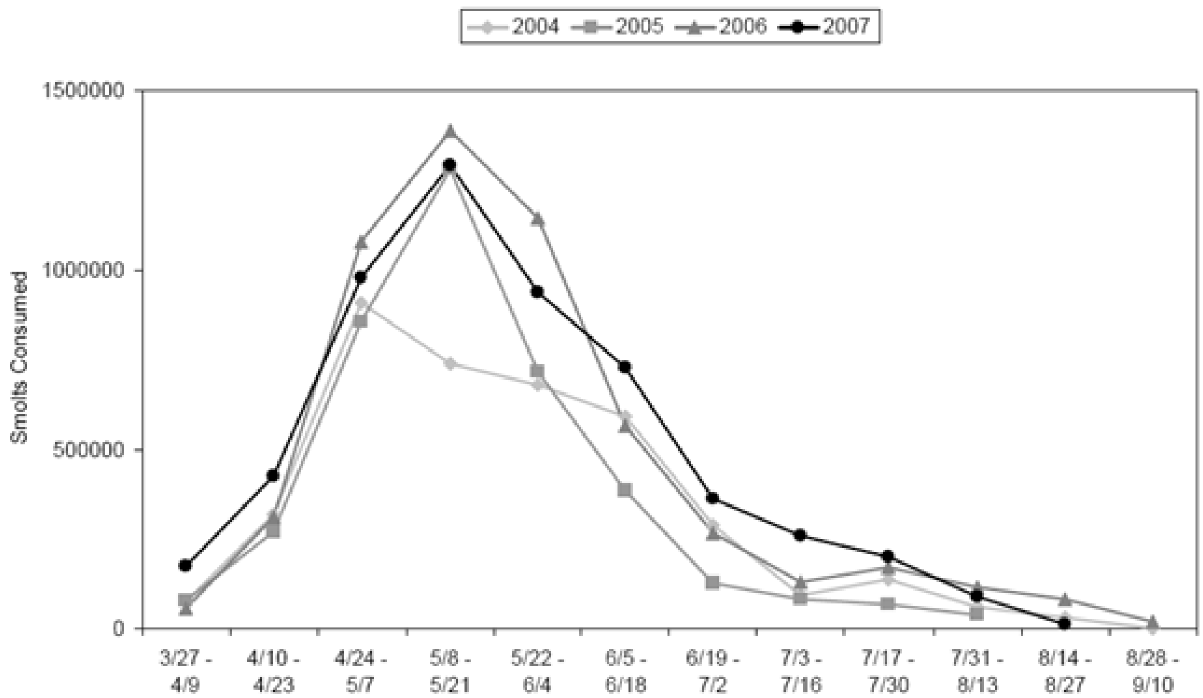


Figure 28. Predation of salmon and steelhead smolts by Caspian terns in the Lower Columbia estuary. Note the overlap of peak predation and emigration timing of UWR Chinook salmon and steelhead smolts.

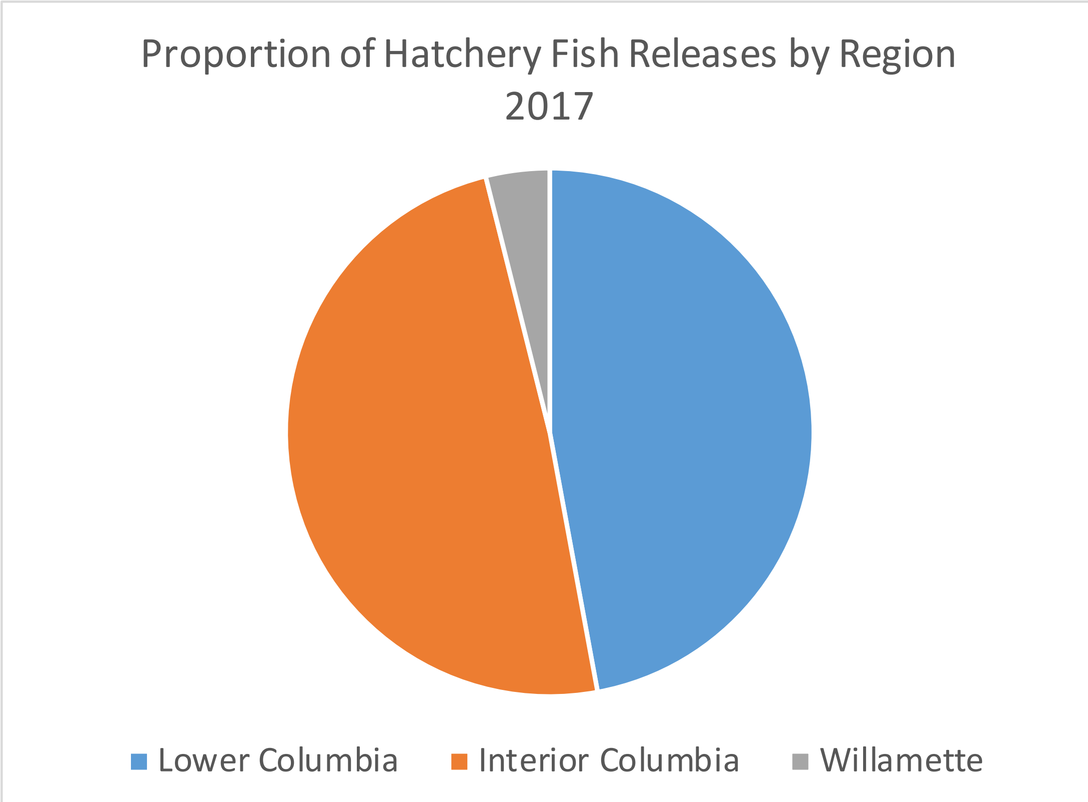


Figure 29. Proportion of hatchery fish originating from the Willamette, Lower Columbia, and Interior Columbia rivers potentially present in the Lower Columbia estuary. The total release is 144 million, of which approximately 4% originate from the UWR.

2.4.2.4 Ocean Residence

UWR Chinook salmon are most susceptible to fishing off the West Coast of Vancouver Island and southeast Alaska due to their ocean distribution. Steelhead are not caught to any measurable degree while in the ocean (PSC 2011). The cumulative harvest rate on these Chinook stocks from all ocean fisheries in recent decades has ranged from 5 percent to 15 percent (Figure 30). The most recent Pacific Salmon Treaty between the US and Canada left ocean fishery impacts on UWR Chinook salmon largely unchanged from previous levels. Fisheries off the coasts of Washington and Oregon do not intercept many Upper Willamette Chinook salmon because of when the fisheries occur and the more northern distribution of these stocks.

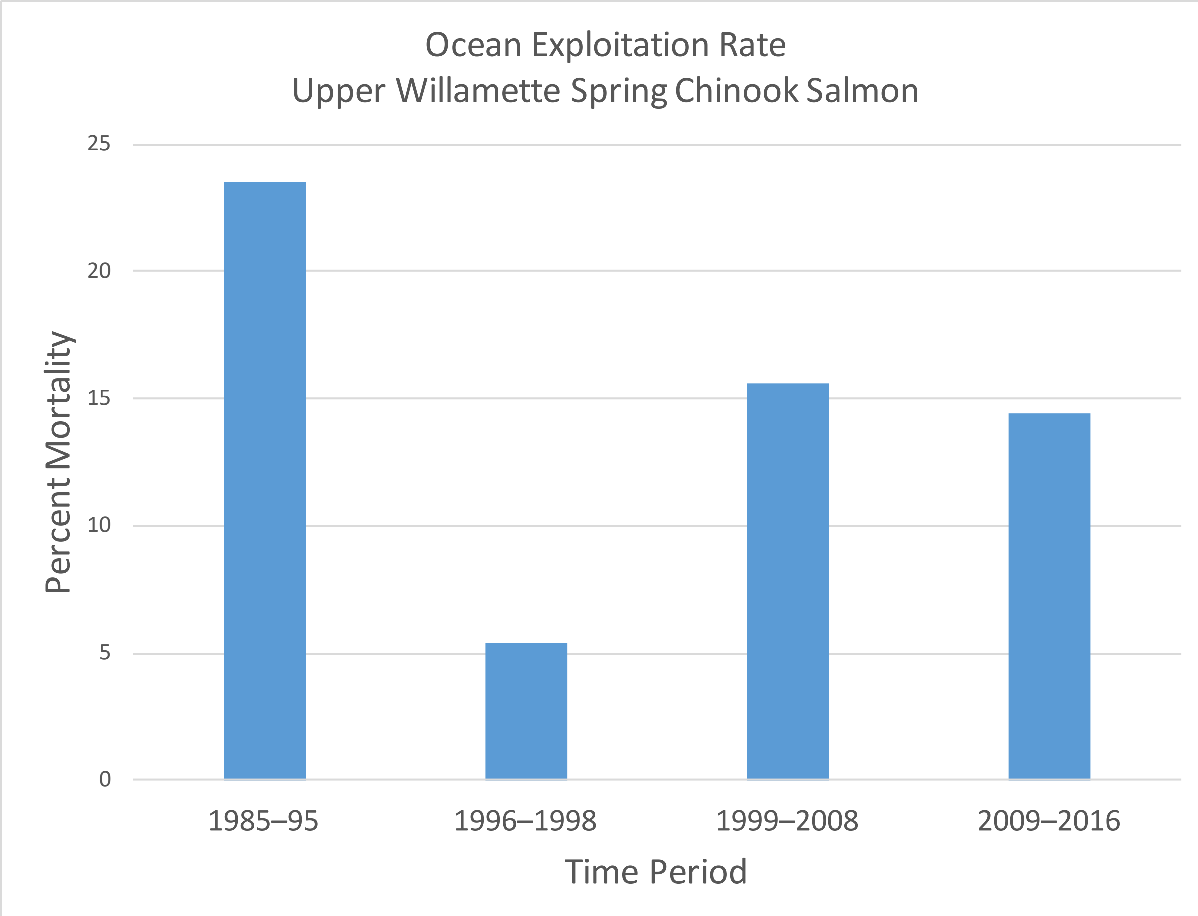


Figure 30. Fishery harvest rates of Upper Willamette spring Chinook in ocean fisheries (PSC 2018).

2.4.2.5 Upstream Adult Migration

UWR spring Chinook salmon enter freshwater and migrate upstream from February through August. Fishery harvest and marine mammal predation (downstream of Willamette Falls) are the primary impacts on these runs in the early phases of adult migration. Later in the season, high water temperatures can cause excessive pre-spawning mortality. Fisheries typically taper off later in the run because catch rates plummet when water temperatures exceed 65 degrees Fahrenheit.

The run timing of UWR steelhead is a legacy of the fact that, before construction of a fish ladder at Willamette Falls in the early 1900s, flow conditions allowed steelhead to ascend Willamette Falls primarily during the late winter and spring. As a result, the majority of the UWR winter steelhead run return to freshwater in January through April, passing Willamette Falls from mid-February to mid-May.

The cumulative harvest rates on natural-origin spring Chinook salmon in freshwater fisheries (all catch and release) range from 5% to 15% (Figure 18; NMFS 2001a). For winter steelhead, all populations experience less than 5% impact from freshwater fisheries (NMFS 2001b).

Keefer et al. (2015) used radio tags with archival temperature loggers to estimate the thermal "history" of adult spring Chinook salmon ascending the Willamette River from 2011 to 2013. They found that the warmest temperatures spring Chinook salmon experienced were in lower Willamette River reaches, where some fish exhibited short-duration behavioral thermoregulation. Cumulative temperature exposure, measured by degree days (DD) above 0 °C, varied by more than seven-fold among individuals (range = 208–1,498 DDs) and more than two-fold among sub-basin populations, on average. Overall, approximately 72 percent of DDs accrued in tributaries and approximately 28 percent were in the Willamette River main stem. DD differences among individuals and populations were related to migration distance, migration duration, and salmon trapping protocols (i.e., extended pre-collection holding in tributaries versus hatchery collection shortly after tributary entry) (Figure 31).

As discussed previously, winter-run steelhead do not have the same issues as spring Chinook salmon on their upstream migration because of when they enter the river they are not exposed to the same water quality threats.

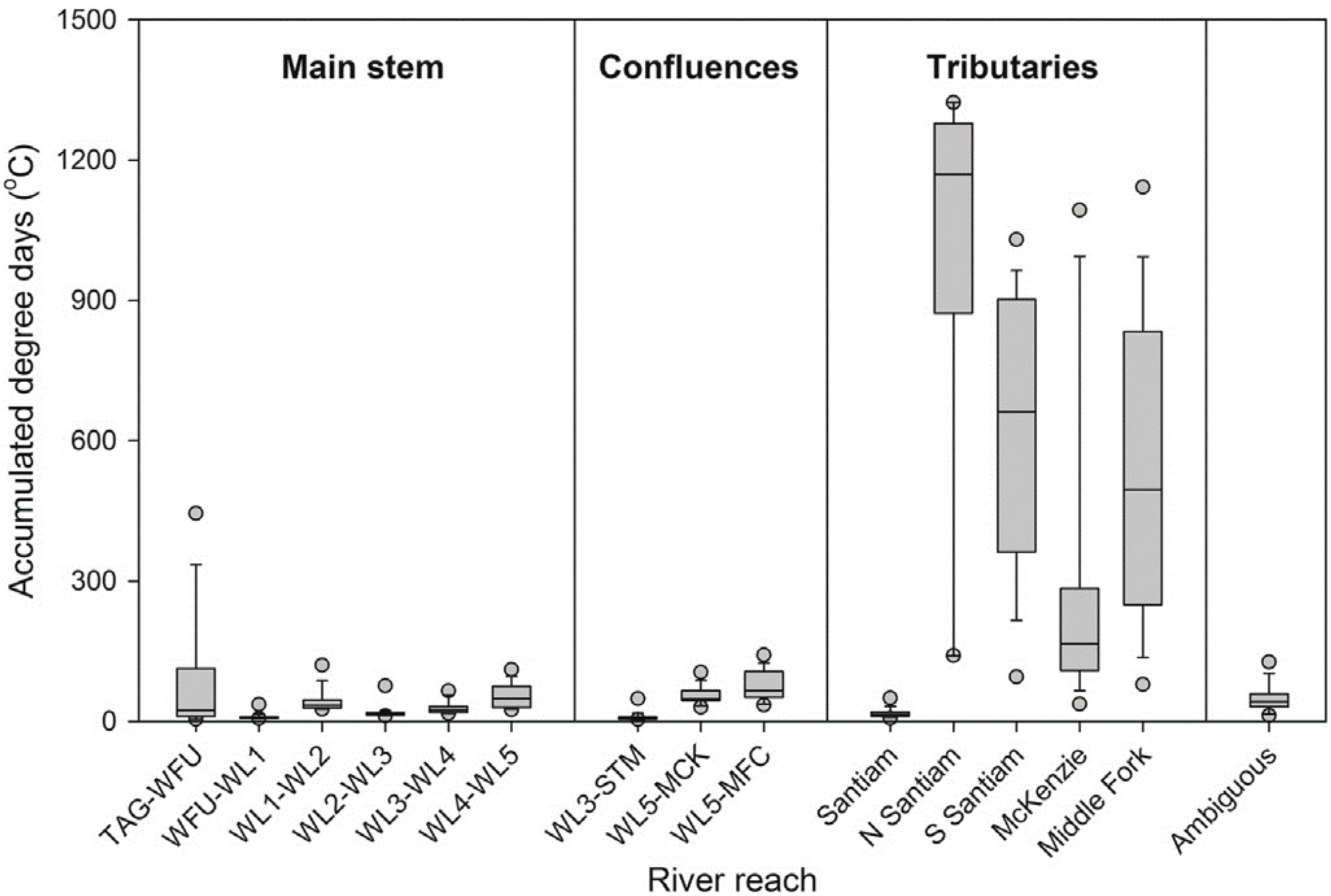


Figure 31. Box plots (median, quartile, 5th, 10th, 90th, 95th percentiles) showing the distributions of individual adult Chinook salmon temperature degree days by river reach with all populations and years combined in the Upper Willamette River. Figure taken from Keefer et al. (2015).

As adults continue migrating upstream into the tributary rivers of the Willamette River they encounter diversion dams with fish ladders that impede and delay their upstream migration (Bennett dams, Lebanon dam, Leaburg dam). Based upon radio telemetry data, delays in passage at these types of dams has been in the range of one to two weeks at the dam location (Janos and McLaughlin 2013). These delays can make spring Chinook salmon more vulnerable to prespawn mortality by not getting to preferred over-summering habitat in the headwaters.

2.4.2.6 Adult Freshwater Residence

The presence of the federal dams has also resulted in the high mortality of adult spring Chinook salmon migrating back to spawning areas in most years and populations, with some areas experiencing over 80% loss of adults prior to spawning (Figure 9). Poor water conditions, presence of high pathogen loads in the federal reservoirs, and disease outbreaks from overcrowding below the dams have been the primary cause of the excessive mortality rates of adult UWR spring Chinook salmon (Bowerman et al. 2018). When spring Chinook have access to headwater habitat areas where the fish can over-summer in natural habitat (with "normal" temperature regimes), mortality rates have been very low (see McKenzie River in Figure 9). Changes to the federal dams are expected to improve temperatures, particularly upon construction of a temperature control structure at Detroit Dam, but they remain a limiting factor. Some impacts from fishing occurs while salmon and steelhead are holding in the rivers during the summer, but the impacts are included in the rates specified previously.

2.4.2.7 Spawning

As discussed previously, most natural populations of spring Chinook salmon currently have high percentages of hatchery fish on the spawning grounds (e.g., 40 to 70 percent; Table 6). The primary cause of high pHOS depends upon the specific population. Some populations have high pHOS due to drastically reduced numbers of natural-origin fish (e.g. Middle Fork Willamette), where essentially low numbers of hatchery fish spawning in the wild comprise the majority of spawners. For other populations, the cause is high numbers of hatchery salmon straying into natural production areas with substantial numbers of natural salmon (e.g. McKenzie River population). The effects of high pHOS range from adverse to beneficial. Where no natural-origin salmon are present, high pHOS is a benefit to provide spawning in areas where no salmon currently exist. This is the situation above most federal dams where hatchery fish are being reintroduced into historic habitat. In these cases, if pHOS is reduced, then the population is at higher risk because of the reduced abundance and reliance on lower natural production (Waples and Do 1994). In other situations, where natural origin fish are reproducing successfully, pHOS can have long term genetic risks to population productivity (Chilcote et al. 2011). In most cases, managers are planning to reduce the percentage of hatchery-origin fish on the spawning grounds once natural-origin fish abundance increases (Table 6). The significant reduction in habitats historically available for salmon has also decreased the genetic diversity and resiliency of these populations (Thompson et al. 2019); further compounding the effects of pHOS.

Estimates of pHOS for winter steelhead are more difficult to calculate due to high flows, turbidity, and the widespread spawning distribution of these fish during the winter. However, as discussed previously, there are no winter steelhead hatchery fish released in the UWR. While researchers have shown spatial overlap of hatchery summer-run steelhead and natural-origin winter-run steelhead, there appears to be less temporal overlap (see effects analysis below), so while any spawning between natural-origin winter steelhead and hatchery-origin summer steelhead is unwanted, it is likely low, and managers are working to reduce the likelihood of interaction between the two ecotypes of steelhead in the UWR. This is further analyzed below.

For populations of spring Chinook salmon and winter steelhead that spawn downstream of Federal hydro projects, various physical factors have been affected. Modification of the flow regime downstream of dams has impaired gravel recruitment and deposition, and together with gravel entrapment above dams, has resulted in reduced quantity and quality of spawning and incubation substrates. In addition, increased flow could influence spawners to spawn in areas that could subsequently be dewater during flood control operations, leading to increased mortality and reduced productivity. High temperatures (especially downstream of Dexter Dam on the Middle Fork Willamette River) also reduce spawning success of spring Chinook salmon.

2.4.2.8 Summary of Environmental Baseline

Altogether, the stressors described above for each life stage of spring Chinook salmon and winter steelhead under present conditions are expected to continue. The status of both species is continuing to decline, even with major management reforms (particularly fishery harvest). The loss of habitat historically available for most populations above the federal dams continues to be a primary limiting factor/threat. For spring Chinook salmon residing below the federal dams, prespawning mortality rates are high and habitat quantity and quality issues persist. Low numbers of natural-origin salmon coupled with high numbers of hatchery-origin salmon results in high pHOS on the spawning grounds. While certain structural improvements have been implemented at the federal dams such as improved collection facilities, salmon and steelhead are still not showing much improvement indicating the key limiting factors/threats have not been addressed.

2.5 Effects of the Action

This section describes the effects of the proposed action, independent of the environmental baseline and cumulative effects. The “effects of the action” means the direct and indirect effects of the action on the species and on designated critical habitat, together with the effects of other activities that are interrelated or interdependent, that will be added to the environmental baseline (50 CFR 402.02). Indirect effects are those that are caused by the proposed action and are later in time, but still are reasonably certain to occur. Effects of the proposed action that are later in time (i.e., after expiration of the proposed action) are included in the analysis in this opinion. In Section 2.7, the proposed action, the status of ESA-protected species and designated critical habitat under the Environmental Baseline, and the cumulative effects of activities within the action area that are reasonably certain to occur, are analyzed comprehensively to determine whether the proposed action is likely to appreciably reduce the likelihood of survival and recovery of ESA protected species.

For this consultation, it is important to summarize the proposed action in order to gain proper perspective for the following analysis of effects. This consultation assesses the effects of the hatchery programs in operation in the Upper Willamette River Basin and the effects, positive and negative, on listed juvenile and adult spring Chinook salmon and winter steelhead. There are four hatchery programs producing spring Chinook salmon, one program producing summer steelhead, and one program releasing rainbow trout.

2.5.1 Factors That Are Considered When Analyzing Hatchery Effects

For Pacific salmon, NMFS evaluates extinction processes and effects of the proposed action beginning at the population scale (McElhany et al. 2000). NMFS defines population performance measures in terms of natural-origin fish and four key attributes: abundance, productivity, spatial structure, and diversity and then relates effects of the proposed action at the population scale and then ultimately to the survival and recovery of an entire ESU and DPS.

This section describes the methodology NMFS follows to analyze hatchery effects. The methodology is based on the best available scientific information. Analysis of the proposed action itself is described in Section 2.5.2 of the opinion.

“Because of the potential for circumventing the high rates of early mortality typically experienced in the wild, artificial propagation may be useful in the recovery of listed salmon species. However, artificial propagation entails risks as well as opportunities for salmon conservation” (Hard et al. 1992). A proposed action is analyzed for effects, positive and negative, on the attributes that define population viability, including abundance, productivity, diversity, and spatial structure. The effects of a hatchery program on the status of an ESU or steelhead DPS “will depend on which of the four key attributes are currently limiting the ESU, and how the hatchery fish within the ESU affect each of the attributes” (70 FR 37215, June 28, 2005). The presence of hatchery fish within the ESU can positively affect the overall status of the ESU by increasing the number of natural spawners, by serving as a source population for repopulating unoccupied habitat and increasing spatial distribution, and by conserving genetic resources. “Conversely, a hatchery program managed without adequate consideration can affect a listing determination by reducing adaptive genetic diversity of the ESU, and by reducing the reproductive fitness and productivity of the ESU”. NMFS also analyzes and takes into account the effects of hatchery facilities, for example, operation of fish collection facilities and water use, on each VSP attribute and on designated critical habitat.

NMFS’ analysis of the proposed action is in terms of effects expected on ESA-listed species and designated critical habitat, based upon the best scientific information. The effects are assessed at a site-specific level, population scale, as well as at the ESU and DPS level, in order for NMFS to make a jeopardy determination based on a comprehensive assessment of effects. (Section 2.7).

The effects, positive and negative, for the hatchery programs analyzed in this consultation are summarized in Table 16.

Table 16. Potential range of effects of hatchery programs on natural population VSP parameters. The range in effects are specific to these particular hatchery programs currently in operation in the individual populations of the Upper Willamette River basin.

VSP parameter of natural-origin population	Hatchery spring Chinook salmon programs (4 programs)	Hatchery programs propagating non-listed summer steelhead (one program)	Hatchery program releasing non-listed rainbow trout (one program)
Abundance	**Positive to negative effect.** The spring Chinook salmon programs increase natural spawning abundance. However, the programs also take natural-origin salmon for broodstock (mining), reducing abundance.	**Negligible to negative effect.** Non-listed summer steelhead affect listed salmon and steelhead from ecological interactions such as predation and competition. These impacts can directly (and indirectly) affect the abundance of listed populations.	**Negligible effect.** The rainbow program does not increase the abundance of any salmon or steelhead population. Rainbow trout may interact with juvenile salmon and steelhead, but impact is negligible.
Productivity	**Positive to negative effect.** These salmon programs are being managed to support reintroduction above federal dams in four populations that has increased spawner:spawner productivity rates. Naturally spawning hatchery fish can also interbreed with natural-origin salmon resulting in lowered fitness/productivity.	**Negligible to negative effect.** The principal effect of the non-listed steelhead program on listed salmon and steelhead is from ecological and genetic interactions. These interactions would all be negative on productivity, with the severity dependent upon specific interactions.	**Negligible effect.** Program results in ecological interactions (competition, predation) of limited scope and duration in reservoirs, McKenzie River, and upstream of some federal dams.
Diversity	**Positive to negligible effect.** The hatchery stocks contain important genetic resources not found in the depressed natural populations, and therefore contribute to the diversity of the ESU. Risk from hatchery fish interbreeding with natural fish is important to manage once natural production increases.	**Negative effect.** The summer steelhead has a negative effect on natural diversity of winter steelhead. Summer and winter can hybridized; changing the gene pool of winter steelhead. Other ecological interactions would be negative.	**Negligible effect.** Rainbow trout stock is substantially different than listed steelhead and no effect is suspected due to differences in spawn timing between hatchery trout and winter steelhead.
Spatial Structure	**Positive effect.** The Chinook programs are being used for reintroduction above federal dams, increasing the distribution of the populations.	**Negligible effect.** The steelhead program is not providing any distribution/spatial structure benefits to listed salmon and steelhead.	**Negligible effect.** The program is not providing any spatial structure benefits to listed salmon and steelhead.

In general, the effects range from beneficial to negative for programs that use local fish[7] for hatchery broodstock (i.e. Chinook salmon) and from negligible to negative when a program does not use local fish for broodstock[8] (i.e. summer steelhead and rainbow trout). Only the Chinook salmon hatchery programs provide VSP benefits to the natural population. Integrated hatchery programs use local fish for broodstock (natural-origin and hatchery-origin fish included in an ESU or DPS) and implement "best management practices" to minimize hatchery-related risks to the natural population. When hatchery programs use fish originating from a different population, MPG, or from a different ESU or DPS, NMFS is particularly interested in how effective the program will be at isolating hatchery fish and avoiding co-occurrence and effects that potentially put the natural population at a disadvantage. The range in effects are specific to these particular hatchery programs currently in operation in the Upper Willamette River basin.

NMFS analyzes six categories of effects to determine the risks and benefits of the hatchery program. Essentially every biological and ecological effect of a hatchery program are evaluated within one or more of the following categories. These six categories are:

(1) broodstock origin and collection,
(2) hatchery fish and the progeny of naturally spawning hatchery fish on spawning grounds,
(3) hatchery fish and the progeny of naturally spawning hatchery fish in juvenile rearing areas, mainstem rivers, estuary, and ocean,
(4) research, monitoring, and evaluation (RM&E) supporting hatchery program implementation,
(5) operation, maintenance, and construction of hatchery facilities (i.e., facility effects), and
(6) fisheries that would not exist but for the availability of hatchery fish to catch.

2.5.1.1 Broodstock collection

Broodstock collection is arguably the single most important aspect of a hatchery program and is therefore a particularly important factor in the effects analysis. The first consideration in analyzing and assigning effects for broodstock collection is the origin and number of fish collected. The analysis considers whether broodstock are of local origin and the consequences of using ESA-listed fish (natural or hatchery-origin). It considers the maximum number of fish proposed for collection, the proportion of the donor population tapped for broodstock, and whether the program "backfills" with fish from outside the local or immediate area. "Mining" a natural population to collect natural-origin fish to supply hatchery broodstock can reduce population abundance, productivity, and potentially spatial structure.

In the Upper Willamette River, it is important to note all of the facilities used for broodstock collection are either 1) associated with the Willamette Project dams, or 2) occur at a hatchery facility built decades ago. Most of the hatchery facilities were built after the dams were constructed to mitigate for the loss of natural-origin salmon and steelhead above the dams (not vice versa). Collection of hatchery broodstock occurs at the dams because it is a convenient location to catch fish for the mitigation hatchery programs. Most of the fish ladders and traps at these dams have been rebuilt over the last decade to make them

[7] The term "local fish" is defined to mean fish that are no more than moderately divergent from the associated local natural population. See 70 FR 37204, June 28, 2005.
[8] Exceptions include restoring extirpated populations and gene banks.

more fish friendly for trap and haul of salmon and steelhead above the projects for reintroduction purposes in historic habitat while collecting broodstock for the hatchery program.

2.5.1.2 Hatchery fish and the progeny of naturally spawning hatchery fish on the spawning grounds

NMFS also analyzes the effects of hatchery returns and the progeny of naturally spawning hatchery fish on the spawning grounds. There are two aspects to this part of the analysis: genetic effects and demographic effects. When genetic introgression occurs, NMFS generally views genetic effects as detrimental based on the weight of available scientific information, we believe that artificial breeding and rearing is likely to result in some degree of genetic change and fitness reduction in hatchery-propagated fish and in the progeny of naturally spawning hatchery fish relative to desired levels of diversity and productivity for natural populations. Hatchery fish thus pose a threat to natural population rebuilding and recovery when they interbreed with fish from natural populations and transfer their inherent fitness limitations to the offspring of the natural population.

However, NMFS recognizes that there are benefits as well, and that the domestication risks may be irrelevant when demographic or short-term extinction risks are significant to population abundance, diversity and productivity. Conservation hatchery programs may accelerate recovery of a target population by increasing abundance faster than may occur naturally (Waples 1999). Hatchery programs can also be used to create genetic reserves for a population to prevent the loss of its unique traits due to catastrophes (Ford 2011). Furthermore, NMFS also recognizes there is considerable uncertainty regarding genetic risk. The extent and duration of genetic change and fitness loss and the short and long-term implications and consequences for different species, for species with multiple life-history types, and for species subjected to different hatchery practices and protocols is not fully understood and is subject of further scientific investigation. As a result, NMFS believes that hatchery intervention is a legitimate and useful tool to alleviate short-term extinction risk, but otherwise managers should seek to limit interactions between hatchery and natural-origin fish and implement hatchery practices that harmonize conservation with the implementation of fisheries and other applicable laws and policies.

Types of Genetic Risk

Hatchery fish can have a variety of genetic effects on natural population productivity and diversity when they interbreed with natural-origin fish. Although there is biological interdependence between them, NMFS considers three major areas of genetic effects of hatchery programs: within-population diversity, outbreeding effects, and hatchery-induced selection. As we have stated above, in most cases, the effects are viewed as risks, but in the case of very small populations, these effects can sometimes be beneficial, reducing extinction risk.

Within-population genetic diversity is a general term for the quantity, variety and combinations of genetic material in a population (Busack and Currens 1995). Within-population diversity is gained through mutations or gene flow from other populations (described below under outbreeding effects) and is lost primarily due to genetic drift, a random loss of diversity due to small population size. The rate of loss is determined by the population's effective population size (N_e). Effective population size, which is basically census size adjusted for variation in sex ratio and reproductive success, determines the level of genetic diversity that can be maintained by a population, and the rate at which diversity is lost. For salmonids, N_e is generally one quarter to one third of the census population. Effective size can be considerably smaller than its census size. For a population to maintain genetic diversity reasonably well, the effective size should be in the hundreds (e.g., Lande and Barrowclough 1987), and diversity loss can be severe if N_e drops to a few dozen.

Hatchery programs, simply by virtue of creating more fish, can increase N_e. In very small populations this can be a benefit, making selection more effective and reducing other small-population risks (e.g., Lacy 1987; Whitlock 2000; Willi et al. 2006). Conservation hatchery programs can thus serve to protect genetic diversity; several, such as the programs preserving and restoring Snake River sockeye salmon, South Fork Nooksack Chinook salmon, and Elwha River Chinook salmon, are important genetic reserves. However, hatchery programs can also directly depress N_e through two principal methods. One is by the simple removal of fish from the population so that they can be used in the hatchery. If a substantial portion of the population is taken into a hatchery, the hatchery becomes responsible for that portion of the effective size, and if the operation fails, the effective size of the population will be reduced (Waples and Do 1994). N_e can also be reduced considerably below the census number of broodstock by using a skewed sex ratio, spawning males multiple times (Busack 2007), and by pooling gametes. Pooling semen is especially problematic because when semen of several males is mixed and applied to eggs, a large portion of the eggs may be fertilized by a single male (Gharett and Shirley 1985; Withler 1988). Factorial mating schemes, in which fish are systematically mated multiple times, can be used to increase N_b(Fiumera et al. 2004; Busack and Knudsen 2007). An extreme form of N_e reduction is the Ryman-Laikre effect (Ryman and Laikre 1991; Ryman et al. 1995), which $N_e$is reduced through the return to the spawning grounds of large numbers of hatchery fish from very few parents.

Inbreeding depression, another N_e-related phenomenon, is caused by the mating of closely related individuals (e.g., siblings, half-siblings, or cousins). The smaller the population, the more likely spawners will be related. Related individuals are likely to contain similar genetic material, and the resulting offspring may then have reduced survival because they are less variable genetically or are homozygous for recessive deleterious mutations. The lowered fitness of fish due to inbreeding depression accentuates the genetic risk problem, helping to push a small population toward extinction.

Outbreeding effects can result from gene flow from other distant populations. Gene flow occurs naturally among salmon and steelhead populations, a process referred to as straying (Quinn 1993; Quinn 1997). Natural straying from nearby populations (with similar ecological conditions) serves a valuable function in preserving diversity that would otherwise be lost through genetic drift and in re-colonizing vacant habitat, and straying is considered a risk only when it occurs at unnatural levels or from unnatural sources. Hatchery programs can result in straying outside natural patterns for two reasons. First, hatchery fish may exhibit reduced homing fidelity relative to natural-origin fish (Grant 1997; Quinn 1997; Jonsson et al. 2003; Goodman 2005), resulting in unnatural levels of gene flow into recipient populations, either in terms of sources or rates. Second, even if hatchery fish home at the same level of fidelity as natural-origin fish, their higher abundance can cause unnatural straying levels into recipient populations. One goal for hatchery programs should be to ensure that hatchery practices do not lead to higher rates of genetic exchange with fish from natural populations than would occur naturally (Ryman 1991). Rearing and release practices and ancestral origin of the hatchery fish can all play a role in straying (Quinn 1997).

Gene flow from other populations can have two effects. It can increase genetic diversity (e.g., Ayllon et al. 2006) which can be a benefit in small populations, but it can also alter established allele frequencies (and co-adapted gene complexes) and reduce the population's level of adaptation, a phenomenon called outbreeding depression (Edmands 2007; McClelland and Naish 2007). In general, the greater the geographic separation between the source or origin of hatchery fish and the recipient natural population, the greater the genetic difference between the two populations (ICTRT 2007), and the greater potential for outbreeding depression. For this reason, NMFS advises hatchery action agencies to develop locally derived hatchery broodstocks. Additionally, unusual rates of straying into other populations within or beyond the population's MPG or ESU or a steelhead DPS can have an homogenizing effect, decreasing intra-population genetic variability (e.g., Vasemagi et al. 2005), and increasing risk to population diversity, one of the four attributes measured to determine population viability. Reduction of within-population and among-population diversity can reduce adaptive potential.

The proportion of hatchery fish spawning among natural fish, or "pHOS", is often used as a surrogate measure of gene flow. Appropriate cautions and qualifications should be considered when using this proportion to analyze hatchery affects. Adult salmon may wander on their return migration, entering and then leaving tributary streams before finally spawning (Pastor 2004). These "dip-in" fish may be detected and counted as strays, but may eventually spawn in other areas, resulting in an overestimate of the number of strays that potentially interbreed with the natural population (Keefer et al. 2008). Caution must also be applied in assuming that strays contribute genetically in proportion to their abundance. Several studies demonstrate little genetic impact from straying despite a considerable presence of strays in the spawning population (Saisa et al. 2003; Blankenship et al. 2007). The causative factors for poorer breeding success of strays are likely similar to those identified as responsible for reduced productivity of hatchery-origin fish in general, e.g., differences in run and spawn timing, spawning in less productive habitats, and reduced survival of their progeny (Reisenbichler and McIntyre 1977; Leider et al. 1990; McLean et al. 2004; Williamson et al. 2010; Chilcote et al. 2011).

Hatchery-influenced selection (often called domestication) occurs when selection pressures imposed by hatchery spawning and rearing differ greatly from those imposed by the natural environment and causes genetic and epigenetic change that is passed on to natural populations through interbreeding with hatchery-origin fish (Christie et al. 2016; Le Luyer et al. 2017). These differing selection pressures can be a result of differences in environments or a consequence of protocols and practices used by a hatchery program. Hatchery-influenced selection can range from relaxation of selection, that would normally occur in nature, to selection for different characteristics in the hatchery and natural environments, to intentional selection for desired characteristics (Waples 1999; Le Luyer et al. 2017).

Genetic change and fitness reduction resulting from hatchery-influenced selection depends on: (1) the difference in selection pressures; (2) the exposure or amount of time the fish spends in the hatchery environment; and, (3) the duration of hatchery program operation (i.e., the number of generations that fish are propagated by the program). On an individual level, exposure time in large part equates to fish culture, both the environment experienced by the fish in the hatchery and natural selection pressures, independent of the hatchery environment (Le Luyer et al. 2017). On a population basis, exposure is determined by the proportion of natural-origin fish in the hatchery broodstock and the proportion of naturally-spawning fish of hatchery-origin (Lynch and O'Hely 2001; Ford 2002), and then by the number of years the exposure takes place. In assessing risk or determining impact, all three levels must be considered. Strong selective fish culture with low hatchery-wild interbreeding can pose less risk than relatively weaker selective fish culture with high levels of interbreeding.

Most of the empirical evidence for fitness depression due to hatchery-influenced selection comes from studies of species that are reared in the hatchery environment for an extended period – one to two years – prior to release (Berejikian and Ford 2004). Exposure time in the hatchery for fall and summer Chinook salmon and chum salmon is much shorter, just a few months. One especially well-publicized steelhead study (Araki et al. 2007; Araki et al. 2008), showed dramatic fitness declines in the progeny of naturally spawning Hood River hatchery steelhead in a single generation. Researchers and managers alike have wondered if these results could be considered a potential outcome applicable to all salmonid species, life-history types, and hatchery rearing strategies (Le Luyer et al. 2017).

NMFS approach to Genetic Risk

Besides the Hood River steelhead work, a number of studies are available on the relative reproductive success (RRS) of hatchery-origin and natural-origin fish (e.g.,Theriault et al. 2011; Ford et al. 2012; Hess et al. 2012). All have shown that generally hatchery-origin fish have lower reproductive success, though the differences have not always been statistically significant and in some years in some studies, the opposite is true. Lowered reproductive success of hatchery-origin fish in these studies is typically considered evidence of hatchery-influenced selection. Although RRS may be a result of hatchery-influenced selection, studies must be carried out for multiple generations to unambiguously detect a genetic effect. To date only the Hood River steelhead (Araki et al. 2007; Christie et al. 2011; Christie et al. 2016) and Wenatchee spring Chinook salmon (Ford et al. 2012) RRS studies have reported multiple-generation effects.

Critical information for analysis of hatchery-induced selection includes the number, location and timing of naturally spawning hatchery-origin fish, the estimated level of gene flow between hatchery-origin and natural-origin fish, the origin of the hatchery stock (the more distant the origin compared to the affected natural population, the greater the threat), the level and intensity of hatchery selection and the number of years the operation has been run in this way. Efforts to control and evaluate the risk of hatchery-influenced selection are currently largely focused on gene flow between natural-origin and hatchery-origin fish[9]. The ICTRT (2007) developed guidelines based on the proportion of spawners in the wild consisting of hatchery-origin fish (pHOS)(Figure 32).

[9] Gene flow between natural-origin and hatchery-origin fish is often, and quite reasonably, interpreted as meaning actual matings between natural-origin and hatchery-origin fish. In some contexts, it can mean that. However, in this document, unless otherwise specified, gene flow means contributing to the same progeny population. For example, hatchery-origin spawners in the wild will either spawn with other hatchery-origin fish or with natural-origin fish. Natural-origin spawners in the wild will either spawn with other natural-origin fish or with hatchery-origin fish. But all these matings, to the extent they are successful, will generate the next generation of natural-origin fish. In other words, all will contribute to the natural-origin gene pool.

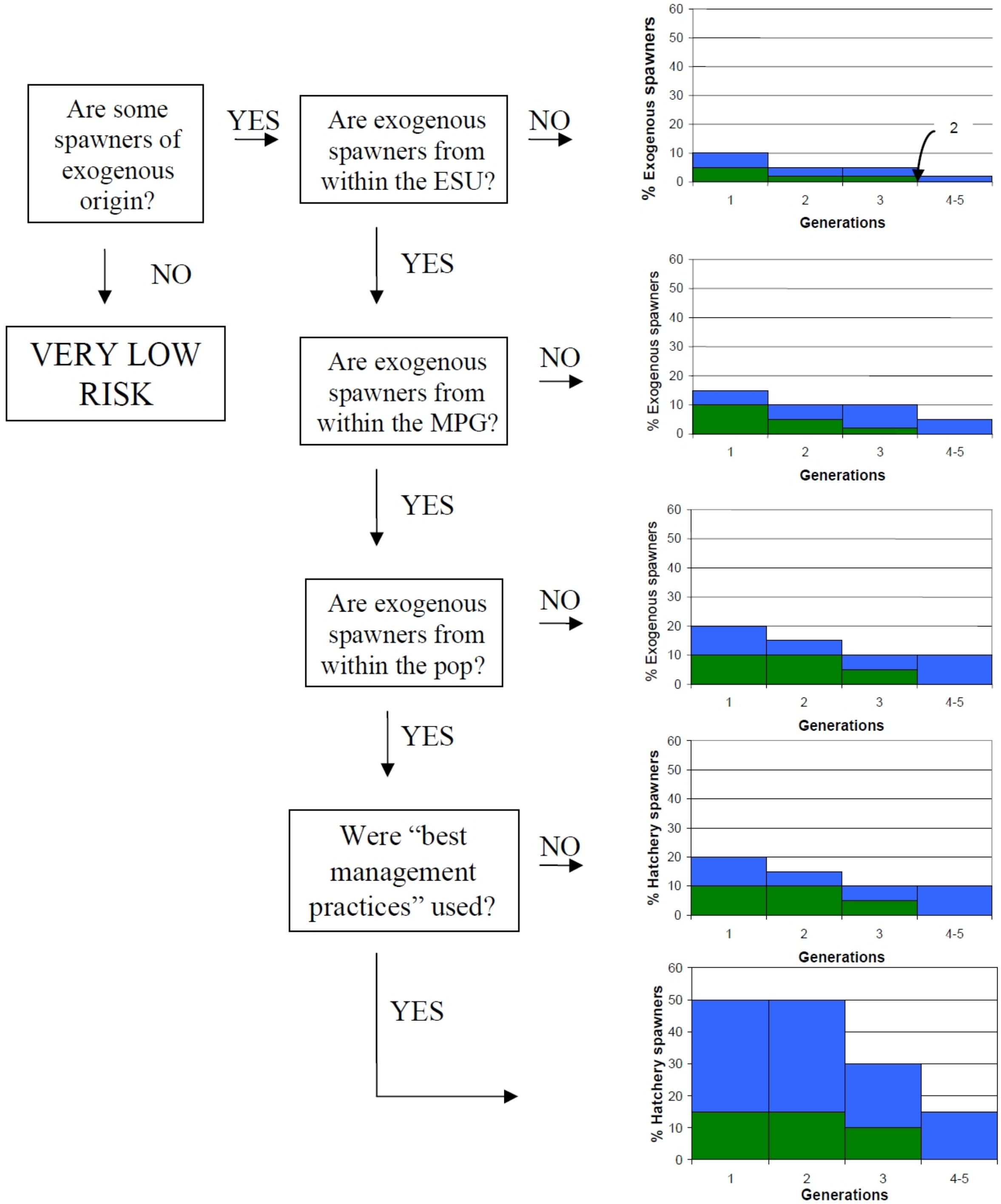


Figure 32. ICTRT (2007) risk criteria associated with spawner composition for viability assessment of exogenous spawners on maintaining natural patterns of gene flow. Green (darkest) areas indicate low risk combinations of duration and proportion of spawners, blue (intermediate areas indicate moderate risk areas and white areas and areas outside the graphed range indicate high risk. Exogenous fish are considered to be all fish of hatchery origin, and non-normative strays of natural origin.

More recently, the Hatchery Scientific Review Group (HSRG) developed gene flow criteria/guidelines based on mathematical models developed by Ford (2002) and by Lynch and O'Hely (2001). Guidelines for isolated programs are based on pHOS, but guidelines for integrated programs are also based on a metric called proportionate natural influence (PNI), which is a function of pHOS and the proportion of natural-origin fish in the broodstock (pNOB)[10]. PNI is in theory a reflection of the relative strength of selection in the hatchery and natural environments: a PNI value greater than 0.5 indicates dominance of natural selective forces. The HSRG guidelines vary according to type of program and conservation importance of the population. For a population of high conservation importance their guidelines are a pHOS of no greater than 5% for isolated programs or a pHOS no greater than 30% and PNI of at least 67% for integrated programs (HSRG 2009). Higher levels of hatchery influence are acceptable, but only when a population is at high risk or very high risk of extinction due to low abundance and the hatchery program is being used to conserve the population and reduce extinction risk, in the short-term. HSRG (2004) offered additional guidance regarding isolated programs, stating that risk increases dramatically as the level of divergence increases, especially if the hatchery stock has been selected directly or indirectly for characteristics that differ from the natural population. The HSRG recently produced an update report (HSRG 2014) in which they stated that the guidelines for isolated programs may not provide as much protection from fitness loss as the corresponding guidelines for integrated programs.

Another HSRG team recently reviewed California hatchery programs and developed guidelines that differed considerably from those developed by the earlier group (California HSRG 2012). The California HSRG felt that truly isolated programs in which no hatchery-origin returnees interact genetically with natural populations were impossible in California, and was “generally unsupportive” of the concept. However, if programs were to be managed as isolated, they recommend a pHOS of less than 5%. They rejected development of overall pHOS guidelines for integrated programs because the optimal pHOS will depend upon multiple factors, such as “the amount of spawning by natural-origin fish in areas integrated with the hatchery, the value of pNOB, the importance of the integrated population to the larger stock, the fitness differences between hatchery- and natural-origin fish, and societal values, such as angling opportunity.” They recommended that program-specific plans be developed with corresponding population-specific targets and thresholds for pHOS, pNOB, and PNI that reflect these factors. However, they did state that PNI should exceed 50% in most cases, although in supplementation or reintroduction programs the acceptable pHOS could be much higher than 5%, even approaching 100% at times. They also recommended for conservation programs that pNOB approach 100%, but pNOB levels should not be so high they pose demographic risk to the natural population.

Discussions involving pHOS can be problematic due to variation in its definition. Most commonly, the term pHOS refers to the proportion of the total natural spawning population consisting of hatchery fish, and the term has been used in this way in all NMFS documents. However, the HSRG has defined pHOS inconsistently in its Columbia Basin system report, equating it with “the proportion of the natural spawning population that is made up of hatchery fish” in the Conclusion, Principles and Recommendations section (HSRG 2009), but with “the proportion of *effective* hatchery origin spawners” in their gene flow criteria. In addition, in their Analytical Methods and Information Sources section (HSRG 2009, appendix C) they introduce a new term, *effective pHOS*. Despite these inconsistencies, their overall usage of pHOS indicates an intent to use pHOS as a surrogate measure of gene flow

[10] PNI is computed as pNOB/(pNOB+pHOS). This statistic is really an approximation of the true proportionate natural influence (HSRG 2009b, appendix A), but operationally the distinction is unimportant.

potential. This is demonstrated very well in the fitness effects appendix (HSRG 2009, appendix A1), in which pHOS is substituted for a gene flow variable in the equations used to develop the criteria. This confusion was cleared up in the 2014 update document (HSRG 2014), where it is clearly stated that the metric of interest is effective pHOS.

In the 2014 report, the HSRG explicitly addressed the differences between *census* pHOS and *effective* pHOS (HSRG 2014). In the document, the HSRG defined PNI as

$$PNI = \frac{pNOB}{(pNOB + pHOS_{eff})}$$

where $pHOS_{eff}$ is the effective proportion of hatchery fish in the naturally spawning population (HSRG 2014). The HSRG recognized that hatchery fish spawning naturally may on average produce fewer adult progeny than natural-origin spawners, as described above. To account for this difference the HSRG defined *effective* pHOS as

$$pHOS_{eff} = RRS * pHOS_{census}$$

where $pHOS_{census}$ is the proportion of the naturally spawning population that is composed of hatchery-origin adults (HSRG 2014).

NMFS believes the adjustment of census pHOS by RRS should be done very cautiously, not nearly as freely as the HSRG document would suggest. The basic reason is quite simple: the Ford (2002) model, the foundation of the HSRG gene flow guidelines, implicitly includes a genetic component of RRS. In that model, hatchery fish are expected to have RRS < 1 (compared to natural fish) due to selection in the hatchery. A component of reduced RRS of hatchery fish is therefore already incorporated in the model and by extension the calculation of PNI. Therefore reducing pHOS values by multiplying by RRS will result in underestimating the relevant pHOS and therefore overestimating PNI. Such adjustments would be particularly inappropriate for hatchery programs with low pNOB, as these programs may well have a substantial reduction in RRS due to genetic factors already incorporated in the model.

In some cases, adjusting pHOS downward may be appropriate, however, particularly if there is strong evidence of a non-genetic component to RRS. An example of a case in which an adjustment by RRS might be justified is that of Wenatchee spring Chinook salmon (Williamson et al. 2010) where, the spatial distribution of natural-origin and hatchery-origin spawners differs, and the hatchery-origin fish tend to spawn in poorer habitat. However, even in a situation like this it is unclear how much of an adjustment would be appropriate. By the same logic, it might also be appropriate to adjust pNOB in some circumstances. For example, if hatchery juveniles produced from natural-origin broodstock tend to mature early and residualize (due to non-genetic effects of rearing), as has been documented in some spring Chinook salmon and steelhead programs, the “effective” pNOB might be much lower than the census pNOB.

It is also important to recognize that PNI is only an approximation of relative trait value, based on a model that is itself very simplistic. To the degree that PNI fails to capture important biological information, it would be better to work to include this information in the underlying models rather than make ad hoc adjustments to a statistic that was only intended to be rough guideline to managers. We look forward to seeing this issue further clarified in the near future. In the meantime, except for cases in which gene flow data reflecting natural spawning effects of hatchery-origin fish are available, or an adjustment for RRS has strong justification, NMFS feels that census pHOS is the appropriate metric to use for genetic risk evaluation.

Additional perspective on pHOS that is independent of HSRG modelling is provided by a simple analysis of the expected proportions of mating types. Figure 33 shows the expected proportion of mating types in a mixed population of natural-origin (N) and hatchery-origin (H) fish as a function of the census pHOS, assuming that N and H adults mate randomly.[11] For example, the vertical line on the diagram marks the situation at a census pHOS level of 10%. At this level, expectations are that 81% of the matings will be NxN, 18% will be NxH, and 1% will be HxH. This diagram can also be interpreted as probability of parentage of naturally produced progeny, assuming random mating and equal reproductive success of all mating types. Under this interpretation, progeny produced by a parental group with a pHOS level of 10% will have an 81% chance of having two natural-origin parents, etc.

Random mating assumes that the natural-origin and hatchery-origin spawners overlap completely spatially and temporally. As overlap decreases, the proportion of NxH matings decreases and with no overlap the proportion of NxN matings is (1-pHOS) and the proportion of HxH matings is pHOS. RRS does not affect the mating type proportions directly, but changes their effective proportions. Overlap and RRS can be related. In the Wenatchee River, hatchery spring Chinook salmon tend to spawn lower in the system than natural-origin fish, and this accounts for a considerable amount of their lowered reproductive success (Williamson et al. 2010). In that particular situation, the hatchery-origin fish were spawning in inferior habitat. Mate selection is known to occur in the wild, but for modeling purposes it is assumed to be random.

[11] These computations are purely theoretical, based on a simple mathematical binomial expansion ($(a+b)^2=a^2 + 2ab + b^2$).

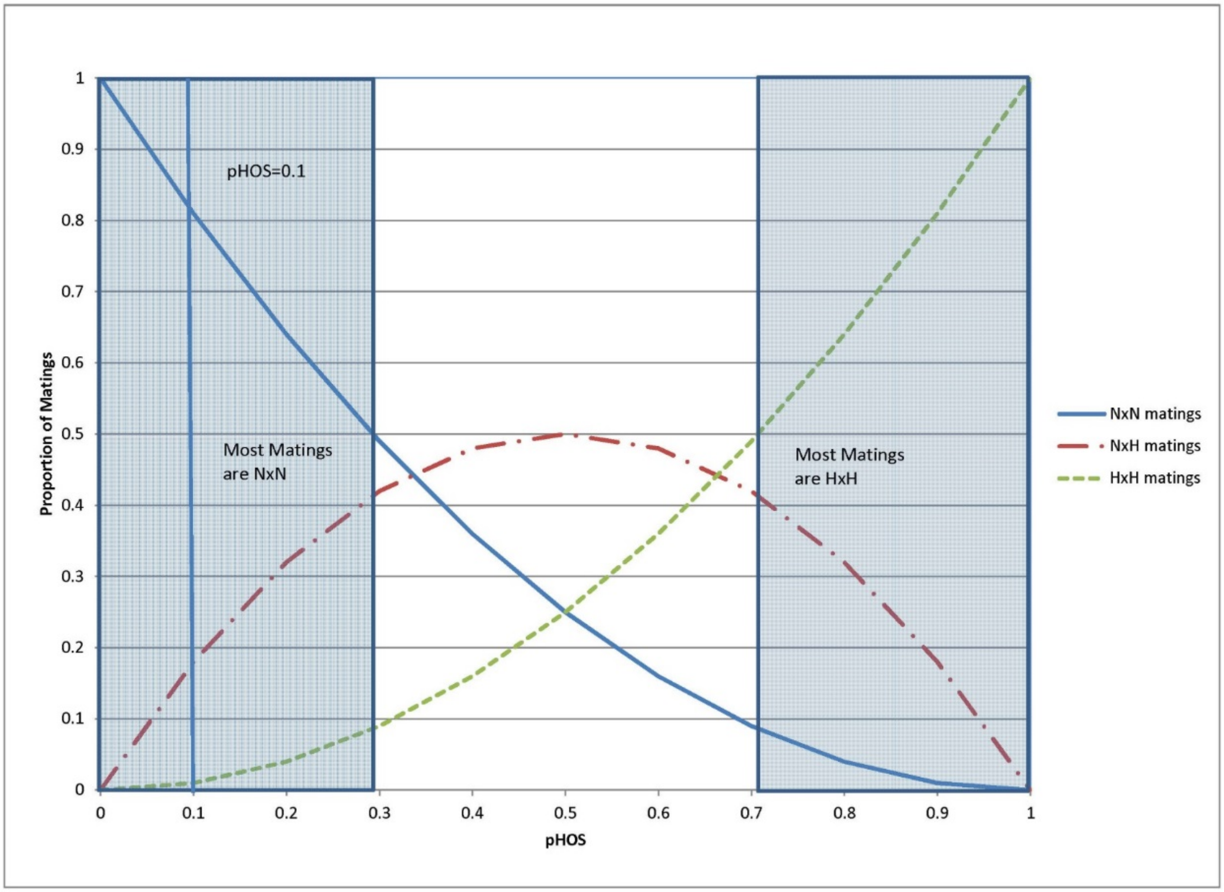


Figure 33. Relative proportions of types of matings as a function of proportion of hatchery-origin fish on the spawning grounds (pHOS) (NxN – natural-origin x natural-origin; NxH – natural-origin x hatchery; HXH – hatchery x hatchery).

Ecological effects included under this factor (i.e., "Hatchery fish and the progeny of naturally spawning hatchery fish on the spawning grounds") refer to effects from competition for spawning sites and redd superimposition, contributions to marine-derived nutrients, and the removal of fine sediments from spawning gravels. Ecological effects of hatchery fish on the spawning grounds may be positive or negative. In that hatcheries contribute added fish to the ecosystem, there can be positive effects. For example, when anadromous salmonids return to spawn, hatchery-origin and natural-origin alike, they transport marine-derived nutrients stored in their bodies to freshwater and terrestrial ecosystems. Their carcasses provide a direct food source for juvenile salmonids and other fish, aquatic invertebrates, and terrestrial animals, and their decomposition supplies nutrients that may increase primary and secondary production (Kline et al. 1990; Piorkowski 1995; Larkin and Slaney 1996; Wipfli et al. 1998; Gresh et al. 2000; Murota 2002; and Quamme and Slaney 2003). As a result, the growth and survival of juvenile salmonids may increase (Hager and Noble 1976; Bilton et al. 1982; Holtby 1988; Ward and Slaney 1988; Hartman and Scrivener 1990; Johnston et al. 1990; Quinn and Peterson 1996; Bradford et al. 2000; Bell 2001; Brakensiek 2002; Ward and Slaney 2002).

Additionally, studies have demonstrated that perturbation of spawning gravels by spawning salmonids loosens cemented (compacted) gravel areas used by spawning salmon (e.g. Montgomery et al. 1996). The act of spawning also coarsens gravel in spawning reaches, removing fine material that blocks interstitial gravel flow and reduces the survival of incubating eggs in egg pockets of redds.

The added spawner density resulting from hatchery-origin fish spawning in the wild can have negative consequences in that to the extent there is spatial overlap between hatchery and natural spawners, the potential exists for hatchery-derived fish to superimpose or destroy the eggs and embryos of listed species. Redd superimposition has been shown to be a cause of egg loss in pink salmon and other species (Fukushima et al. 1998, and references therein).

2.5.1.3 Hatchery fish and the progeny of naturally spawning hatchery fish in juvenile rearing areas (tributaries, mainstem, estuary, and ocean).

Tributaries

NMFS also analyzes the potential for competition, predation, and premature emigration when the progeny of naturally spawning hatchery fish and hatchery releases share juvenile rearing areas. Generally speaking, competition and a corresponding reduction in productivity and survival may result from direct interactions when hatchery-origin fish interfere with the accessibility to limited resources by natural-origin fish or through indirect means, when the utilization of a limited resource by hatchery fish reduces the amount available for fish from the natural population (SIWG 1984). Naturally produced fish may be competitively displaced by hatchery fish early in life, especially when hatchery fish are more numerous, are of equal or greater size, when hatchery fish take up residency before naturally produced fry emerge from redds, and if hatchery fish residualize. Hatchery fish might alter naturally produced salmon behavioral patterns and habitat use, making them more susceptible to predators (Hillman and Mullan 1989; Steward and Bjornn 1990). Hatchery-origin fish may also alter naturally produced salmonid migratory responses or movement patterns, leading to a decrease in foraging success (Hillman and Mullan 1989; Steward and Bjornn 1990). Actual impacts on naturally produced fish would thus depend on the degree of dietary overlap, food availability, size-related differences in prey selection, foraging tactics, and differences in microhabitat use (Steward and Bjornn 1990).

Competition may result from direct interactions, or through indirect means, as when utilization of a limited resource by hatchery fish reduces the amount available for naturally produced fish (SIWG 1984). Specific hazards associated with competitive impacts of hatchery salmonids on listed naturally produced salmonids may include competition for food and rearing sites (NMFS 2012). In an assessment of the potential ecological impacts of hatchery fish production on naturally produced salmonids, the Species Interaction Work Group (SIWG 1984) concluded that naturally produced coho and Chinook salmon and steelhead are all potentially at "high risk" due to competition (both interspecific and intraspecific) from hatchery fish of any of these three species. In contrast, the risk to naturally produced pink, chum, and sockeye salmon due to competition from hatchery salmon and steelhead was judged to be low in this consultation.

Several factors influencing the risk of competition posed by hatchery releases: whether competition is intra- or interspecific; the duration of freshwater co-occurrence of hatchery and natural-origin fish; relative body sizes of the two groups; prior residence of shared habitat; environmentally induced developmental differences; and, density in shared habitat (Tatara and Berejikian 2012). Intraspecific competition would be expected to be greater than interspecific, and competition would be expected to increase with prolonged freshwater co-occurrence. Although newly released hatchery smolts are commonly larger than natural-origin fish, and larger fish usually are superior competitors, natural-origin fish have the competitive advantage of prior residence when defending territories and resources in shared natural freshwater habitat. Tatara and Berejikian (2012) further reported that hatchery-induced developmental differences from co-occurring natural-origin fish life stages are variable and can favor both hatchery- and natural-origin fish. They concluded that of all factors, fish density of the composite population in relation to habitat carrying capacity likely exerts the greatest influence.

En masse, hatchery salmon smolt releases may cause displacement of rearing naturally produced juvenile salmonids from occupied stream areas, leading to abandonment of advantageous feeding stations, or premature out-migration (Pearsons et al. 1994). Pearsons et al. (1994) reported small-scale displacement of juvenile naturally produced rainbow trout from stream sections by hatchery steelhead. Small-scale displacements and agonistic interactions observed between hatchery steelhead and naturally produced juvenile trout were most likely a result of size differences and not something inherently different about hatchery fish.

A proportion of salmon and steelhead smolts released from a hatchery may not migrate to the ocean but rather reside for a period of time in the vicinity of the release point. These non-migratory smolts (residuals) may directly compete for food and space with natural-origin juvenile salmonids of similar age. They also may prey on younger, smaller-sized juvenile salmonids. This behavior has been studied and observed most frequently in the case of hatchery steelhead, and residualism has been reported as a potential issue for hatchery coho and Chinook salmon as well. Adverse impacts from residual Chinook and coho hatchery salmon on naturally produced salmonids are generally a possibility. The issue of residualism for these species has not been as widely investigated compared to steelhead, and given that the number of smolts released from Chinook and coho salmon programs is generally higher than for steelhead programs, ecological impacts on co-occurring natural-origin fish may be heightened if the species residualize. Therefore, for all species, the monitoring of natural stream areas downstream of hatchery release points is necessary to determine significance of hatchery smolt residualism on the natural-origin juvenile salmonids.

The risk of adverse competitive interactions between hatchery-origin and natural-origin fish can be minimized by:

- Releasing hatchery smolts that are physiologically ready to migrate. Hatchery fish released as smolts emigrate seaward soon after liberation, minimizing the potential for competition with juvenile naturally produced fish in freshwater (Steward and Bjornn 1990; California HSRG 2012).
- Releasing all hatchery fish at times when natural-origin fish vulnerable to resource competition are not present in downstream areas in substantial numbers.

- Releasing all hatchery fish after the majority of sympatric natural-origin juveniles have emigrated seaward to reduce the risk of competition for food and space.
- Operating hatcheries such that hatchery fish are reared to sufficient size that smoltification occurs in nearly the entire population (Bugert *et al.* 1991).
- Releasing hatchery smolts in lower river areas, below areas used for stream-rearing naturally produced juveniles.
- Monitoring the incidence of non-migratory smolts (residuals) after release and adjusting rearing strategies, release location and timing if substantial competition with naturally rearing juveniles is documented.

Critical to analyzing competition risk is information on the quality and quantity of spawning and rearing habitat in the action area,[12] including the distribution of spawning and rearing habitat by quality and best estimates for spawning and rearing habitat capacity. Additional important information includes the abundance, distribution, and timing for naturally spawning hatchery-origin fish and natural-origin fish; the timing of emergence; the distribution and estimated abundance for progeny from both hatchery and natural-origin natural spawners; the abundance, size, distribution, and timing for juvenile hatchery fish in the action area; and the size of hatchery fish relative to co-occurring natural-origin fish.

Another important possible ecological effect of hatchery releases is predation. Salmon and steelhead are piscivorous and can prey on other salmon and steelhead. Predation, either direct (direct consumption) or indirect (increases in predation by other predator species due to enhanced attraction) can result from hatchery fish released into the wild. Considered here is predation by hatchery-origin fish and by the progeny of naturally spawning hatchery fish (direct predation effects), and predation by avian and other predators attracted to the area by an abundance of hatchery fish (indirect effects). Hatchery fish originating from egg boxes and fish planted as non-migrant fry or fingerlings can prey upon fish from the local natural population during juvenile rearing. Hatchery fish released at a later stage as smolts that emigrate quickly to the ocean can prey on fry and fingerlings that are encountered during the downstream migration. As mentioned above, some of these hatchery fish do not emigrate and instead take up residence in the stream (residuals) where they can prey on stream-rearing juveniles over a more prolonged period. The progeny of naturally spawning hatchery fish also can prey on fish from a natural population and pose a threat. In general, the threat from predation is greatest when natural populations of salmon and steelhead are at low abundance and when spatial structure is already reduced, when habitat, particularly refuge habitat, is limited, and when environmental conditions favor high visibility.

SIWG (1984) rated most risks associated with predation as unknown, because there was relatively little documentation in the literature of predation interactions in either freshwater or marine areas. More studies are now available, but they are still too sparse to allow many generalizations to be made about risk. Newly released hatchery-origin yearling salmon and steelhead may prey on juvenile fall Chinook and steelhead, and other juvenile salmon in the freshwater and marine environments (Hargreaves and LeBrasseur 1985; Hawkins and Tipping 1999; Pearsons and Fritts 1999). Low predation rates have been reported for released steelhead juveniles (Hawkins and Tipping 1999; Naman and Sharpe 2012). Hatchery steelhead timing and release protocols used widely in the Pacific Northwest were shown to be associated with negligible predation by migrating hatchery steelhead on fall Chinook salmon fry, which

[12]"Action area" means all areas to be affected directly or indirectly by the action in which the effects of the action can be meaningfully detected and evaluated.

had already emigrated or had grown large enough to reduce or eliminate their susceptibility to predation when hatchery steelhead entered the rivers (Sharpe et al. 2008). Hawkins (1998) documented hatchery spring Chinook salmon yearling predation on naturally produced fall Chinook salmon juveniles in the Lewis River. Predation on smaller Chinook salmon was found to be much higher in naturally produced smolts (coho salmon and cutthroat, predominately) than their hatchery counterparts.

Predation may be greatest when large numbers of hatchery smolts encounter newly emerged fry or fingerlings, or when hatchery fish are large relative to naturally produced fish (SIWG 1984). Due to their location in the stream or river, size, and time of emergence, newly emerged salmonid fry are likely to be the most vulnerable to predation. Their vulnerability is believed to be greatest immediately upon emergence from the gravel and then their vulnerability decreases as they move into shallow, shoreline areas (USFWS 1994). Emigration out of important rearing areas and foraging inefficiency of newly released hatchery smolts may reduce the degree of predation on salmonid fry (USFWS 1994).

Some reports suggest that hatchery fish can prey on fish that are up to 1/2 their length (Pearsons and Fritts 1999; HSRG 2004), but other studies have concluded that salmonid predators prey on fish 1/3 or less their length (Horner 1978; Hillman and Mullan 1989; Beauchamp 1990; Cannamela 1992; CBFWA (Columbia Basin Fish and Wildlife Authority) 1996). Hatchery fish may also be less efficient predators as compared to their natural-origin conspecifics, reducing the potential for predation impacts (Sosiak et al. 1979; Bachman 1984; Olla et al. 1998).

Large concentrations of migrating hatchery fish may attract predators (birds, fish, and seals) and consequently contribute indirectly to predation of emigrating wild fish (Steward and Bjornn 1990). The presence of large numbers of hatchery fish may also alter natural-origin salmonid behavioral patterns, potentially influencing their vulnerability and susceptibility to predation (Hillman and Mullan 1989; USFWS 1994). Hatchery fish released into natural-origin fish production areas, or into migration areas during natural-origin fish emigration periods, may therefore pose an elevated, indirect predation risk to commingled listed fish. Alternatively, a mass of hatchery fish migrating through an area may overwhelm established predator populations, providing a beneficial, protective effect to co-occurring natural-origin fish. Newly released hatchery-origin smolts generally exhibit reduced predator avoidance behavior relative to co-occurring natural-origin fish (Bori and Davis 1989; and as reviewed in Flagg et al., 2000). Also, newly released smolts have been found to survive at a reduced rate during downstream migration relative to their natural-origin counterparts (Flagg et al., 2000; Melnychuk et al. 2014). These studies suggest that predator selection for hatchery-origin and natural-origin fish in commingled aggregations is not equal. Rather, the relatively naïve hatchery-origin fish may be preferentially selected in any mixed schools of migrating fish until they acclimate to the natural environment, and hatchery fish may in fact sate (and swamp) potential predators of natural-origin fish, shielding them from avian, mammal, and fish predation.

There are several steps that hatchery programs can implement to reduce or avoid the threat of direct or indirect predation:

- Releasing all hatchery fish as actively migrating smolts through volitional release practices so that the fish migrate quickly seaward, limiting the duration of interaction with any co-occurring natural-origin fish downstream of the release site.

- Releasing all hatchery fish at times when natural-origin fish of individual sizes vulnerable to direct predation are not present in downstream areas in substantial numbers.
- Releasing all hatchery fish after the majority of sympatric natural-origin juveniles have emigrated seaward to reduce the risk that avian, mammal, and fish predators may be attracted to commingled abundances of hatchery and natural-origin salmon or steelhead.
- Ensuring that a high proportion of the population have physiologically achieved full smolt status. Juvenile salmon tend to migrate seaward rapidly when fully smolted, limiting the duration of interaction between hatchery fish and naturally produced fish present within, and downstream of, release areas.
- Releasing hatchery smolts in lower river areas near river mouths, and below upstream areas used for stream-rearing young-of-the-year naturally produced salmon fry, thereby reducing the likelihood for interaction between the hatchery and naturally produced fish.
- Operating hatchery programs and releases to minimize the potential for residualism.

Mainstem rivers, estuary, and ocean

Most of the concern over the potential ecological effects of hatchery fish on natural populations is in rearing areas where the majority of natural-origin fish occur (previous section 2.5.1.3). In mainstem river habitat, ecological interactions between hatchery and natural fish can certainly occur but the magnitude and scope can be drastically different than in natal rearing areas due to the habitat characteristics, life history type and age of natural fish using mainstem river habitat, and the specific time period when hatchery fish may be present. A similar situation occurs in estuarine and nearshore ocean habitat. Salmon can occupy estuarine habitats through the summer and winter seasons before smolting as age-1 fish. Negative ecological interactions between natural-origin fish and hatchery fish is possible, particularly during periods of drought when streamflows are lower, stream temperatures are higher, and overall survival of rearing salmon is lower. The same can be true for early marine rearing during poor ocean survival regimes when productivity is lower, food availability is lower, salmon survival is lower; while the same number of hatchery fish are released that may negatively affect salmon smolts in the ocean. In most cases, spatial and temporal segregation between salmon and hatchery fish make the risk of negative ecological interactions low. The hatchery programs that release the greatest number of hatchery fish, and thus have the greatest risk of ecological interactions, release the hatchery Chinook salmon in the summer months. This time period is when natural-origin smolts are already in the ocean and much larger in size, and thus likely dominant ecological interactions.

Based on a review of the scientific literature, NMFS' conclusion is that the influence of density-dependent interactions on the growth and survival of salmon and steelhead in mainstem river, estuarine, and nearshore ocean habitat can occur, particularly during drought and poor ocean conditions that limit available resources. During other periods, density-dependence may be significantly lower to non-existent. While there is evidence that large-scale hatchery production can affect salmon survival at sea, the degree of effect or level of influence is not yet well understood or predictable. NMFS will look for new research that identifies and measures the frequency, intensity, and resulting effect of density-dependent interactions between hatchery and natural-origin fish. In the meantime, NMFS will monitor emerging science and information and will re-initiation section 7 consultation in the event that new information reveals effects of the action that may affect listed species or critical habitat in a manner or to an extent not considered in this consultation (50 CFR 402.16).

Disease

The release of hatchery fish and hatchery effluent into juvenile rearing areas can lead to transmission of pathogens, contact with chemicals or altering of environmental parameters (e.g., dissolved oxygen) that can result in disease outbreaks. Fish diseases can be subdivided into two main categories: infectious and non-infectious. Infectious diseases are those caused by pathogens such as viruses, bacteria, and parasites. Noninfectious diseases are those that cannot be transmitted between fish and are typically caused by genetic or environmental factors (e.g., low dissolved oxygen). Pathogens can also be categorized as exotic or endemic. For our purposes, exotic pathogens are those that have no history of occurrence within state boundaries. For example, *Oncorhynchus masou virus* (OMV) would be considered an exotic pathogen if identified anywhere in Oregon state. Endemic pathogens are native to a state, but may not be present in all watersheds.

In natural fish populations, the risk of disease associated with hatchery programs may increase through a variety of mechanisms (Naish et al. 2007), including:

- Introduction of exotic pathogens
- Introduction of endemic pathogens to a new watershed
- Intentional release of infected fish or fish carcasses
- Continual pathogen reservoir
- Pathogen amplification

The transmission of pathogens between hatchery and natural fish can occur indirectly through hatchery water influent/effluent or directly via contact with infected fish. Within a hatchery, the likelihood of transmission leading to an epizootic (i.e., disease outbreak) is increased compared to the natural environment because hatchery fish are reared at higher densities and closer proximity than would naturally occur. During an epizootic, hatchery fish can shed relatively large amounts of pathogen into the hatchery effluent and ultimately, the environment, amplifying pathogen numbers. However, few, if any, examples of hatcheries contributing to an increase in disease in natural populations have been reported (Naish et al. 2008; Steward and Bjornn 1990). This lack of reporting is because both hatchery and natural-origin salmon and trout are susceptible to the same pathogens (Noakes et al. 2000), which are often endemic and ubiquitous (e.g., *Renibacterium salmoninarum*, the cause of Bacterial Kidney Disease).

Adherence to a number of state, federal, and tribal fish health policies limits the disease risks associated with hatchery programs (IHOT 1995; USFWS 2004). Specifically, the policies govern the transfer of fish, eggs, carcasses, and water to prevent the spread of exotic and endemic reportable pathogens. For all pathogens, both reportable and non-reportable, pathogen spread and amplification are minimized through regular monitoring (typically monthly) removing mortalities, and disinfecting all eggs. Vaccines may provide additional protection from certain pathogens when available (e.g., *Vibrio anguillarum*). If a pathogen is determined to be the cause of fish mortality, treatments (e.g., antibiotics) will be used to limit further pathogen transmission and amplification. Some pathogens, such as *infectious hematopoietic necrosis virus* (IHNV), have no known treatment. Thus, if an epizootic occurs for those pathogens, the only way to control pathogen amplification is to cull infected individuals or terminate all susceptible fish. In addition, current hatchery operations often rear hatchery fish on a timeline that mimics their natural life history, which limits the presence of fish susceptible to pathogen infection and prevents hatchery fish from becoming a pathogen reservoir when no natural fish hosts are present.

In addition to the state, federal and tribal fish health policies, disease risks can be further minimized by preventing pathogens from entering the hatchery facility through the treatment of incoming water (e.g., by using ozone) or by leaving the hatchery through hatchery effluent (Naish et al. 2007). Although preventing the exposure of fish to any pathogens prior to their release into the natural environment may make the hatchery fish more susceptible to infection after release into the natural environment, reduced fish densities in the natural environment compared to hatcheries likely reduces the risk of fish encountering pathogens at infectious levels (Naish et al. 2007). Treating the hatchery effluent would also minimize amplification, but would not reduce disease outbreaks within the hatchery itself caused by pathogens present in the incoming water supply. Another challenge with treating hatchery effluent is the lack of reliable, standardized guidelines for testing or a consistent practice of controlling pathogens in effluent. However, hatchery facilities located near marine waters likely limit freshwater pathogen amplification downstream of the hatchery without human intervention because the pathogens are killed before transmission to fish when the effluent mixes with saltwater.

Noninfectious diseases are those that cannot be transmitted between fish and are typically caused by genetic or environmental factors (e.g., low dissolved oxygen). Hatchery facilities routinely use a variety of chemicals for treatment and sanitation purposes. Chlorine levels in the hatchery effluent, specifically, are monitored with a National Pollutant Discharge Elimination System (NPDES) permit administered by the Environmental Protection Agency. Other chemicals are discharged in accordance with manufacturer instructions. The NPDES permit also requires monitoring of settleable and unsettleable solids, temperature, and dissolved oxygen in the hatchery effluent on a regular basis to ensure compliance with environmental standards and to prevent fish mortality. In contrast to infectious diseases, which typically are manifest by a limited number of life stages and over a protracted time period, non-infectious diseases caused by environmental factors typically affect all life stages of fish indiscriminately and over a relatively short period of time. One group of non-infectious diseases that are expected to occur rarely in current hatchery operations are those caused by nutritional deficiencies.

2.5.1.4 Research, monitoring, and evaluation

NMFS also analyzes proposed RM&E for effects on listed species and on designated critical habitat. Generally speaking, negative effects on the fish from RM&E are weighed against the value or benefit of new information, particularly information that tests key assumptions and that reduces critical uncertainties. RM&E actions including but not limited to collection and handling (purposeful or inadvertent), holding the fish in captivity, sampling (e.g., the removal of scales and tissues), tagging and fin-clipping, and observation (in-water or from the bank) can cause harmful changes in behavior and reduced survival. These effects should not be confused with handling effects analyzed under broodstock collection. In addition, NMFS also considers the overall effectiveness of the RM&E program. There are five factors that NMFS takes into account when it assesses the beneficial and negative effects of hatchery RM&E: (1) the status of the affected species and effects of the proposed RM&E on the species and on designated critical habitat, (2) critical uncertainties over effects of the proposed action on the species, (3) performance monitoring and determining the effectiveness of the hatchery program at achieving its goals and objectives, (4) identifying and quantifying collateral effects, and (5) tracking compliance of the hatchery program with the terms and conditions for implementing the program. After assessing the proposed hatchery RM&E and before it makes any recommendations to the action agencies, NMFS considers the benefit or usefulness of new or additional information, whether the desired information is available from another source, the effects on ESA-listed species, and cost.

Hatchery actions also must be assessed for masking effects. For these purposes, masking is when hatchery fish included in the proposed action mix with and are not identifiable from other fish. The effect of masking is that it undermines and confuses RM&E, and status and trends monitoring. Both adult and juvenile hatchery fish can have masking effects.

When presented with a proposed hatchery action, NMFS analyzes the nature and level of uncertainties caused by masking and whether and to what extent listed salmon and steelhead are at increased risk. The analysis also takes into account the role of the affected salmon and steelhead population(s) in recovery and whether unidentifiable hatchery fish compromise important RM&E.

2.5.1.5 The operation, maintenance, and construction of hatchery facilities

Operation, maintenance, and construction activities associated with hatchery facilities can alter fish behavior and can injure or kill eggs, juveniles and adults. They can also degrade habitat function. Here, NMFS analyzes a hatchery program for effects on listed species from encounters with hatchery structures and for effects on habitat conditions that support and promote viable salmonid populations. For example, NMFS wants to know if the survival or spatial structure of ESA listed fish (adults and juveniles) is affected when they encounter ladders and other hatchery structures or by changes in the quantity or quality of streamflow caused by diversions. NMFS analyzes changes to riparian habitat, channel morphology and habitat complexity, and in-stream substrates attributable to operation, maintenance, and construction activities and confirms whether water diversions and fish passage facilities are constructed and operated consistent with NMFS criteria.

2.5.1.6 Fisheries

Regarding hatchery-related effects, there are two aspects of fisheries that NMFS considers. One is when listed species are inadvertently and incidentally taken in fisheries targeting hatchery fish, and the other is when fisheries are used as a tool to prevent hatchery fish, including hatchery fish included in an ESA-listed ESU that are surplus to recovery needs, from spawning naturally. In each case, the fishery must be strictly regulated based on the take, including catch and release effects, of natural-origin, ESA-listed species.

2.5.2 Effects of the Proposed Action

Analysis of the proposed action identified six risk factors that are likely to have adverse effects on ESA-listed spring Chinook salmon and winter steelhead and on designated critical habitat: 1) broodstock collection, 2) interactions between hatchery fish and their progeny and wild fish on spawning grounds, 3) interactions between hatchery fish and their progeny and wild fish in juvenile rearing areas, 4) hatchery fish and the progeny of naturally spawning hatchery fish in the mainstem rivers, in the estuary, and in the ocean, 5) hatchery research, monitoring and evaluation, and 6) operation, maintenance and construction of hatchery facilities. For the remaining risk factor (fisheries), ESA consultation was completed in 2001 and is still in effect (NMFS 2001a; NMFS 2001b), and is therefore included in this analysis as part of the environmental baseline.

A summarized analysis of all applicable (i.e., negative, beneficial, or negligible) hatchery effect factors is presented below (Table 17), followed by an expanded discussion of effects assigned for each applicable factor. The framework NMFS followed for analyzing effects of the proposed hatchery programs is described in Section 2.5.1 of this opinion.

Table 17. Summarized effects of hatchery programs on spring Chinook salmon and winter steelhead in the UWR and their designated critical habitat.

Factors	Range in Potential Effects for This Factor	Analysis of Effects for Each Factor
Broodstock origin and collection	Negligible to negative effect	**UWR Spring Chinook Salmon: Negative effect** The hatchery spring Chinook salmon programs propose to take natural-origin salmon for broodstock purposes in order to integrate the broodstock with the natural population. The removal of natural fish from spawning decreases abundance and is a negative effect. However, this action results in a hatchery stock more similar to the natural population (reduces domestication influences and improves PNI), which is a positive change since the hatchery program is being used for supplementation above the federal dams. For the hatchery summer steelhead and hatchery rainbow trout programs, effects of collecting spring Chinook salmon for broodstock are negligible. **UWR Winter Steelhead: Negligible effect** The potential effect of broodstock collection (spring Chinook, summer steelhead, and rainbow trout) on ESA-listed winter steelhead is negligible due to differences in run timing. Summer steelhead and spring Chinook salmon broodstock collections occur during the peak of return back to the collection facilities (June through September) and winter steelhead return prior to this time. Any winter steelhead collected at the facilities are passed upstream unharmed. No broodstock are collected for the hatchery rainbow trout program in the UWR.
Hatchery fish and the progeny of naturally spawning hatchery fish on the spawning grounds	Negligible to negative effect	**UWR Spring Chinook Salmon:** **Demographic Effects: Positive effect;** **Genetic Effects: Varies. Negative to positive effect;** **ESU Viability: Positive effect;** **Marine-derived Nutrients: Positive effect.** All natural Chinook populations in the action area are severely depressed (Molalla, North Santiam, South Santiam, Middle Fork Willamette) or in recent decline (McKenzie). There are risks and benefits of using the hatchery Chinook salmon

Factors	Range in Potential Effects for This Factor	Analysis of Effects for Each Factor
		programs. Naturally spawning hatchery salmon in the McKenzie River have a negative effect on this population because substantial natural production still exists and hatchery fish are interbreeding with natural fish (causing hatchery induced selection pressures). The other Chinook hatchery programs are being used for reintroduction above the federal dams to increase spawning abundances in historic habitats. Genetic pedigree analyses and juvenile salmon surveys have shown hatchery fish reproducing successfully and thus providing significant demographic benefits to natural populations. Recent genetic studies have also shown important genetic resources valuable for the recovery of the ESU are found in the hatchery stocks (which originated from local, natural-origin fish when the dams were built). The hatchery stocks also exhibit similar biometrics as natural-origin salmon in terms of age structure, return timing, and spawn timing. The hatchery broodstocks contain important genetic resources that used to exist in wild salmon returning before the federal dams were built and eliminated those runs. As recovery of NORs occurs, hatchery supplementation and pHOS will be reduced and this risk factor will decrease. The effect of the hatchery salmon programs on population viability is positive for most populations where hatchery supplementation is being used for recovery. Hatchery salmon are producing offspring that results in increased abundance and productivity of the natural population. This is occurring in all areas where hatchery salmon are being outplanted into historic areas above federal dams. As the number of NORs increases, hatchery supplementation decreases, so that natural population viability can be evaluated in the absence of hatchery influence. Given the high pHOS in most populations, the additional marine nutrients supplied by naturally spawning hatchery salmon is providing a significant input of marine derived nutrients to the ecosystem (particularly headwater areas), and therefore, a positive effect. For the hatchery summer steelhead and rainbow trout programs, there is no effect to spring Chinook salmon. **UWR Winter Steelhead:** **Demographic Effects: Negative effect;** **Genetic Effects: Negative effect;** **DPS Viability: Negative effect;** **Marine-derived Nutrients: Negligible effect.** Hatchery summer steelhead that are not harvested or collected at collection facilities can spawn naturally in ESA-listed winter steelhead populations (North Santiam and South Santiam). If

Factors	Range in Potential Effects for This Factor	Analysis of Effects for Each Factor
		summer-run and winter-run are present in the same area, they can spawn together resulting in a hybridization between run types, which risks a reduction in productivity. Since summer-run do not occur naturally in the UWR, this would be a negative effect on the listed DPS. The temporal overlap in spawn timing is low between summer steelhead spawning with winter steelhead, but any interbreeding between the run types would result in a negative effect on winter steelhead productivity and diversity. The hatchery summer steelhead program provides no population viability benefits and any effects of the program would be negative to the DPS. The genetic analyses support a low degree of interbreeding between summer and winter steelhead in areas where hatchery fish are released. The Molalla, Calapooia, and all westside tributaries do not have any hatchery releases of summer steelhead. Since pHOS of summer steelhead is low overall, the contribution of hatchery steelhead carcass nutrients to the ecosystem is negligible. For the hatchery Chinook salmon and rainbow trout programs there is no effect on winter steelhead due to hatchery and natural-origin fish being on the spawning grounds together.
Hatchery fish and the progeny of naturally spawning hatchery fish in juvenile rearing areas (tributaries, mainstem, estuary, and ocean)	Negligible to negative effect	**UWR Spring Chinook Salmon: Negative effect** **UWR Winter Steelhead: Negative effect** Interactions of concern in juvenile rearing areas are fish disease pathogen transfer and amplification; competition between hatchery-origin fish (all species) and natural-origin spring Chinook salmon and winter steelhead for food and space; and hatchery fish predation on natural-origin salmon and steelhead. *Fish Disease Pathogen Transfer and Amplification* - The proposed HGMPs address general threats from fish disease pathogen transfer and amplification. The plans describe fish disease pathogen issues of concern and actions that would be implemented to minimize risks of disease transfer and amplification. In the recent past, disease issues have been minimal from proper care, implementation of best management practices, and in-hatchery monitoring. For these reasons, the risk of fish disease pathogen transfer and amplification associated with hatchery production through the programs would be negligible. *Competition* –The spatial overlap between the releases of hatchery fish (Chinook salmon and summer steelhead smolts, and hatchery rainbow trout) and natural-origin salmon and

Factors	Range in Potential Effects for This Factor	Analysis of Effects for Each Factor
		steelhead is concentrated in the mainstem rivers below the federal dams where hatchery fish are released. Rainbow trout are released primarily in the reservoirs and streams above the dams and the McKenzie River. The highest concentration of hatchery fish occurs in the Willamette River downstream to the ocean, as all the fish gather together as they emigrate to the ocean. The spatial overlap between hatchery- and natural-origin fish is limited because 1) all hatchery fish are released as smolts that are actively emigrating downstream to the ocean, thus minimizing interactions with naturally rearing fish in different habitats, and 2) most of the habitat where natural-origin fish rear throughout the population areas are not exposed to releases of hatchery fish. In addition, the progeny of hatchery Chinook spawning above the federal dams (intentional supplementation), can interact with natural-origin salmon and steelhead, but this effect is low because overall densities are low. Adverse effects from the generally larger-sized hatchery smolts may occur with natural-origin fish in specific situations, but the overall effect of competitive interactions between hatchery and natural fish at the population level is low. *Predation* – The spatial overlap between the releases of hatchery smolts and natural origin fish is limited to the mainstem river reaches below the dams. The greatest likelihood of predation occurs between hatchery steelhead and age-0 Chinook fry in the interaction zones. Steelhead are much larger than Chinook fry at this time and predation is likely to occur at some level. The time period of increased predation risk from hatchery fish is within one week of release as the hatchery steelhead readily emigrate downstream. A small proportion of hatchery steelhead (<10%) are likely to residualize near the hatchery and never emigrate to the ocean. These fish would continue to have an adverse effect on natural-origin salmon and steelhead in freshwater. No releases of hatchery smolts occur above the federal dams; although naturally produced salmon and steelhead (from natural- or hatchery-origin parents) may predate upon salmon and steelhead fry of smaller size. Interactions between hatchery fish and natural-origin salmon and steelhead in most natal rearing areas (e.g. tributaries of mainstem rivers and above the federal dams where adult fish are released) are even more limited or non-existent because no hatchery fish are released in these areas.
Hatchery research,	Beneficial to negative effect	**UWR Spring Chinook Salmon: Negligible effect** **UWR Winter Steelhead: Negligible effect**

Factors	Range in Potential Effects for This Factor	Analysis of Effects for Each Factor
monitoring, and evaluation		A variety of hatchery research, monitoring and evaluation occurs periodically throughout the action area. Spawning ground surveys, monitoring of hatchery facilities, and specific research projects occur annually. The effects on natural-origin salmon and steelhead are low, where no fish are captured or handled. In other cases, salmon and steelhead may be intercepted accidentally, with proper care and release procedures followed to minimize harm and unintentional mortality. The HGMPs define the criteria and guidelines for these monitoring activities to ensure the actions are ceased if natural-origin fish encounters go above prescribed limits. The effects of these RM&E actions on the viability of ESA-listed spring Chinook salmon and winter steelhead are expected to be negligible. In nearly all cases, the information and data gained from RM&E is critical to help inform the conservation and recovery of ESA-listed populations.
Operation, maintenance, and construction of hatchery facilities	Negligible to negative effect	**UWR Spring Chinook Salmon: Negligible effect** **UWR Winter Steelhead: Negligible effect** No new construction of hatchery facilities is proposed through this consultation. Most of the hatchery facilities are associated with the federal dams and fish collection facilities so it is difficult to separate out effects because the facilities are interconnected. The impacts associated with hatchery facilities is from the continued operation, maintenance, and repair of existing facilities. The principal effects are from water withdrawal for use at the hatchery, discharge of hatchery effluent, and operation of hatchery traps and facilities. Impacts of water use associated with the hatchery facilities on spring Chinook salmon and winter steelhead and their habitat is negligible because of the short duration and length of stream affected (very minor and limited to several hundred meters). Operation of the fish collection facilities can impact and benefit natural-origin fish depending upon the specific operations. Collection of natural fish for trap and haul above the federal dams is beneficial to restore production in historic habitat. Most of the facilities are operated throughout the year to pass natural fish above the federal dams; regardless if the hatchery is in operation. All effects anticipated in the future are the same (or reduced effect) compared to the environmental baseline.
Fisheries	Negligible to negative effect	**UWR Spring Chinook Salmon and Winter Steelhead: Not Applicable** Fisheries are included in the environmental baseline. Past and current effects of fisheries on natural-origin salmon and

Factors	Range in Potential Effects for This Factor	Analysis of Effects for Each Factor
		steelhead are described in the Environmental Baseline. Similar fisheries and effects are expected in the future under the existing ESA-approved Fisheries Management and Evaluation Plans (FMEPs).

2.5.2.1 Broodstock Origin and Collection

There are two categories of activities related to broodstock origin and collection that may affect listed spring Chinook and winter steelhead: 1) purposefully collecting natural-origin fish to incorporate into hatchery broodstocks, and 2) the incidental handling of natural-origin fish associated with all hatchery programs. Both of these activities are evaluated below for listed spring Chinook and winter steelhead.

2.5.2.1.1 UWR spring Chinook salmon: Negative effect

2.5.2.1.1.1 Hatchery Spring Chinook Salmon

The proposed action collects broodstock for the salmon programs at the existing fish collection facilities associated with the federal dams. See Figure 1 in the proposed action for the specific locations and associated dams. The McKenzie Hatchery is the one exception, where there is no associated dam at the hatchery, and unmarked Chinook salmon that volitionally migrate to the hatchery may be used for broodstock. At the fish collection facilities, salmon are also trapped and hauled above the dams for reintroduction purposes (Sard 2016). For this consultation, only the collection of salmon for broodstock purposes is evaluated here (natural- and hatchery-origin salmon). All of the other actions associated with the facilities (e.g. operation of fish ladders, collection and transport of fish) were previously consulted upon (NMFS 2008) and, therefore, is included in the environmental baseline.

The proportionate natural influence (PNI) values for these populations are currently calculated as zero; as no natural-origin salmon have been spawned in the broodstock due to lack of proper ESA authorization to do so (being evaluated here in this consultation). It has been nearly two generations (~10 years) since natural-origin salmon were used for broodstock purposes in meaningful numbers. Sharpe et al. (2017) shows changes in the spawn timing of these hatchery programs to earlier in the year compared to natural-origin populations, which is of concern given the hatchery programs are being used for reintroduction above the federal dams. Waters et al. (2015) and (2016) further elaborate on the biological risks of not integrating a hatchery program used for conservation/reintroduction with it's respective natural population.

The proposed action specifies a sliding scale management regime for the take of natural-origin salmon for broodstock purposes. When the return of natural-origin fish is very low (below minimum abundance thresholds specified in the HGMPs), then no natural-origin salmon may be taken for broodstock (zero impact). When returns are higher, then a greater number of natural-origin salmon may be taken for broodstock up to a maximum impact level of 10%. The proposed action is to minimize the overall impacts of broodstock collection on the natural population, while balancing the genetic benefits of integrating natural-origin fish into the broodstock and obtaining higher PNI values in the short term. If returns are above minimum thresholds, then impacts start at 2% of the natural population and increases up to a maximum of 10% depending upon the run size. The one exception is in the Middle Fork Willamette River population, where natural-origin returns are very low (<50) and all of these fish can be used for broodstock until significant survival improvements occur and natural production increases (ODFW and NMFS 2011). Below is an assessment of a range of impacts from 2% to the maximum of 10% impact to the natural salmon populations and corresponding pNOB and PNI values under those scenarios.

At run sizes above the minimum abundance thresholds, 2% of the natural-origin run can be taken for broodstock purposes (Table 18). Under this scenario, pNOB ranges from 2% to 3%. These levels of integration are minimal according to recent guidelines for hatchery management of an integrated stock (HSRG 2004; HSRG 2009; HSRG 2014). Since these salmon hatchery programs are currently being used for conservation and reintroduction objectives, allowing a higher impact level provides more fish to incorporate into hatchery broodstocks.

As natural-origin salmon returns increase, up to 10% of the run can potentially be taken for broodstock integration (Table 19). The run size at which an increase up to 10% can occur varies depending upon the specific population. The corresponding pNOB values under this scenario range from 4% to 77% (Table 19). The limiting factor to attaining greater pNOB values is the lack of the abundance of natural-origin salmon. Once natural-origin fish returns increase, then a greater number of fish can be potentially integrated into the hatchery broodstocks.

Table 18. Scenario where natural-origin salmon can be taken for broodstock, assuming minimum run sizes and a 2% impact cap to the natural population, and corresponding pNOB values. *The Middle Fork Willamette HGMP allows up to 100% due to the lack of natural-origin returns (no population productivity).

Hatchery Program	Number of broodstock needed for full production	Minimum run size before NOB can be taken	Impact if minimum run size exceeded	NOB at min run size with 2% impact	pNOB (at min run size, 2% impact)
North Santiam	540	650	2%	13	0.02
South Santiam	800	650	2%	13	0.02
McKenzie	520	650	2%	13	0.03
Middle Fork Willamette	1400	NA	<100%*	50	0.04

Table 19. Scenario where natural-origin salmon can be taken for broodstock, assuming minimum run sizes where 10% of run can be taken from the natural population, and corresponding pNOB values.

Hatchery Program	Number of broodstock needed for full production	Minimum run size for 10% impact level	Max impact natural-origin population	Number of NOB	pNOB
North Santiam	540	2,001	10%	200	0.37
South Santiam	800	1,001	10%	100	0.13
McKenzie	520	4,001	10%	400	0.77
Middle Fork Willamette	1400	NA	<100%*	50	0.04

The broodstock management criteria in the proposed action reaches a pNOB of 100% when run sizes are substantially higher than have been observed over the last two decades. Therefore, pNOB will not be 100% unless significant recovery occurs in all of the natural populations.

For the McKenzie hatchery program, the incorporation of natural-origin salmon into the broodstock has been zero in recent years (pNOB=0) and the recent average proportion of hatchery-origin fish on the spawning grounds (pHOS) has been approximately 30% (Table 20). Although this could be considered justifiable in terms of protecting the natural-origin run in the McKenzie River, these gene-flow conditions could be expected to reduce fitness through hatchery-influenced selection (domestication selection). Although the extent of fitness loss from managing the population this way cannot be quantified, several papers (Baskett and Waples 2013; Duchesne and Bernatchez 2002; Ford 2002; Lynch and O'Hely 2001; Theodorou and Couvet 2004; Wang and Ryman 2001) have pointed out the importance of using natural-origin fish in the broodstock to maintain diversity and reduce genetic impacts of hatchery programs. Therefore, the use of natural-origin fish in these broodstocks at some level seems advisable.

Table 20. Proportionate natural influence (PNI) values for existing (recent), proposed (near-term), and long-term future targets for natural-origin spring Chinook salmon populations with hatchery programs in the UWR.

Hatchery Program	Recent pNOB (no ESA authorization)	Recent pHOS	Recent PNI	Near-term pNOB	Near-term PNI	Long-term target pHOS	Long-term target pNOB	Long-term Target PNI
North Santiam	0	0.8	0.00	0.2	0.20	0.1	0.5	0.83
South Santiam	0	0.65	0.00	0.2	0.24	0.3	0.5	0.63
McKenzie	0	0.3	0.00	0.2	0.40	0.1	0.5	0.83
Middle Fork Willamette	0	0.9	0.00	0.1	0.10	0.1	0.5	0.83

Based on a genetic analysis by Johnson and Friesen (2013), at a maximum impact level of 2% of the natural-origin run, pNOB levels would be 3-6% at recent natural-origin abundance levels (Table 18). The inclusion of a low level of broodstock was driven by genetic drift concerns and some natural-origin fish incorporated into the broodstock was deemed sufficient to prevent the hatchery stock from drifting in genetic profile from the natural-origin spawners. Indeed this level of pNOB would be adequate for these purposes, and would be recommended if the spawning of hatchery origin fish in the wild was very low. However, in this case, drift is not a concern because interbreeding between natural-origin and hatchery-origin fish is more than adequate to prevent drift because of the substantial proportion of hatchery-origin fish on the spawning grounds (pHOS). This is borne out by the results of the report, which show the hatchery fish to be virtually indistinguishable from the natural-origin fish at the microsatellite loci analyzed (Johnson and Friesen 2013).

A pNOB less than 10%, while limiting the demographic impact on natural-origin fish, is low by contemporary standards based on the Ford (2002) model (which currently is the only genetic risk planning tool with any level of widespread acceptance that deals with domestication issues). The Hatchery Scientific Review Group (e.g., HSRG 2014) recommends, based on this model, that populations of high conservation concern such as McKenzie River spring Chinook be managed at a proportionate natural influence (PNI) of 67%. Under the proposed action, a maximum PNI of 22% can be expected under current conditions. The difference in fitness consequences between the two levels cannot be determined absolutely, but a new risk assessment tool now under review (Busack, NMFS, unpubl.) suggests that the pNOB levels in the proposed action are a substantial improvement over the previous management regime in terms of reducing fitness loss, but higher levels of pNOB would be very beneficial. Fitness loss with low pNOB levels (<10%) can be expected to be on the order of 150-200% greater than they would be under a regime of 50% PNI (pNOB=0.3), and 250%-480% greater than under a PNI regime of 67%.

A generally unrecognized aspect of the pNOB-pHOS balance is the impact on effective number of breeders. Duchesne and Bernatchez (2002) present a technique for calculating inbreeding based on pNOB and pHOS, which can be equated to effective number of breeders, in populations affected by hatchery programs. Low pNOB levels reduce the effective number of breeders considerably. Given that, the census numbers may overestimate effective number of spawners considerably. In the McKenzie River population, this means that the per-generation effective size will be more than the classic 500 conservation biology abundance level (e.g., Lande and Barrowclough 1987), but it still represents a diversity impact that could be mitigated through use of higher pNOB values (

Table 21).

Table 21. Reduction in effective number of breeders in McKenzie spring Chinook salmon under several pNOB options. pHOS is assumed to be 30% in all cases.

Scenario	pNOB	Reduction in overall N_b
Previous operations	0%	73%
Minimal integration	6%	63%
PNI=50%	30%	25%
PNI=67%	60%	4%

The two analyses together argue for a higher pNOB level than recommended by Johnson and Friesen (2013) and thus taking more natural-origin salmon from the population for all of the salmon hatchery programs. The concern now becomes balancing that benefit against the risk to the natural-origin population from taking more fish as broodstock. Although the current natural-origin escapement is considerably lower than historical levels, there is still an overall abundance of more than 1,000 spawners per year (>4,000 spawners per generation), which could afford a higher use of natural-origin fish for broodstock without jeopardizing the naturally spawning population. A pNOB level of 0.3, which should yield an approximate PNI level of 50%, would require only approximately 10% of the natural origin run. This level would be a substantial improvement in fitness protection over the current level of pNOB=0, and at the same time not presenting excessive demographic risk to the natural-origin population in the McKenzie River.

As stated above, there are trade-offs between impacting the natural population (removing fish for broodstock) and providing genetic benefits to the hatchery broodstock and higher PNI values. PNI values in the recent past have been near zero due to no natural fish being incorporated into the broodstocks and pHOS remaining above 0.3 for all populations (Table 20). The proposed action will result in an improvement in PNI values by incorporating natural fish into the broodstocks. Higher PNI values would reduce the effect of hatchery-induced selection of the hatchery programs on natural populations, but also at the same time reduce the abundance and productivity of the same population by removing spawners. Given the benefits and risks of implementing this approach to increase PNI values for the populations in the near term, the proposed hatchery programs should increase pNOB which would result in greater PNI values for these populations in the short term. This management approach would meet the recommendations provided by HSRG (2009) for these programs.

The pHOS effects will be discussed in more detail below, but to understand the importance of broodstock selection as part of the overall effects, pNOB and its relationship to PNI is considered in detail here. Over the long-term, PNI values greater than 0.67 (with low pHOS) will be primarily dependent upon the successful recovery of natural-origin salmon (ODFW and NMFS 2011). Since these populations have hatchery broodstocks integrated with their natural population, the HSRG (2009) recommends the proportion of natural-origin adults in the broodstock exceed pHOS by at least a factor of two and pHOS be less than 0.30, which would equate to PNI values greater than 0.67. The Conservation and Recovery Plan for Upper Willamette spring Chinook salmon (ODFW and NMFS 2011) directs similar management for salmon hatcheries in these natural populations with pHOS less than 0.10 (North Santiam, McKenzie, and Middle Fork Willamette) and less than 0.30 for the South Santiam in order to meet recovery goals. The proposed action will increase PNI in the near future and over the long-term as natural fish increase. If it is assumed pNOB is 0.5, then PNI for these populations is greater than 0.67 (Table 20). Attaining this pNOB in the near term will not likely be possible due to the low number of natural-origin salmon in the populations resulting in substantial impacts to the natural populations. However, pNOB in the range of 0.2 to 0.5 may be possible in the future with overall impacts to the natural population being less than 10%, and thus be a conservation measure worth implementing in the short term.

Although incorporating natural-origin fish into the hatchery broodstock may result in demographic risk when natural-origin abundance is low, this risk is acceptable when weighed against the genetic benefits of doing so. Further, as described in the environmental baseline, pre-spawning mortality is high for most Chinook salmon populations residing below the federal dams due to water quality issues such as elevated water temperature, supersaturated oxygen levels, and elevated pathogen loads (Bowerman et al. 2018). For the Middle Fork Willamette, most Chinook salmon left in the river below the dams die before spawning, with the median mortality rate being 90% (Bowerman et al. 2018). In these situations, natural-origin salmon remaining in the river will not spawn and thus will not contribute anything to the next generation of salmon. However, if the natural-origin salmon are collected and used for broodstock purposes, at least some benefit is occurring from increasing abundance and infusing natural genes into the hatchery stock (Waters et al. 2015). Since hatchery Chinook salmon are being used for reintroduction of the federal dams, this would be a benefit to these populations by maintaining a hatchery stock that resembles the natural population more than if no natural-origin fish were spawned as broodstock (and died naturally in the river before spawning). For the McKenzie River, where pre-spawning mortality rates are low (<10%), taking natural-origin salmon for broodstock purposes definitely reduces spawning escapement, and therefore natural production, resulting in an adverse effect to the McKenzie River Chinook salmon population.

In years when the return at Leaburg Dam is greater than 650 fish (which occurs most years), then unmarked salmon that volitionally enter McKenzie hatchery can be used for broodstock. This reduces the effects to the natural population in several ways. First, most of the unmarked salmon entering the hatchery are misclipped fish based upon the thermal marking of the otoliths in hatchery fish (Sharpe et al. 2017). A low proportion of hatchery fish do not get an adipose fin clip prior to being released as smolts due to error in marking fish (typically less than 5% of the release). However, there is a percentage of these fish that are indeed natural-origin salmon that are collected in the hatchery (typically 30-40% of the non-adipose fin-clipped salmon at this hatchery). These natural-origin Chinook salmon that volitionally enter the hatchery are likely to have originated in the lower river near the hatchery. Since the majority of salmon that spawn in the lower river are of hatchery-origin, these fish are likely progeny of hatchery fish, but there would be benefits to using these fish for broodstock to reduce the effects of hatchery selection and domestication in the broodstock, since the surviving offspring of hatchery fish spawning naturally have gone through natural selection in the wild (compared to artificial rearing at the hatchery). The upper river natural-origin salmon are not likely to be affected by the broodstock collection protocols specified for using natural-origin salmon because these fish would not have a tendency to enter the hatchery in the lower river, but migrate upstream above Leaburg Dam to their natal spawning areas.

In summary, the above analyses shows the benefits of higher integration rates (pNOB) for the salmon hatchery broodstocks in obtaining higher PNI values compared to the environmental baseline. Under the sliding scale matrices of the proposed action, a maximum impact level of 10% for each natural population provides more opportunities to increase pNOB and PNI in the short term. The specific circumstances in any given year will direct if it is appropriate to take up to the specified limits or not. The option to not take natural-origin fish is also a possibility, even though the criteria may be met. Section 2.9.4 Terms and Conditions further specifies how the take of natural-origin salmon for broodstock purposes shall be conducted on an annual basis.

2.5.2.1.1.2 Hatchery Summer Steelhead

The collection of hatchery summer steelhead for broodstock at Foster FCF occurs from April through October when spring Chinook salmon are also present. No additional impacts to Chinook from the steelhead broodstock collection are expected to result from steelhead collection activities, as the fish ladder is in operation throughout the entire migration period of summer steelhead and spring Chinook salmon. The operation of the FCF is included in the environmental baseline for the operation of the fish ladder. After fish are collected and sorted, spring Chinook salmon are loaded onto trucks if being outplanted, and summer steelhead taken to the hatchery for broodstock. No additional adverse effects on spring Chinook salmon are expected from the collection of summer steelhead for broodstock.

2.5.2.1.1.3 Hatchery Rainbow Trout

No broodstock are collected for the hatchery rainbow trout program in the UWR. Broodstock is maintained through reproduction in various hatchery facilities throughout Oregon (e.g. Roaring River and Desert Springs hatcheries). No effects on listed spring Chinook salmon will occur from this program.

2.5.2.1.2 UWR winter steelhead: Negligible effect

No winter steelhead are collected for broodstock. The trapping of winter steelhead in the South and North Santiams at Foster and Minto dams, respectively, for outplanting was previously consulted upon (NMFS 2008) and included in the environmental baseline. No hatchery broodstock collection occurs in the Molalla and Calapooia rivers.

2.5.2.1.2.1 Hatchery Summer Steelhead

The HGMP includes collection of summer steelhead for broodstock, but it results in no adverse effects to winter steelhead. Winter steelhead and summer steelhead have different migration timing for the most part, but there can be overlap at Foster and Minto FCFs during the later part of the winter steelhead run when early returning summer steelhead begin to be collected at these fish ladders. Typically the numbers of both species during the period of overlap are low and winter steelhead are easily sorted based upon visual appearance and released or trucked upstream unharmed while the summer steelhead are removed from the rivers. The vast majority of the collection of broodstock for the hatchery summer steelhead program typically occurs after the upstream migration of winter steelhead and thus impacts are negligible from handling effects.

2.5.2.1.2.2 Hatchery Rainbow Trout

No broodstock collection facilities are operated or used for the hatchery rainbow trout programs. Therefore, there are no effects on winter steelhead related broodstock collection.

2.5.2.2 Hatchery fish and the progeny of naturally spawning hatchery fish on spawning grounds

Hatchery fish can spawn in the wild. There are two general categories of effect from this: 1) genetic effects, and 2) demographic effects (abundance and composition of spawners). The primary concerns over hatchery fish spawning in the wild is with their conspecifics of the same species. Since Chinook salmon do not interbreed with *O. mykiss* (steelhead and resident), this effect is not analyzed in this section. Only the effects of hatchery fish spawning with the same species are assessed here.

2.5.2.2.1 UWR spring Chinook salmon: Positive effect

2.5.2.2.1.1 Hatchery Spring Chinook Salmon

In assessing the effects of hatchery spring Chinook salmon on the spawning grounds, it is important to first describe the strategy outlined in the Upper Willamette River Conservation and Recovery Plan (ODFW and NMFS 2011) for the management of natural-origin and hatchery-origin Chinook salmon in the population areas of this ESU. Each spring Chinook salmon population has unique circumstances with its current risk status, current limiting factors/threats, and reintroduction efforts to put salmon back into historical habitat above impassable dams (Sard 2016). The overall ESU strategy can be summarized into two conservation and recovery strategies (Figure 34): 1) protect natural-origin Chinook salmon in population areas where they are successfully reproducing, and 2) reintroduce Chinook salmon back into core historical habitats, where they have been eliminated, using the most appropriate stock of hatchery fish available (ODFW and NMFS 2011). In summary, management is structured to minimize hatchery-related risks where natural production currently is occurring in greater abundance, such as in the Clackamas River, McKenzie River, South Santiam River above Foster Dam, and Fall Creek above the dam. The goal in these population areas is to minimize pHOS. The management targets for these areas are to have pHOS in the range of zero to 10% (NMFS 2008; HSRG 2009; ODFW and NMFS 2011). For the other population areas above the federal dams, intentional outplanting of hatchery Chinook salmon is occurring in an effort to restore production back into historical habitat of spring Chinook salmon above Big Cliff, Detroit, Green Peter, Cougar, Dexter, Lookout Point, and Hills Creek dams. No outplanting of salmon is occurring above Dorena, Cottage Grove, and Fern Ridge dams where historically Chinook salmon did not likely have demographically independent populations.

The proposed action adopts the management regime prescribed in the Conservation and Recovery Plan for spring Chinook salmon (ODFW and NMFS 2011). This management regime is also in accordance (more conservative) with the specific recommendations from HSRG (2009) for these hatchery programs. The HSRG (2009) recommends primary populations (e.g. North Santiam, McKenzie, Middle Fork Willamette), have pHOS less than 0.30 and PNI greater than 0.67. Contributing populations, such as the South Santiam, Molalla, Calapooia, should have pHOS less than 0.30 and PNI greater than 0.50. The specific PNI and pHOS values for the hatchery salmon programs are found in Table 20 and evaluated below.

The success of reintroduction above the federal dams is being evaluated principally through genetic pedigree analyses (Sard 2016, Evans et al. 2016) , where all salmon outplanted above the dams are genetically sampled. All resultant offspring that are sampled at various life stages (juvenile and adult) can then be genetically tested to verify whether the salmon is offspring from outplanting/reintroduction efforts above the dams (essentially tracing the family tree of salmon outplanted above the dams). To date, extensive monitoring and evaluation have shown hatchery salmon outplanted above the federal dams to produce hundreds of thousands of juvenile spring Chinook salmon fry in the North Santiam, South Santiam, McKenzie, and Middle Fork Willamette population areas (Monzyk et al. 2016; Romer et al. 2016). These juvenile salmon emigrate to the reservoirs, but recovery has been thwarted by lack of successful passage downstream of the reservoirs and dams, which has been poor overall (Hansen et al. 2017).

To date, there have been several cases where reintroductions above dams using hatchery Chinook salmon have resulted in substantial numbers of returning natural-origin Chinook salmon (a demographic benefit to the natural populations, Evans et al. 2016). These successes demonstrate the hatchery management approach in the UWR described by ODFW and NMFS (2011) is having the intended results. In the Clackamas River, reintroduction of spring Chinook salmon occurred in the late 1970's when the Clackamas hatchery program was initiated. Improvements to upstream and downstream passage at River Mill, Faraday, and North Fork dams on the mainstem Clackamas River have allowed natural-origin Chinook salmon to substantially increase in abundance. Current management allows only the passage of unmarked, natural-origin Chinook salmon above North Fork Dam. The Clackamas River now supports the highest abundance of natural-origin Chinook salmon (1000's of salmon returning annually) throughout the UWR ESU. Fall Creek is another successful reintroduction using hatchery Chinook salmon. The primary improvement to Fall Creek has been the drawdown of the reservoir in the fall to stream level that allows juvenile salmon to emigrate downstream of the dam. Returns of natural-origin Chinook salmon number in the hundreds of fish and hatchery Chinook salmon are no longer needed for reintroduction. In the South Santiam, returns of natural-origin salmon have increased at Foster Dam in sufficient numbers to eliminate the need for hatchery supplementation (Evans et al. 2015). Foster reservoir and dam are relatively small and allow for some downstream passage of Chinook salmon. With these recent successes using hatchery Chinook salmon for reintroduction into historical habitats throughout the ESU, it is likely increases will also occur in the North Santiam, South Fork McKenzie, and Middle Fork Willamette population areas once improvements to downstream passage are implemented (Figure 35).

- wild fish only (with varying degrees of success)

- reintroduction needed into historically productive habitat

- mitigation hatchery program area (long term). Natural production not as critical as upstream areas for meeting recovery goals.

- mitigation hatchery program area (long term), but significant natural production likely needed in this area to meet population goals.

Figure 34. Map of spring Chinook salmon population areas showing the goals for natural-origin fish management areas, reintroduction areas, and hatchery mitigation areas. Figure taken from the Upper Willamette River Conservation and Recovery Plan for Chinook Salmon and Steelhead (ODFW and NMFS 2011).

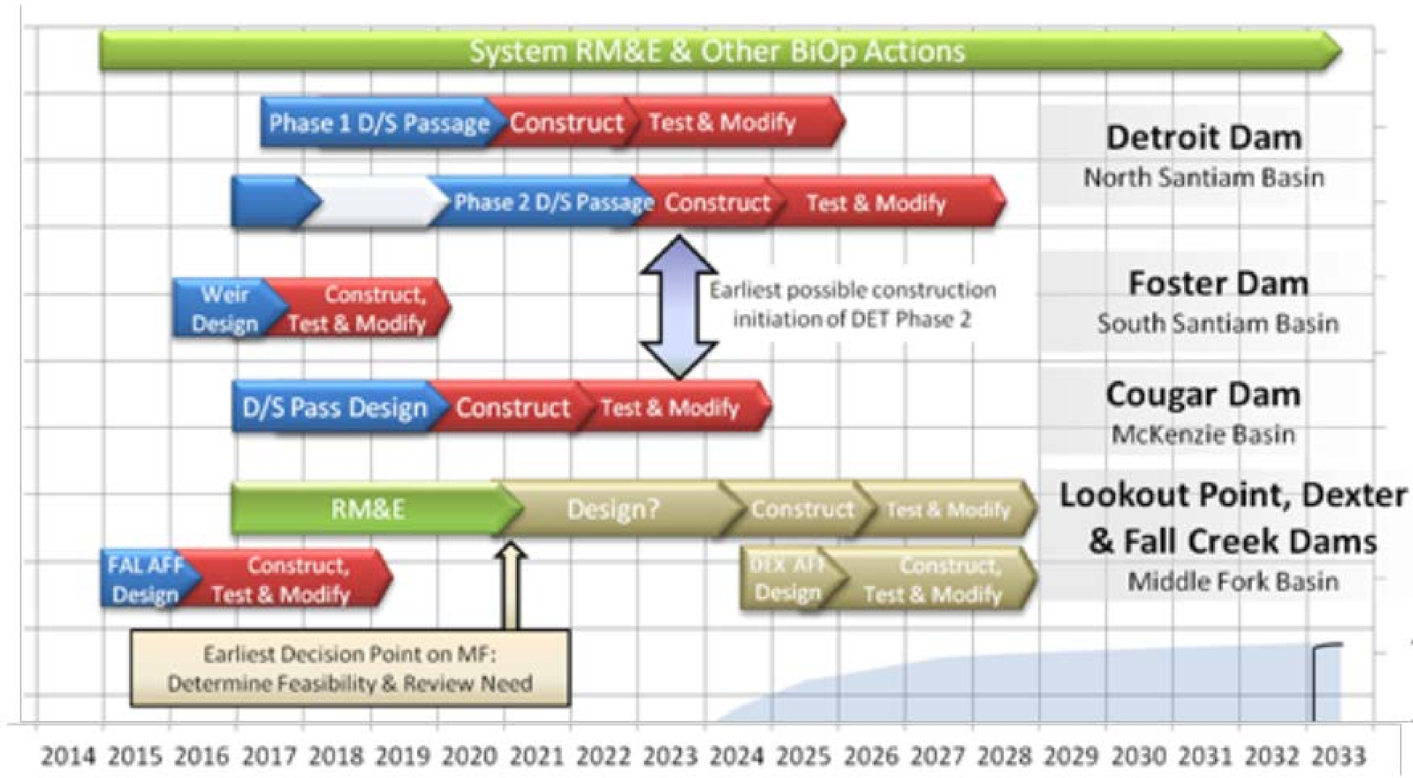


Figure 35. Timetable for design, construction, and modification of adult collection and downstream passage systems at Corps projects in the Upper Willamette Basin (from U.S. Army Corps of Engineers). Figure taken from Myers (2017).

Johnson and Friesen (2013) and Evans et al. (2015) evaluated the genetics of hatchery and natural-origin spring Chinook salmon throughout the UWR. In all cases, the hatchery stocks showed resemblance to their respective natural population, which is desirable, and which provides evidence that the reforms made since ESA-listing to manage broodstocks separately (with no intermixing) are providing biological benefits. Due to limited natural-origin fish in most populations (with the exception being the McKenzie), natural fish exhibited lower heterozygosity than in the hatchery stocks. This may have been due to sample sizes or due to the fact that the effective population sizes of the hatchery broodstocks have been larger over the last decades than natural-origin populations. The hatchery broodstocks contain important and valuable genetic resources that have been lost in natural populations after the construction of the federal dams that blocked access to historic habitat for spring Chinook salmon. As natural production continued to decline in the areas downstream of the dams, the hatchery broodstocks represent the only remaining genes from the historic salmon runs above the dams.

Following is an assessment of the effects of hatchery Chinook salmon on the spawning grounds for each population where hatchery fish are released. Two categories are assessed for this population: demographic and genetic effects. As described above, each population area has unique circumstances for hatchery management that reflect the current status of the natural population, historic habitat blocked by federal dams, and the need for hatchery supplementation. Hatchery Chinook salmon are not currently being released into the Calapooia River; although supplementation may occur in the future to jumpstart natural production. The Coast Fork Willamette River is not a demographically independent population needed for recovery and it is not analyzed here.

Middle Fork Willamette population

Supplementation using hatchery Chinook salmon has occurred above the federal dams in the Middle Fork Willamette population area for over 20 years. Successful reintroduction has occurred in Fall Creek, a tributary to the Middle Fork Willamette River (below Dexter, Lookout Point, and Hills Creek dams). Hatchery salmon supplementation occurred for 4-5 generations, with the abundance and productivity of natural-origin salmon increasing to the point where sufficient returns to Fall Creek dam allowed hatchery releases to be terminated. Currently, 300-600 natural-origin salmon return to Fall Creek dam over the last two generations without hatchery supplementation. Hatchery supplementation provided a demographic boost to this sub-population that went extinct after the construction of Fall Creek dam. The success of this reintroduction using hatchery supplementation was due in large part to the drawdown of the reservoir to allow downstream passage of juvenile salmon in the fall and early winter (NMFS 2008). Without this hatchery supplementation effort, returns to this population (which is essential for the recovery of the ESU) would be entirely from natural-origin returns to Dexter Dam, which currently numbers less than 100 fish. Since hatchery supplementation was terminated, the potential adverse genetic effects from hatchery-induced selection have been eliminated, and natural selection is driving adaptation (O'Malley and Bohn 2018).

Hatchery supplementation above Dexter, Lookout Point, and Hills Creek dams in the Middle Fork Willamette population has also occurred over the last 4-5 generations. However, the measure of success as indicated by natural-origin salmon returns to Dexter FCF (the lowermost collection facility) has been extremely poor. Even though hatchery supplementation efforts are producing high numbers of juvenile salmon in all areas where hatchery Chinook salmon spawn, downstream passage of these juvenile salmon through the Middle Fork Willamette River has been extremely poor (in contrast to Fall Creek). No demographic boost has been observed above Dexter Dam due to current conditions. Given the natural population was extirpated as a result of habitat lost behind the federal dams, the only remaining genetic remnants of the historic population is found in the current hatchery stock (Johnson and Friesen 2013). Until conditions improve, the highest risk to this population is from low abundance of natural-origin salmon due to poor survival, where present demographic concerns outweigh longer term genetic risks.

McKenzie population

Since natural-origin Chinook returns to this population have been relatively abundant, the management direction is to reduce the effects of naturally-spawning hatchery fish in the McKenzie River, while using hatchery supplementation where needed to reintroduce salmon in areas where federal dams have extirpated natural production. The goal is to minimize genetic effects on the current Chinook population, while providing a demographic boost to abundance above federal dams where no production is occurring (Figure 34, Evans et al. 2015). Hatchery supplementation is currently occurring above Cougar Dam on the South Fork McKenzie River.

Reintroduction of Chinook salmon above Cougar Dam in the South Fork McKenzie River using hatchery salmon has resulted in juvenile offspring. The abundance of fry produced by hatchery fish numbers in the hundreds of thousands annually (Hansen et al. 2017). However, adult returns from this area have been poor, not exceeding replacement, and thus rebuilding of this run has not occurred to date from reintroduction efforts (Figure 37; Sard 2016, Sard et al. 2016a; Sard et al. 2017). The poor passage of juvenile salmon downstream of Cougar Reservoir and Dam has been the primary factor contributing to the poor adult returns (Hanson et al. 2017). Multiple age classes of juvenile salmon have been observed in Cougar Reservoir (indicating poor passage efficiency of fish) and mortality rates through the dam are high (Hansen et al. 2017). Because of this, some Chinook salmon spend their entire life above Cougar Dam and end up spawning as adults (Sard et al. 2016b). Currently, the demographic risks from having low abundances of returning salmon is the primary limiting factor. Once passage survival is improved and natural-origin salmon returns exceed 600 fish (400 females and 200 males), then hatchery genetic risks are of concern and hatchery supplementation will be terminated. This management approach allows hatchery genetic risks to be greater while salmon abundance is low, and terminate hatchery risks once natural-origin salmon begin to recover (600 fish, Sard 2016).

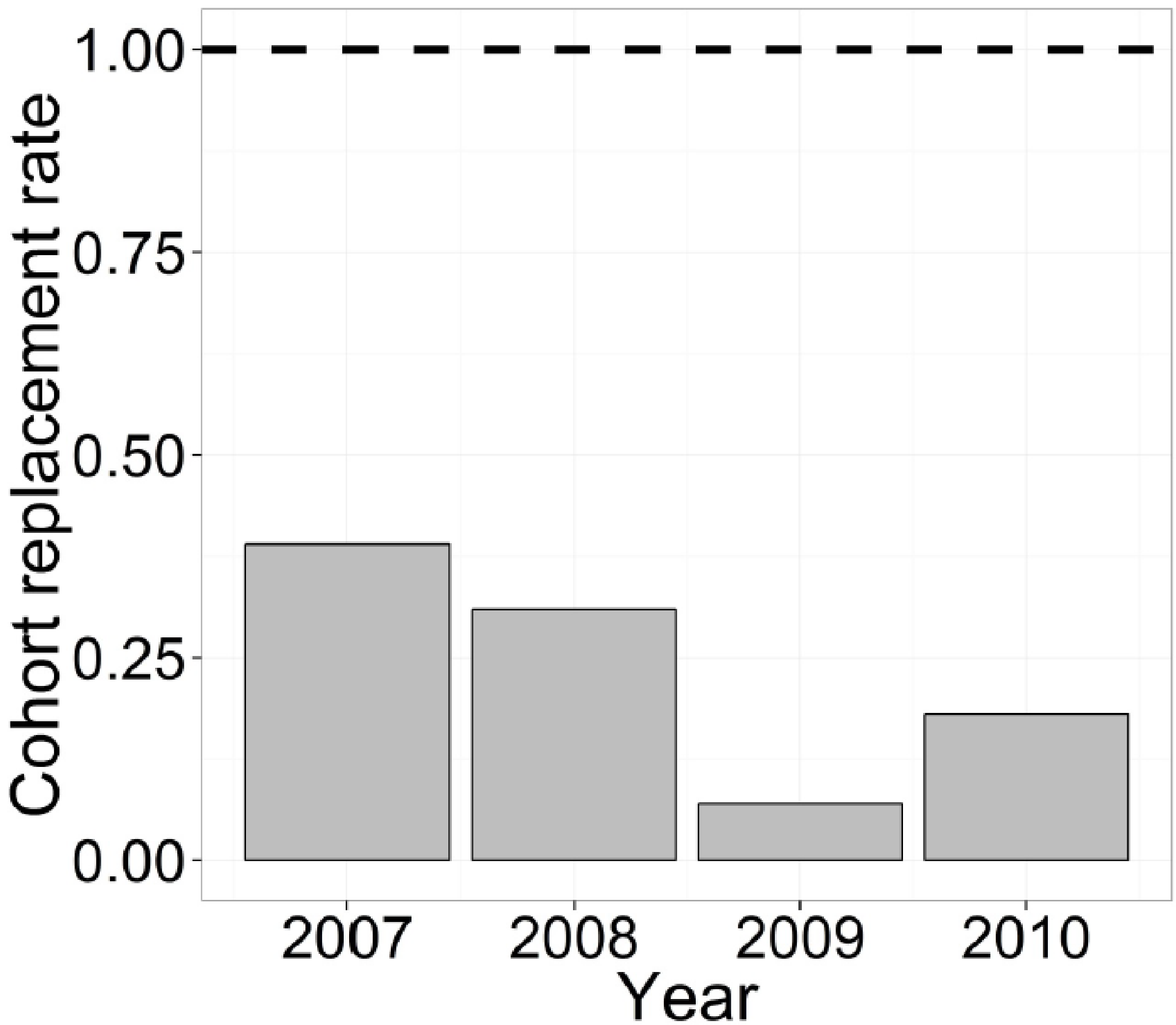


Figure 36. Cohort replacement rate (females only) above Cougar Dam, SF McKenzie River based upon genetic pedigree analyses. Figure taken from Sard et al. (2017). In order for the run to rebuild, replacement rates have to be greater than one (offspring exceed spawners).

Genetic pedigree analyses for more than a generation of returns at Cougar Dam has shown salmon are not replacing themselves. Until downstream passage conditions improve, the benefits of hatchery supplementation will likely not change. Given these constraints, the outplanting of salmon collected at Cougar FCF will also have to be managed conservatively, as proposed in the McKenzie salmon HGMP. Genetic analyses has shown a significant number of salmon that enter Cougar FCF were not produced above Cougar Dam (Figure 37). Approximately 35% of the salmon entering Cougar FCF were produced downstream (not above Cougar Dam). Given the poor survival conditions for salmon outplanted above Cougar Dam, management is structured to keep these fish spawning below the dam in their natal habitats where natural reproduction is likely to be much higher. The proposed action specifies the criteria that will be used to minimize the adverse effects of outplanting natural-origin salmon not produced above Cougar Dam. The outplanting protocols will be adaptively managed in the future based upon genetic pedigree analyses and actions to improve downstream passage survival of juvenile salmon through Cougar Reservoir and Dam.

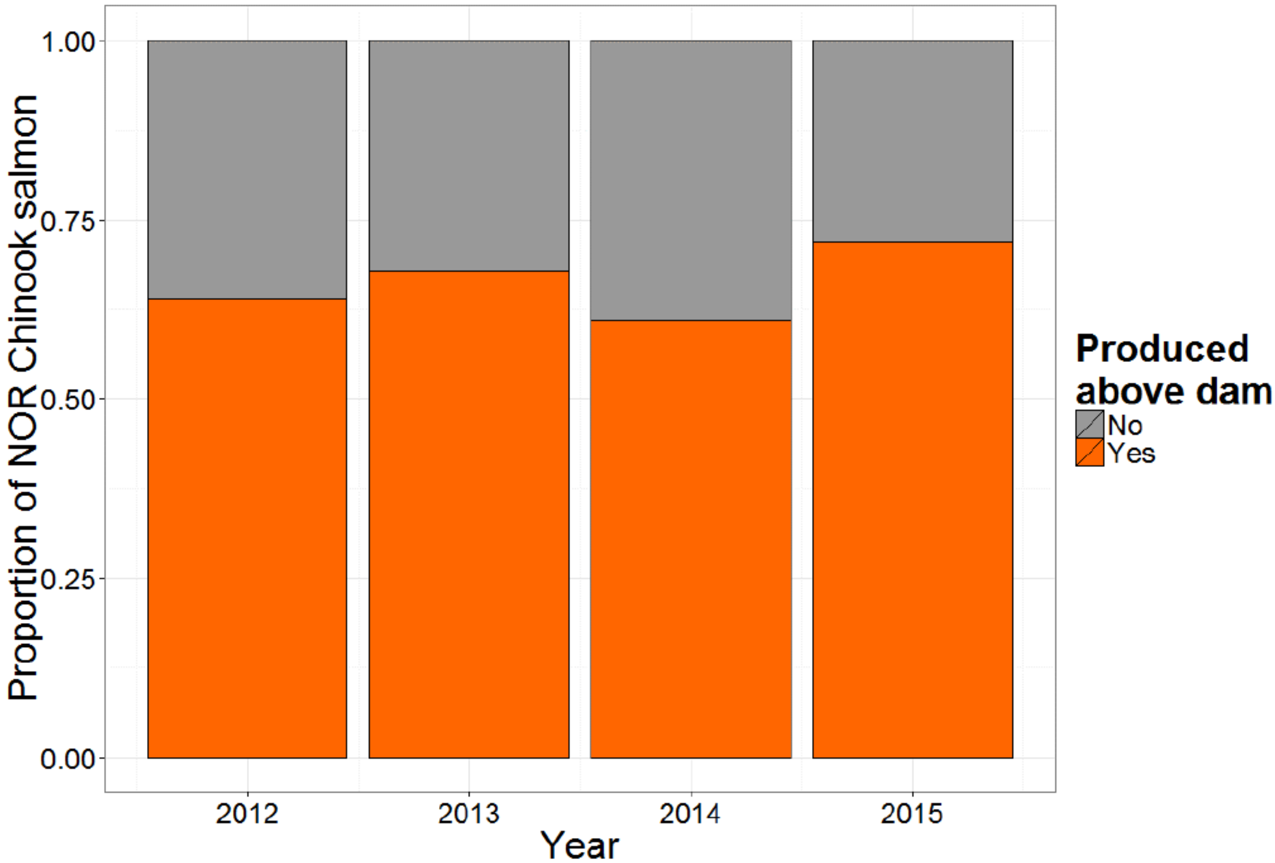


Figure 37. The proportion of natural-origin salmon collected at Cougar FCF that were produced above Cougar Dam versus below Cougar Dam based upon genetic pedigree analyses. Figure taken from Sard et al. (2017).

To date, hatchery supplementation above Cougar Dam has resulted in substantial natural production of offspring (age-0 fry), providing a demographic boost to juvenile production. However, these efforts have not resulted in replacement rates greater than one and this sub-population is not increasing. The primary reason for the poor performance is lack of adequate downstream passage by juvenile salmon by Cougar Dam. The genetic risks associated with hatchery-induced selection are of less concern, given the run of salmon above Cougar Dam has been extirpated. If salmon production is to be restored, the only viable option available at this time is to use hatchery supplementation. Since the mainstem McKenzie River natural-origin population is currently exhibiting low productivity, NMFS believes that the risk of mining this population to outplant natural-origin Chinook salmon above Cougar Dam is a greater threat to the natural-origin population than the genetic risk of outplanting hatchery-origin fish above the dam. Therefore, any reintroduction scenario poses risk to the McKenzie River natural population and the least risky approach is to use hatchery supplementation until natural-origin returns increase to the point where demographic risks are reduced and the population can support the removal of some natural-origin adults for outplanting (Sard 2016). When that occurs, hatchery supplementation will be reduced so that natural selection is driving adaptation for salmon above Cougar Dam and long-term genetic risks will be reduced from not having continual hatchery supplementation. PNI values for the McKenzie River population will increase to greater than 0.67 once natural production increases and the hatchery broodstock incorporates more natural-origin fish into the broodstock. Hatchery supplementation above Cougar Dam will cease once 400 females return to Cougar FCF, which can occur relatively quickly if downstream passage improvements increase the survival of Chinook salmon through the dam.

Calapooia population

Hatchery salmon outplants into the Calapooia River ceased over two generations ago when habitat improvements to the Calapooia River were made. Fixes were implemented on several low-head dams on the Calapooia River that helped move Chinook salmon upstream past the obstructions. Spring Chinook salmon have not increased since.

Several stakeholders have expressed the need to supplement the Calapooia River using hatchery fish in order to jumpstart the population because of demographic risks (too few returning fish). The proposed action includes this step for purposes of analysis, and NMFS regards this as a possibility in the future provided that stakeholders first develop a reintroduction plan for the Calapooia River. If survival conditions are improved in the population area, hatchery supplementation could jumpstart production and result in returns of natural origin salmon to a greater degree than natural recolonization processes. Given the status of the ESU, improvements in the Calapooia River would increase the abundance, productivity, and spatial distribution in the population and reduce the overall risk of the ESU as a whole.

South Santiam population

Reintroduction of Chinook above Foster Dam on the South Santiam River using hatchery fish occurred over the last 4-5 generations (Evans et al. 2015, Evans et al. 2016). A formal reintroduction effort above Green Peter Dam on the Middle Santiam River has not occurred to date. Supplementation efforts using hatchery salmon have increased the return of natural-origin salmon back to Foster FCF over the last decade. Genetic pedigree analyses have confirmed replacement rates to be greater than one for the last three brood years where information is available (Figure 38). Given the increase in natural-origin returns to Foster FCF, hatchery supplementation was terminated; and no hatchery salmon have been outplanted above Foster Dam over the last generation. The success of this program is attributed to juvenile downstream passage survival rates in the range of 50% to 92% depending upon reservoir height and passage route at Foster Dam (Hansen et al. 2017). Foster reservoir is smaller in size and the dam is low-head with more fish friendly turbines, which aids passage of spring Chinook salmon. The hatchery program provided a demographic boost through supplementation for the area above Foster Dam in the South Santiam, but then was terminated (no hatchery Chinook outplanted above Foster Dam) once natural-origin abundance thresholds were met. Presently, the genetic risks of the hatchery program are low for the sub-population above Foster Dam and natural selection is occurring (Evans et al. 2015, Evans et al. 2016). However, there is still some uncertainty about the effects of F1 hatchery progeny produced below Foster Dam migrating up to Foster FCF and being passed upstream. This would continue to infuse hatchery genes into the natural population above Foster Dam at a higher rate than desired. In recent years, there is concern with the trapping efficiency at the newly rebuilt Foster FCF, as issues have been identified related to the collection of natural-origin and hatchery-origin salmon. In addition, the number of natural-origin salmon returning to the South Santiam has been much reduced compared to previous years. Hopefully the returns rebound in the near future so that hatchery supplementation is not needed again.

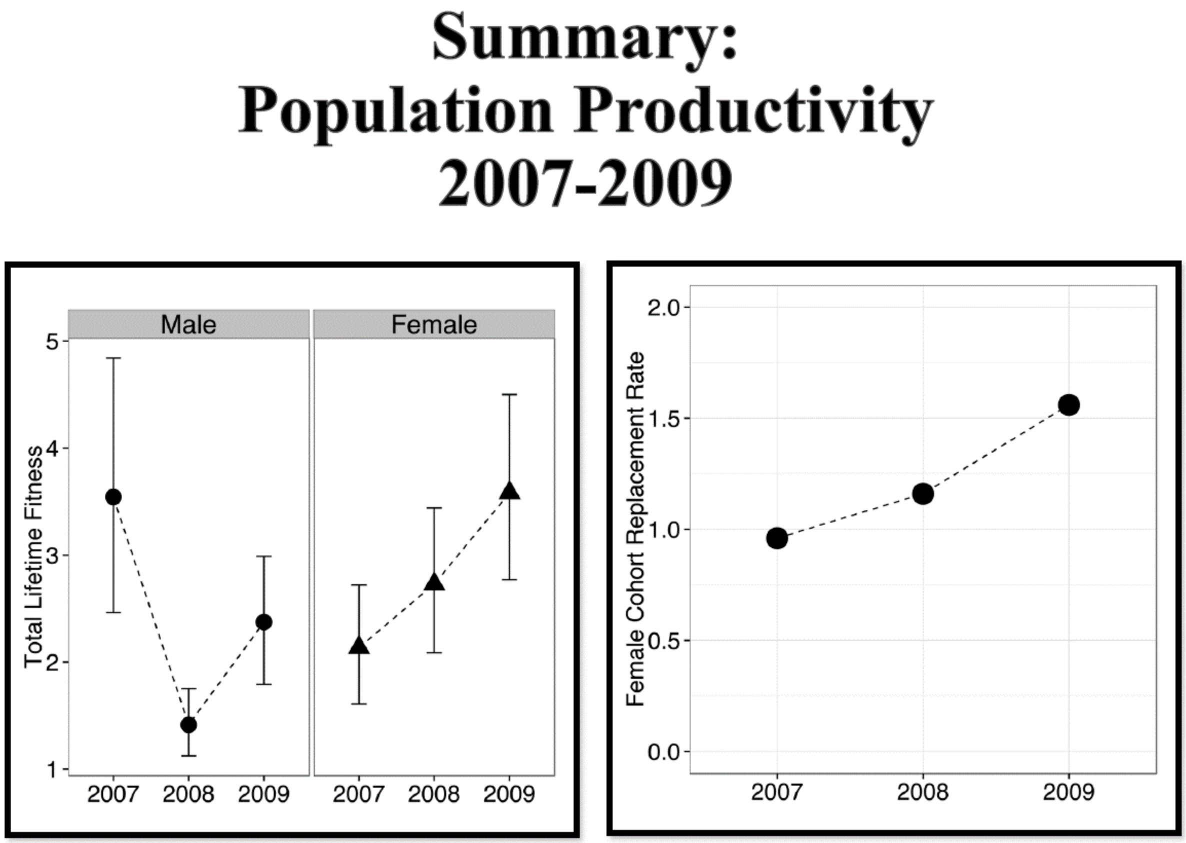


Figure 38. Replacement rates (progeny produced per spawner) for Chinook salmon above Foster Dam, South Santiam River based upon genetic pedigree analyses. Figure taken from O'Malley et al. (2017a).

North Santiam population

Reintroduction of salmon above Big Cliff and Detroit dams on the North Santiam River using hatchery Chinook salmon has occurred for the last 3-4 generations. Genetic pedigree analyses has shown replacement rates to be below one (Figure 39), but these results are confounded by several issues that make the results more uncertain. Only a proportion of the salmon were sampled in the first years and thus the estimates do not reflect the entire run. More recent analyses have shown higher replacement rates near one. To date, hatchery fish have been used for supplementation above Big Cliff/Detroit dams because of the uncertainty with survival of natural-origin salmon as juveniles through the reservoirs and dams. No natural-origin salmon are proposed to be outplanted above Detroit Dam until genetic pedigree analyses confirms conditions are favorable for natural production as measured by replacement rates. Hatchery supplementation is providing a demographic boost to the population by producing offspring above and below the federal dams. Genetic risks are of lesser concern given the low abundance of natural-origin fish.

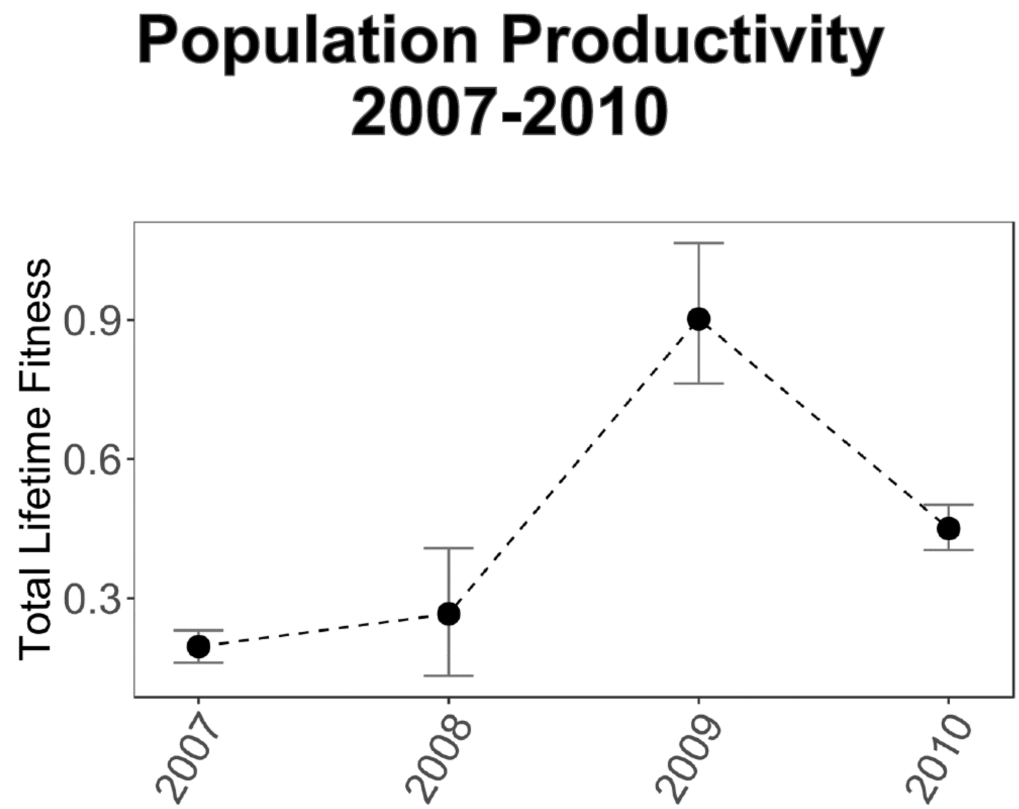


Figure 39. Replacement rates of spring Chinook salmon from above Minto Dam on the North Santiam River based upon genetic pedigree analyses. Figure taken from Black et al. (2017).

Molalla population

Hatchery fish are released as smolts in the Molalla River, and no outplanting of adult salmon occurs at this time. Hatchery fish may spawn naturally if they are not harvested in sport fisheries and survive over the summer. Natural-origin returns in the Molalla River are very low. Consequently any straying by hatchery fish represents high pHOS due to low numbers. Naturally spawning hatchery fish may be providing a demographic boost to the population; although genetic pedigree analyses of natural production has not occurred in the Molalla like in other populations. It is expected hatchery fish are producing the majority of F1 progeny based upon pHOS and the suitability of the habitat.

Marine-derived Nutrients

The current hatchery programs contribute marine derived nutrients to freshwater ecosystems and this benefits ESA-listed species. Some hatchery fish escape to natural spawning areas and thereby enhance the amount of marine-derived nutrients available from the decomposed carcasses. Marine-derived nutrients are important to the UWR because streams and rivers tend to be low in terrestrial nutrients; the return of anadromous fish from the ocean environment acts as a key mechanism for bringing nutrients into the freshwater ecosystems (Cederholm et al. 1999). Salmon carcasses, natural-origin and hatchery, provide food for aquatic and terrestrial species via direct consumption. The carcasses can also decompose with the primary nutrients available in the water and deposited in the sediments which are then available for primary production by plants and animals. Both of these pathways increase the productivity of the freshwater environment and benefit natural fish populations.

Since the number of natural-origin (and hatchery-origin) Chinook salmon presently returning to the UWR has significantly declined from historic levels, the level of marine-derived nutrients being contributed by salmon to the freshwater ecosystem is poor; even if every hatchery fish was outplanted after spawning by the hatchery.

Summary of Effect

There are four factors related to the genetic effects of the hatchery Chinook salmon programs on each population affected in the UWR ESU that have been evaluated above: within population diversity, inbreeding depression, outbreeding depression, and hatchery-induced selection. Due to the low abundance of naturally produced salmon in the Molalla, North Santiam, South Santiam, and Middle Fork Willamette populations, the existing hatchery programs are providing benefits in terms of increasing within population diversity (Johnson and Friesen 2013) and reducing inbreeding depression by increasing natural abundance (e.g. O'Malley et al. 2014; Black et al. 2017; Sard et al. 2017). The risks of hatchery induced selection (domestication) is less of a problem than the current very low abundances of naturally-produced fish in these populations. There is more risk from low population abundance than hatchery induced selection. The effects of outbreeding among populations in this ESU is low and within natural straying rates observed among salmon species (Quinn 2005; Schroeder et al. 2007).

2.5.2.2.1.2 Hatchery Summer Steelhead

Summer steelhead do not interbreed with spring Chinook salmon and spawn timing is temporally separated so no interactions occur on the spawning grounds. Because of this, there is no effect of hatchery summer steelhead spawning with Chinook salmon.

2.5.2.2.1.3 Hatchery Rainbow Trout

Rainbow trout do not interbreed with spring Chinook salmon. Therefore, there is no effect of hatchery rainbow trout spawning with Chinook salmon.

2.5.2.2.2 UWR winter steelhead: Negative effect

Hatchery salmon can spawn in the wild. However, the interaction and overlap between hatchery Chinook salmon and ESA-listed UWR steelhead DPS, consisting exclusively of winter steelhead, on the spawning grounds is negligible due the differences in spawn timing. No effect of the program is expected during winter steelhead spawning.

2.5.2.2.2.1 Hatchery Summer Steelhead

The consequences of non-native hatchery summer steelhead spawning in the wild with ESA-listed winter steelhead is evaluated here in five sections: 1) the existing genetic structure of the UWR winter steelhead DPS, 2) current life history characteristics of hatchery summer and native winter steelhead in the UWR, 3) current genetic effects of summer steelhead in the UWR, 4) relationship of genetics and habitat, and 5) the co-occurrence of summer and winter steelhead in same population areas.

In the biological opinion for the Willamette Project, Reasonable and Prudent Alternative (RPA) 9.5.2 directed the co-managers to further study the extent of hatchery steelhead spawning in the wild and interactions with ESA-listed winter steelhead (NMFS 2008). Several other RPAs (i.e. RPAs 6.1.6, 6.1.7, and 6.1.8) were implemented for the hatchery summer steelhead program to reduce potential negative effects and research, monitoring, and evaluation (RME) was required to evaluate how these management changes were working. Over the course of the last 10 years, a substantial amount of information has been collected that help inform the genetic effects from hatchery summer steelhead on ESA-listed winter steelhead in the UWR. We have included key results of these findings in our evaluation of gene flow from the hatchery steelhead program to ESA-listed steelhead below.

The hatchery summer steelhead is an isolated harvest program that releases non-native fish that are not included in the UWR steelhead DPS. The program operators use only hatchery summer steelhead produced by the program (identified by return timing at Foster Dam from June through August and the presence of an adipose fin clip mark) as broodstock, and no natural-origin winter steelhead will be collected and spawned. The proposed action includes advancing the spawn timing of summer steelhead (spawning broodstock earlier) in order to segregate summer and winter steelhead spawning as much as possible. The management intent of these programs is to have few returning fish in excess of broodstock needs escape to spawn in the wild. The proposed action includes a standard to limit gene flow from hatchery summer steelhead to winter steelhead populations to less than 2%. Summer steelhead that do spawn in the wild are expected to have low reproductive success relative to ESA-listed winter steelhead because they spawn earlier (see section below analyzing the run and timing of steelhead) than natural-origin fish due to several generations of selective breeding for earlier spawn timing (Crawford 1979), and thus spawn under sub-optimal conditions (Williamson et al. 2010). They may also be less successful than natural-origin winter steelhead due to other aspects of domestication (Araki et al. 2007; Christie et al. 2016). To the extent they do reproduce and contribute to the next generation of natural-origin fish, however, they pose a risk of adverse genetic effects to ESA-listed winter steelhead populations. In this section, we analyze the effects of potential gene flow from the hatchery summer steelhead program to the winter steelhead populations, specifically effects on gene flow caused by outbreeding and hatchery-influenced selection.

Existing Genetic Structure of Winter Steelhead in the UWR

The 2008 biological opinion for the Willamette Project specified several RPA actions for the hatchery steelhead program to reduce effects of this program on ESA-listed winter steelhead. One of the actions was to gain more information on the genetic structure of steelhead throughout the UWR, and specifically, assessing juvenile *O. mykiss* to determine their ancestry and degree of hybridization with hatchery summer steelhead (RPA 9.5.2). Since 2008, several studies have been conducted to evaluate the genetics of steelhead, including the reproductive success of summer steelhead in the wild and hybridization between summer and winter runs. Findings from these studies are reported below to the extent the information provides insight on the influence of the hatchery summer steelhead program on ESA-listed winter steelhead.

Van Doornik et al. (2015) provides a basinwide assessment of the genetic diversity of steelhead in the UWR (Figure 40). Based upon juvenile and adult samples of hatchery and natural steelhead collected from 1986 through 2009, they found strong evidence for four different population groups: summer steelhead, early run winter steelhead, late-run winter steelhead, and rainbow trout. ESA-listed late-run winter steelhead were genetically distinct from hatchery summer steelhead due to spatial and temporal separation during spawning. Van Doornik et al. (2015) concluded “native steelhead in the Willamette River remain genetically distinct from introduced stocks, likely due to adaptive differences as well as sufficient temporal and spatial segregation among spawning populations.” It is important to note many of the samples came from fish collected in the 1980-1990s and those samples represent the genetic structure of steelhead at that point in time. Since 1997, hatchery releases of both summer and winter steelhead have been terminated in all westside streams and the Molalla River due to ESA listing, but release of summer steelhead continues in the North and South Santiam rivers.

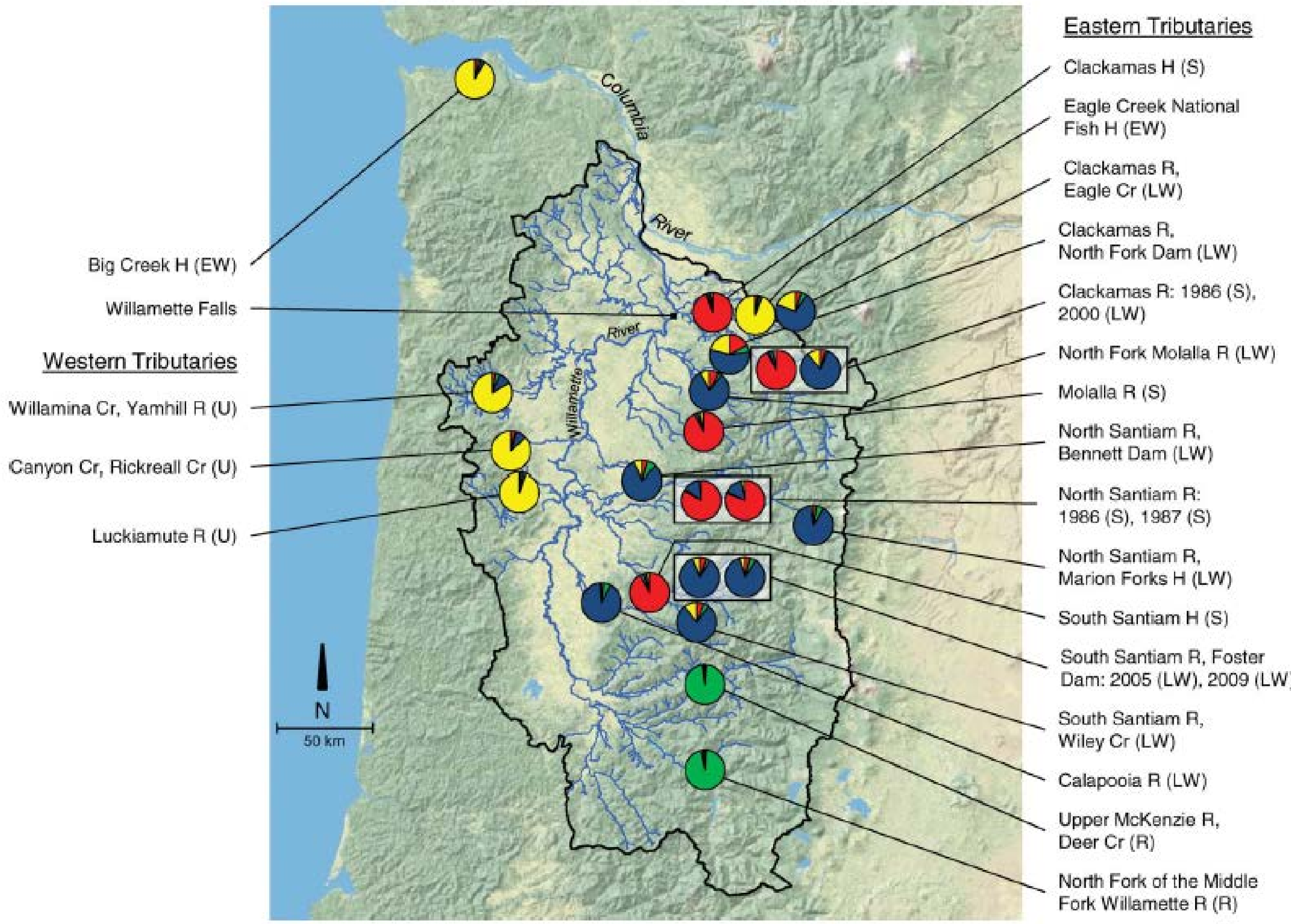


Figure 40. Population group membership for UWR steelhead samples using STRUCTURE analyses. Blue color shows late-run winter steelhead, yellow color shows early-run winter steelhead, red color shows summer steelhead, and green shows rainbow trout. Figure taken from Van Doornik et al. (2015).

Johnson et al. (2013) characterized the genetic diversity of steelhead incorporating recent samples collected in 2009-2011 throughout the UWR. There was strong evidence for hatchery summer steelhead spawning naturally and producing offspring in the McKenzie River (outside of the DPS; Table 22), in contrast there was "scant evidence for natural summer steelhead production in the North Santiam River and no evidence from the South Santiam River" using *ONCOR*. In the North Santiam and South Santiam rivers, hatchery summer steelhead produced few (one) offspring, but there was evidence of hybridization between summer and winter steelhead (Table 22). Analysis of steelhead from the North Santiam and South Santiam rivers concluded that 11% and 15% of the fish sampled were characterized as hybrids, respectively. The authors indicated these hybrids were most likely the offspring of summer x winter-run hybrids (F_2 hybrids). The majority of *O. mykiss* samples in the North Santiam and South Santiam rivers were identified as ESA-listed, late-run winter steelhead (Table 22). On a basinwide scale, 10.5% of the juvenile *O. mykiss* sampled as juveniles at Willamette Falls were identified as "pure" summer steelhead offspring and 10.6% of the offspring were identified as hybrids between summer and winter-run steelhead. This confirms summer run steelhead are successfully reproducing in the UWR; with the highest proportion from any one river likely coming from the McKenzie River.

Table 22. Counts of juvenile *O. mykiss*, according to group or hybrid class (EW= eastern tributaries winter steelhead, S=summer steelhead, WW= western tributaries winter steelhead, RB=rainbow trout) as inferred through ONCOR and STRUCTURE analyses of genotypic data from 15 microsatellite loci. Table taken from Johnson et al. (2013).

	Class	McKenzie R.	N. Santiam R.	S. Santiam R.
ONCOR				
	S	62	1	0
	EW	25	34	27
	RB	4	1	0
	WW	0	0	0
STRUCTURE				
	S	63	0	0
	EW	2	25	20
	RB	4	0	0
	WW	0	1	1
	S hybrids	18	4	4
	Other hybrids	4	6	2

Weigel et al. (2019) conducted a genetic analysis of natural-origin, adult steelhead sampled at Willamette Falls to determine hybridization between summer and winter steelhead. The samples represented steelhead from throughout the Willamette River and not just the UWR DPS. Weigel et al. (2019) reported 19% to 26.4% of the natural-origin adult steelhead sampled at Willamette Falls had introgressive hybridization by summer steelhead, depending upon the selected criteria. The estimated number of F1 hybrids ranged from 4.9% to 10.1% of the steelhead sampled, depending upon how the genetic make-up for a hybrid was interpreted (Q values ranged from 0.3 to 0.7). In evaluating the accuracy of determining hybrids, they cited a 20% error rate in assignment of steelhead based upon previous work and simulations (Figure 41). For illustration of this uncertainty, a F1 hybrid between a summer and winter steelhead should exhibit a Q value of 0.5, where half of the genetic material comes from the offspring's father and half from the mother. However, simulated data for an F1 hybrid in this study ranges from < 0.2 to > 0.8; representing a tremendous range in values when the value should be

0.5. Therefore, it is recognized the hybridization rates stated above have a tremendous amount of uncertainty associated with them. Johnson et al. (2018) also found uncertainty in classifying hybrids.

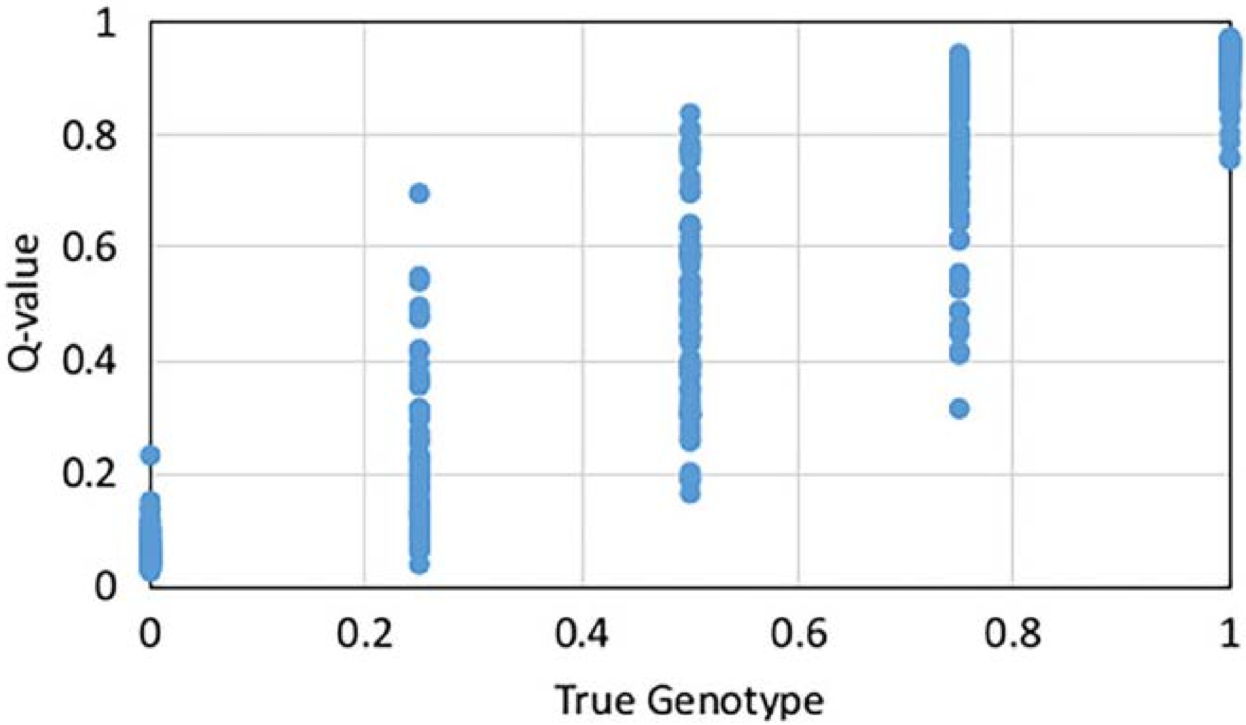


Figure 41. STRUCTURE output for individual simulated genotypes (y-axis) versus true genotype (x-axis). The simulated hybrids are shown on the x-axis according to the proportion of native winter steelhead (0.5 for F1 hybrids, 0.25 for F1 x summer, and 0.75 for F1 x winter). Figure taken from Weigel et al. (2019).

Weigel et al. (2019) reported the genetic structure of adult steelhead sampled at Willamette Falls. However, Weigel et al. (2018) provides additional information on where these fish actually returned to for spawning, based upon the radio-tagging studies of Jepsen et al. (2015). Figure 42 shows the genetic classifications for adult steelhead returning to tributaries of the UWR. The results of this study suggest relatively high levels of summer steelhead hybridization (>20% of the sample) in steelhead returning to the Clackamas, Tualatin, Molalla, Yamhill, South Santiam, and Middle Fork Willamette rivers. None of the west side tributaries have received releases of hatchery summer steelhead. The lowest incidence of hybrids occurred in steelhead returning to the Calapooia and McKenzie rivers (Figure 42). These results are different than previous genetic analyses reported above (e.g. Johnson et al. 2013; Van Doornik et al. 2015). In addition, Jepson et al. (2015) reported no evidence of summer steelhead entering the westside tributaries (Tualatin, Yamhill, Luckiamute) based upon three years of radio telemetry (see section below for a full discussion of this). The Molalla River had one summer steelhead stray into this river. Nearly all summer steelhead returned to the rivers where they were released as smolts (Jepson et al. 2015). We note these issues here because it appears from this study relatively high rates of hybridization in winter steelhead occupying westside tributaries, even though all of other best available information would suggest the influence of hatchery summer steelhead in these tributaries to be non-existent (i.e. no hatchery summer steelhead stocked in the past, no hatchery summer steelhead observed straying into these tributaries from the radio-tagging studies, and minimal streamflows during summer steelhead migration to attract adults). Van Doornik et al. (2015) classified westside tributary winter steelhead as a separate classification group based upon their analysis and not hybrids with summer steelhead. Warheit (2014) has shown hatchery steelhead introgression to be overestimated when a priori information on genetic classifications is lacking and/or insufficient. This may be the case for the results from Weigel et al. (2019), where only two classifications of steelhead were used in the analysis.

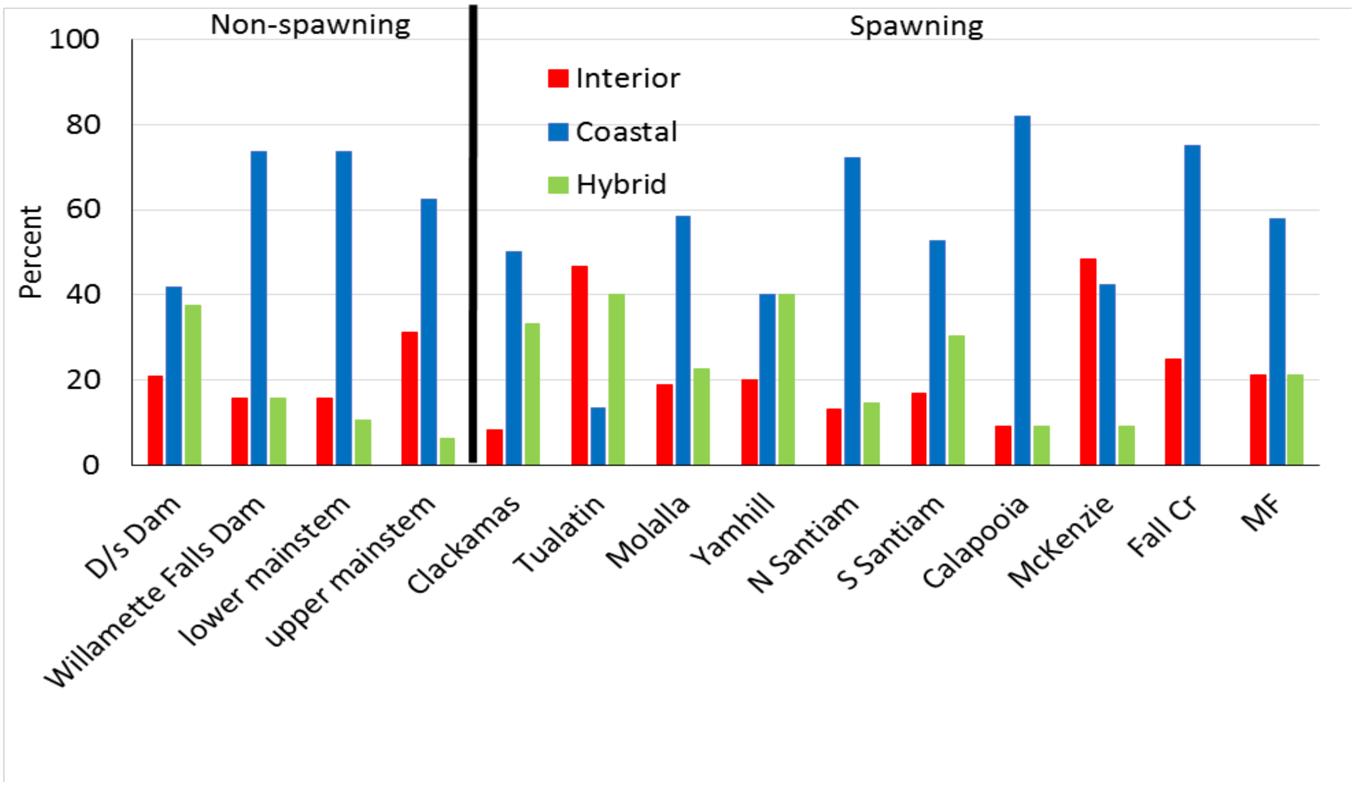


Figure 42. Genetic structure classifications of steelhead based upon tissue samples taken from radio-tagged adult steelhead at Willamette Falls. Figure taken from Weigel et al. (2018). Important note: "Interior" is summer steelhead; "coastal" denotes winter steelhead, and hybrid is F_1 between summer and winter steelhead or backcross.

Another genetic structure analysis using SNPs (instead of microsatellites) was conducted by Weigel et al (2018) for winter steelhead outplanted above Foster Dam on the South Santiam River from samples in 2012 through 2016. In each year, a very low percentage of adults were summer steelhead and/or F1 hybrids (summer and winter steelhead; Figure 43). However, approximately 25% of the adult steelhead were classified as progeny of a winter steelhead mated with a hybrid summer x winter backcross.[13] These results differ from that reported by Johnson et al. (2013) for juvenile steelhead samples collected

[13] A backcross is defined here as a summer/winter steelhead hybrid that mates with a winter steelhead.

above Foster Dam, where all juveniles were identified as pure winter steelhead (based upon their genetic classification criteria).

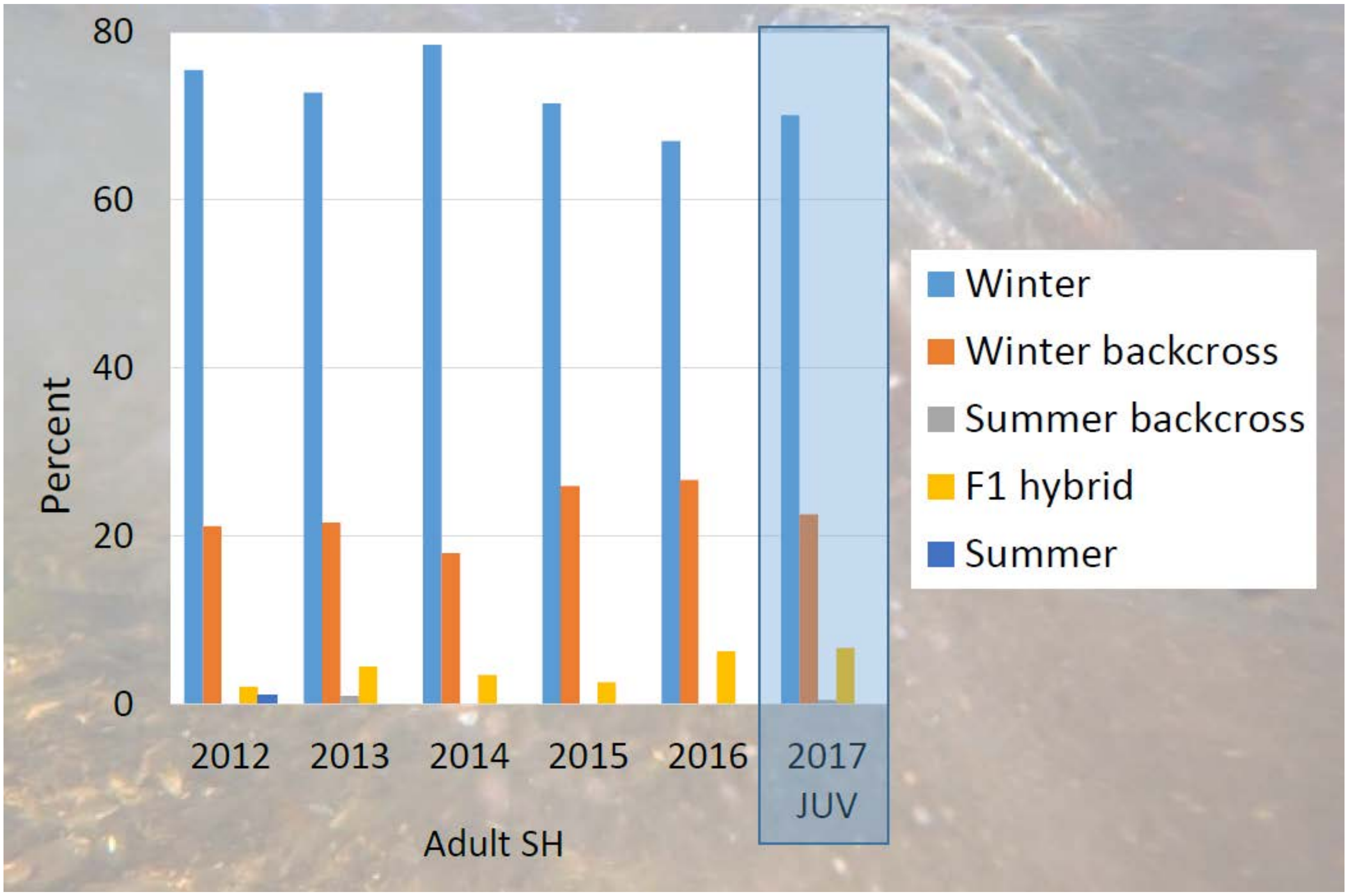


Figure 43. Genetic composition of unmarked steelhead outplanted above Foster Dam, South Santiam. Please note the technical concerns of these findings in the text. Figure taken from Weigel et al. (2018b).

Johnson et al. (2018) further studied the genetics (microsatellite markers) of *O. mykiss* throughout the UWR, as directed by NMFS (2008). The new information in this report (not reported above) is from samples collected in 2014 from juvenile *O. mykiss*. In the North Santiam and South Santiam, 8% and 14% of these samples were classified as hybrids between non-native summer steelhead and ESA-listed winter steelhead, respectively, using STRUCTURE analyses. These juveniles would have most likely been produced by adult steelhead spawning in 2012 and 2013. Interestingly, 13% of the samples in the Molalla River were classified as hybrids (summer x winter crosses) even though no hatchery summer steelhead are released in this river. No F1 offspring from summer and winter steelhead matings were detected applying NEWHYBRIDS analyses (in contrast to the results of Weigel et al. 2019). However, Johnson et al. (2018) also concluded there is a tremendous amount of uncertainty in classifying hybrids and backcrosses using microsatellites for UWR steelhead. Therefore, the current hybridization between summer and winter steelhead could not be quantified.

Kostow et al. (2003) evaluated the effects of the same non-native, hatchery summer steelhead stock (Skamania) on ESA-listed winter steelhead in the Clackamas River, a tributary to the Willamette River below the falls. Genetic analyses showed low levels of hybridization between summer and winter steelhead as a result of temporal and spatial separation. The authors stated the "*This data supports the hypothesis that among-stock reproductive isolation is relatively high. However, interbreeding is not completely precluded by these results because population genetic data before the hatchery programs are not available for comparisons.*" The hatchery summer steelhead program was terminated in the late 1990's, with no hatchery steelhead being passed at North Fork Dam into the upper Clackamas River. Kostow and Zhou (2006) reported an increase in winter steelhead productivity after elimination of the hatchery steelhead program, but further analyses showed the productivity increase was due to other environmental factors (Courter and Wyatt 2016; Courter et al. 2018).

Blankenship et al. (2011) and Matala et al. (2014) conducted genetic structure analyses on steelhead throughout the entire Columbia River Basin, including samples from the Willamette River Basin. The emphasis of these studies was determining the relationships between habitat characteristics and steelhead genetics. The genetic structure of steelhead within populations of a DPS and among DPS's were highly correlated to landscape features such as precipitation and temperature. Within the Willamette River Basin, differences in steelhead genetics were observed between the westside tributary populations and eastside tributary populations consistent with differences in the amount of rainfall, streamflow patterns, and air and stream temperatures. Upper Willamette winter steelhead also showed a similarity with other steelhead stocks found in the Lower Columbia River DPS.

In summary, populations of winter steelhead throughout the Upper Willamette River DPS still exhibit unique genetic structure. Introgression of hatchery summer steelhead into these winter steelhead populations has occurred since the hatchery program has been in existence. The degree to which introgression has likely occurred varies among populations in the DPS, with the greatest likelihood in the North Santiam and South Santiam populations because hatchery summer steelhead are released in these areas. There may also be some genetic legacy effects of past hatchery releases of steelhead that have been discontinued for over 20 years. There is also uncertainty (and likely errors) in correctly classifying hybrids of summer and winter steelhead in the UWR. Some of these studies show relatively high introgression of summer steelhead in population areas where summer steelhead do not occur (i.e. westside tributaries); raising concerns about whether the assumptions used for identifying hybrid steelhead are indeed correct. Other genetic studies show strong relationships between steelhead genetics and aquatic habitat, even within steelhead populations of the Willamette/Lower Columbia River Domain.

Current Life History Characteristics of Hatchery Summer and Native Winter Steelhead in the UWR

The previous section reported the current genetic structure of steelhead in the UWR using the best available science to date. However, it is important to acknowledge these studies assessed genetic samples from a range of years in the past when hatchery management was quite different than the proposed action. This section now describes the life history characteristics of the contemporary runs of summer and winter steelhead returning to the UWR that is a reflection of past and present hatchery management and the effects of these programs on steelhead. This information is important because the interactions of summer and winter steelhead on the spawning grounds (pHOS) and ultimately the gene flow from summer steelhead to winter steelhead in the following section. Many of the data inputs for the gene flow modeling are derived from the latest information on the spawn timing of steelhead (both summer and winter runs). An important risk factor evaluated for the hatchery summer steelhead program is the degree to which summer steelhead spawn and hybridize with ESA-listed winter steelhead. This potential area of overlap represents how non-native summer steelhead genes can be incorporated into the winter steelhead genome (Figure 44). The key issue assessed here is the extent of overlap in spawning by summer steelhead with winter steelhead (i.e., the region of overlap).

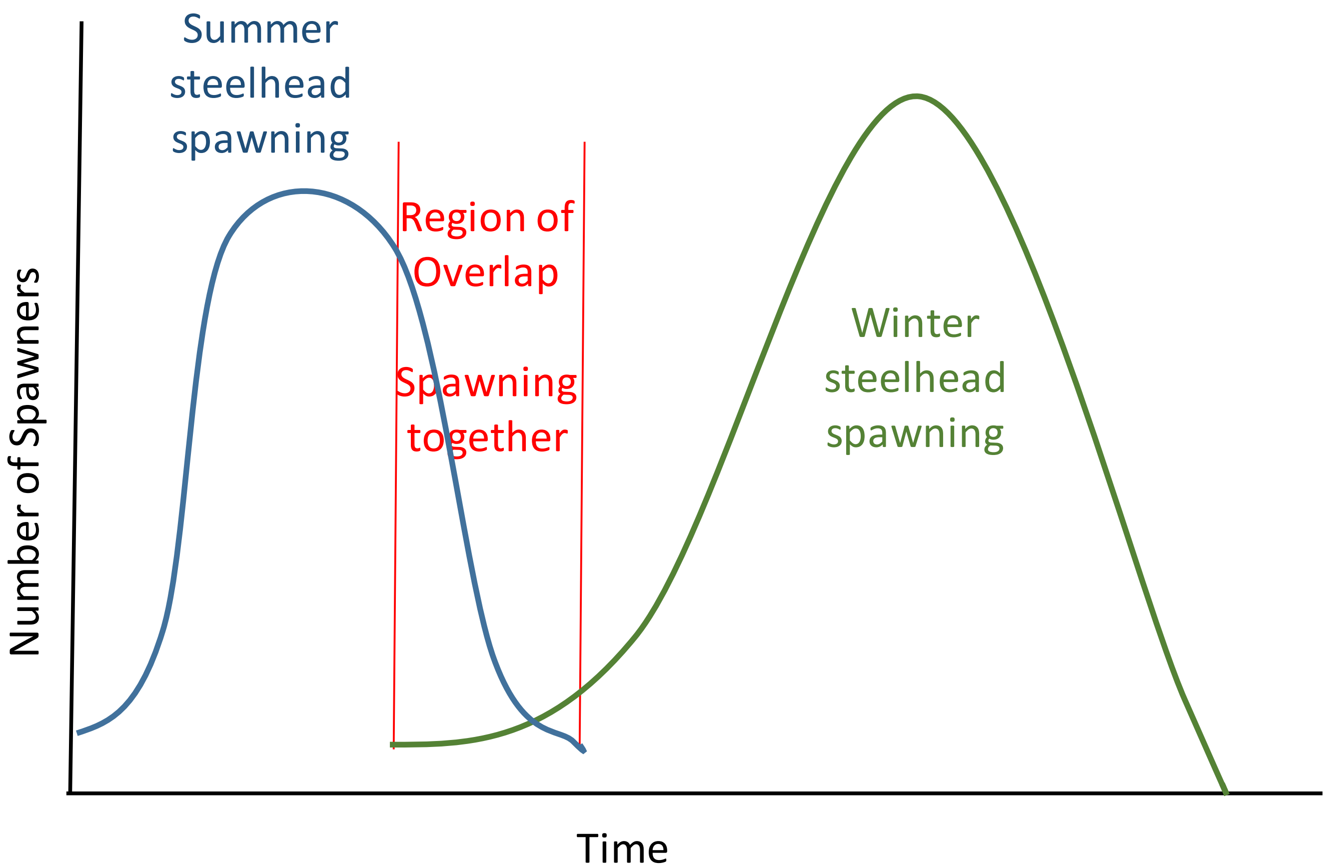


Figure 44. Conceptual diagram of summer and winter steelhead spawning through time. The shape and placement of the spawning histograms for each run type is conceptual for illustration purposes only. The region of overlap in time is when summer and winter steelhead can potentially spawn together, creating hatchery- by natural-origin (HxN) matings. The actual run and spawn timing data is presented in the text.

As described in section 2.2.1.2, ESA-listed winter steelhead have a different run and spawn timing relative to hatchery summer steelhead released in the Upper Willamette River. This section describes recent information collected on the run and spawn timing of both runs of steelhead specifically in the Upper Willamette River. Within the DPS area, hatchery summer steelhead are currently released only in the North Santiam and South Santiam rivers (Figure 45). No summer steelhead are released into the Molalla, Calapooia, Yamhill, Luckiamute, and Tualatin rivers within the DPS. However, information is analyzed for all populations throughout the entire DPS where information is available to ascertain the effects of hatchery fish straying into areas where no hatchery steelhead are released (Figure 45). Outside of the DPS, summer steelhead are also released into the McKenzie, Middle Fork Willamette, and mainstem Willamette (Eugene) rivers.

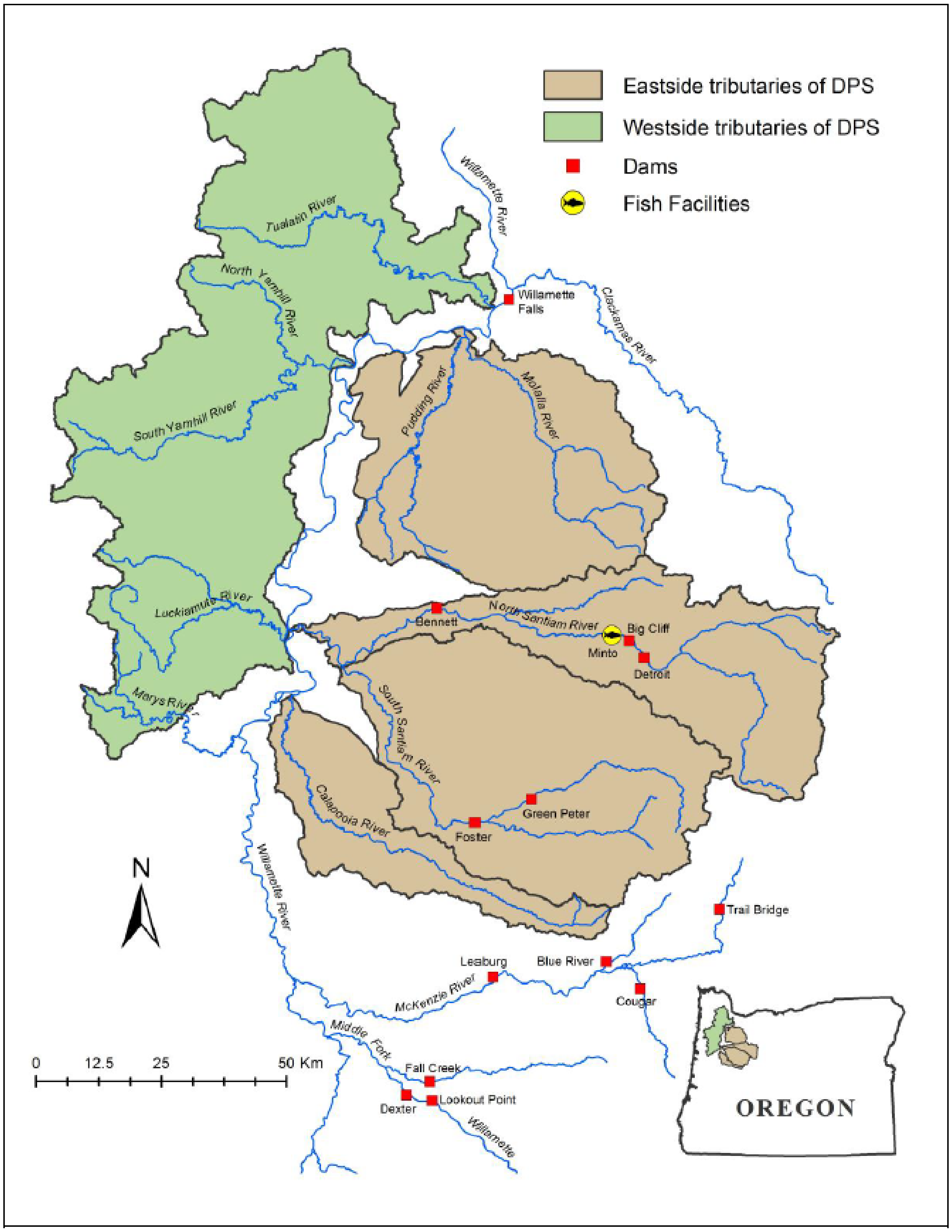


Figure 45. Geographic boundaries of the UWR winter steelhead DPS, with emphasis on the westside and eastside tributaries. Figure taken from Johnson et al. (2013).

The first counting station for winter steelhead entering the UWR is at Willamette Falls. The winter steelhead migration period extends from early December through early May. However, the vast majority of all winter steelhead pass Willamette Falls from early February through early April (Figure 46; Table 23). In 2014, 84% of the winter steelhead passed after February 15th (Table 23). Based upon recent radio-tagging studies of steelhead (Jepson et al. 2015), winter steelhead migrate up the mainstem Willamette River quickly and enter spawning tributaries throughout the entire basin. Most of the winter steelhead have been observed returning to the Molalla, North Santiam, South Santiam, and Middle Fork Willamette rivers (Table 23).

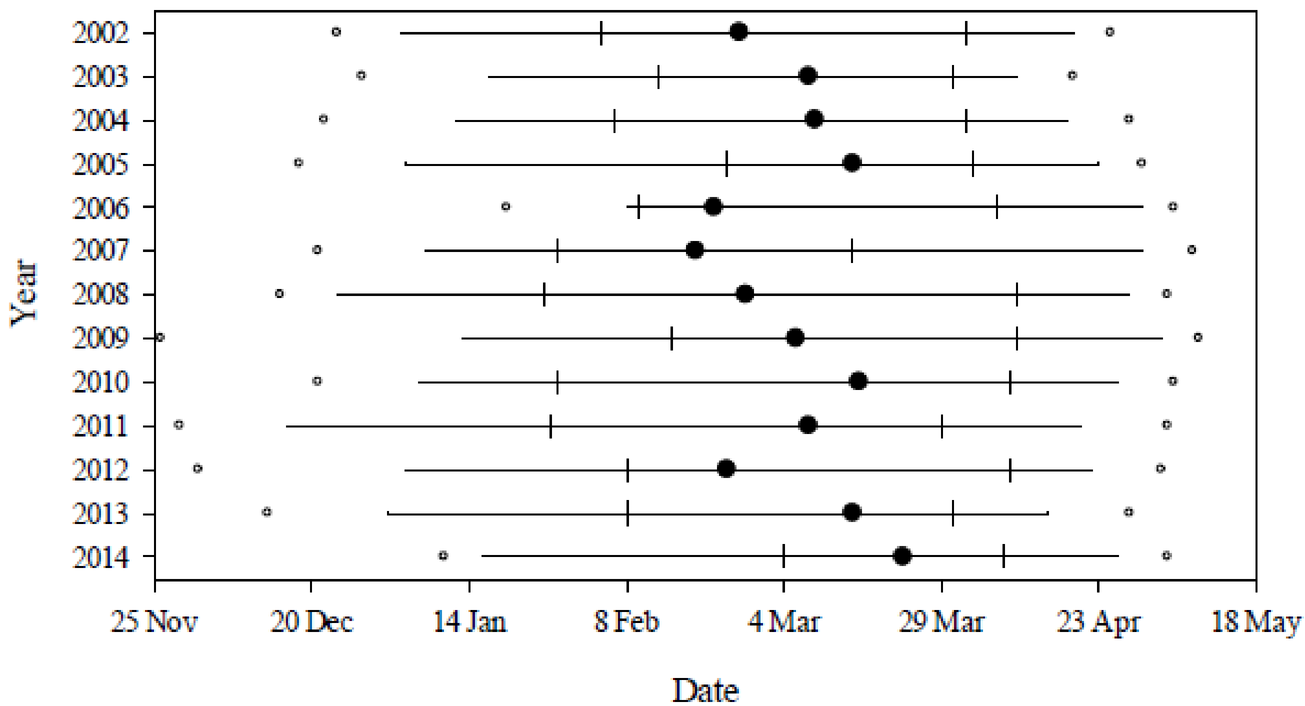


Figure 46. Annual migration timing distributions for winter steelhead counted at Willamette Falls, 2002-14. Symbols show median (black dots), quartile (vertical lines), and 10th and 90th percentiles (ends of horizontal lines), and 5th and 95th percentiles (open dots). Figure taken from Jepson et al. (2015).

Weigel et al. (2019) derived the run timing of natural-origin adult steelhead ("pure" winter steelhead and hybrids (summer x winter crosses)) sampled at Willamette Falls in 2013 and 2014 (Figure 47). For all classes of winter steelhead and their hybrids, median migration at Willamette Falls was in March. "Pure" winter steelhead exhibited the longest period of migration spanning from November through June; whereas hybrid summer backcrosses migration spanned from mid-January through March (Figure 47). It is also important to note there were drastic differences in the classification of steelhead between the runs in 2013 and 2014. In 2013, many of the classified hybrid steelhead migrated Willamette Falls from mid-February through mid-March; whereas in 2014 few hybrid steelhead were observed. These results are somewhat counter-intuitive to what is known about the ecology of winter steelhead in the UWR; as winter steelhead passing the falls after February 15th have been typically referred to as the later, wild steelhead run not impacted by past hatchery practices (Busby et al. 1996; NWFSC 2015; Johnson et al. 2018). Hatchery summer steelhead had a median passage date in mid-June.

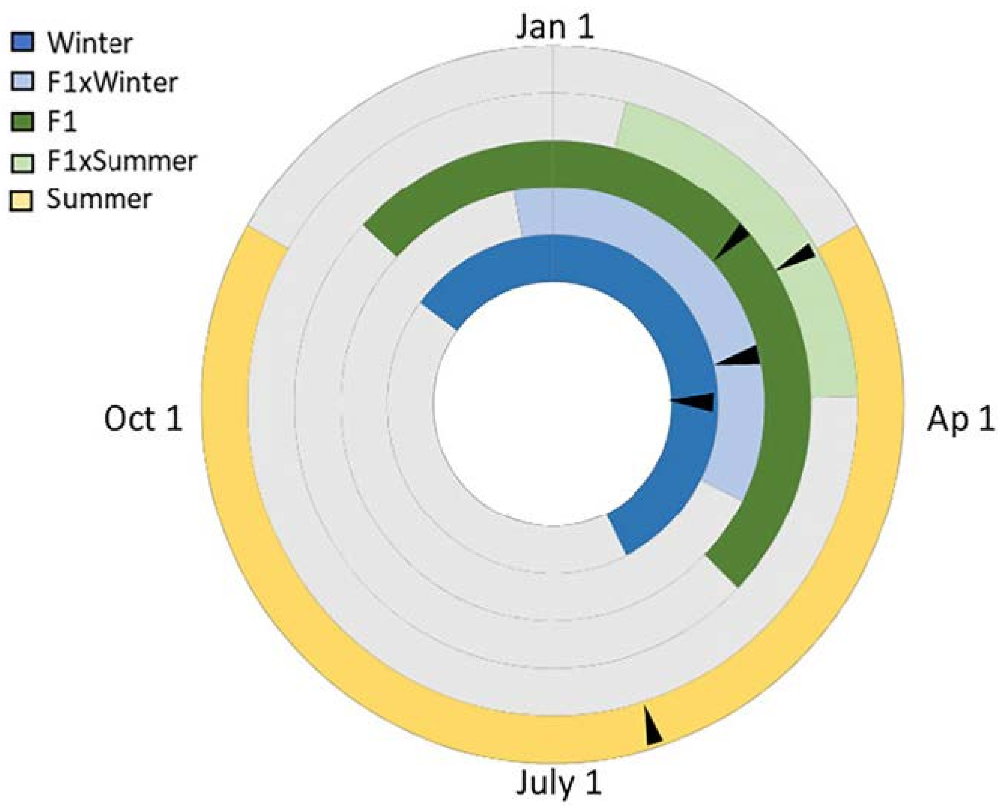


Figure 47. Migration timing (range and median) of natural-origin steelhead by genotype (native, winter steelhead, F1, and backcrossed hybrids) and hatchery-origin summer steelhead at Willamette Falls. The native winter and hybrid run timing is based on the genotyped sample collected for this study. The hatchery summer steelhead run timing is based on the run counts at Willamette Falls for the adult returns for the 2014 spawning year (return date from 1 November 2013 to 31 October 2014). Figure taken from Weigel et al. (2019).

Table 23. Abundance estimates of winter steelhead in tributaries of the UWR in 2014. Table taken from Jepson et al. (2015).

Tributary	*n*	% (95% ci)	Winter Steelhead Counted: From 15 Feb. n = 4,510 Estimate	Winter Steelhead Counted: From 1 Nov. n = 5,349 Estimate
None	34	16.0 (11.7 – 21.6)	723 (528 - 973)	858 (626 – 1,154)
Clackamas	11	5.2 (2.9 – 9.0)	234(132 - 408)	278 (156 - 484)
Tualatin	3	1.4 (0.5 – 4.1)	64 (22 - 184)	76 (26 - 218)
Molalla	30	14.2 (10.1 – 19.5)	638 (455 - 879)	757 (540 – 1,042)
Yamhill	7	3.3 (1.6 – 6.7)	149 (73 - 300)	177 (86 - 356)
Rickreall Cr.	1	0.5 (0.1 – 2.6)	21 (4 - 118)	25 (4 - 140)
N. Santiam	45	21.2 (16.3 – 27.2)	957 (733 – 1,228)	1,135 (870 – 1,456)
S. Santiam	51	24.1 (18.8 – 30.2)	1,085 (848 – 1,364)	1,287 (1,006 – 1,618)
Santiam R. (lower)	1	0.5 (-.1 – 2.6)	21 (4 - 118)	25 (4 - 140)
Calapooia	5	2.4 (1.0 – 5.4)	106 (46 - 244)	126 (54 - 289)
McKenzie	3	1.4 (0.5 – 4.1)	64 (22 - 184)	76 (26 - 218)
Coast Fork	1	0.5 (0.1 – 2.6)	21 (4 - 118)	25 (4 - 140)
Fall Creek	2	0.9 (0.3 – 4.4)	43 (12 - 152)	50 (14 - 180)
Middle Fork	18	8.5 (5.4 – 13.0)	383 (245 - 587)	454 (291 - 696)

Jepson et al. (2015) reported winter steelhead that returned to the Yamhill, Tualatin, and Molalla rivers tended to pass Willamette Falls a bit earlier overall (mean tag dates in early March) than winter steelhead from upriver populations (e.g. McKenzie and Middle Fork). The time of entry into the rivers where the steelhead would spawn was related to migration distance from Willamette Falls. There was no apparent differences between westside and eastside rivers at similar latitudes. Besides the data on winter steelhead migration from radio-tagging, winter steelhead are also observed at three other counting stations: Bennett dams, Minto Dam, and Foster Dam. The Bennett dams (upper and lower) on the lower North Santiam River show winter steelhead migrating upstream primarily from late February through late March (Figure 48). Collections of winter steelhead at Minto and Foster dams are later, reflecting the time it takes for winter steelhead to continue migrating upstream in these rivers.

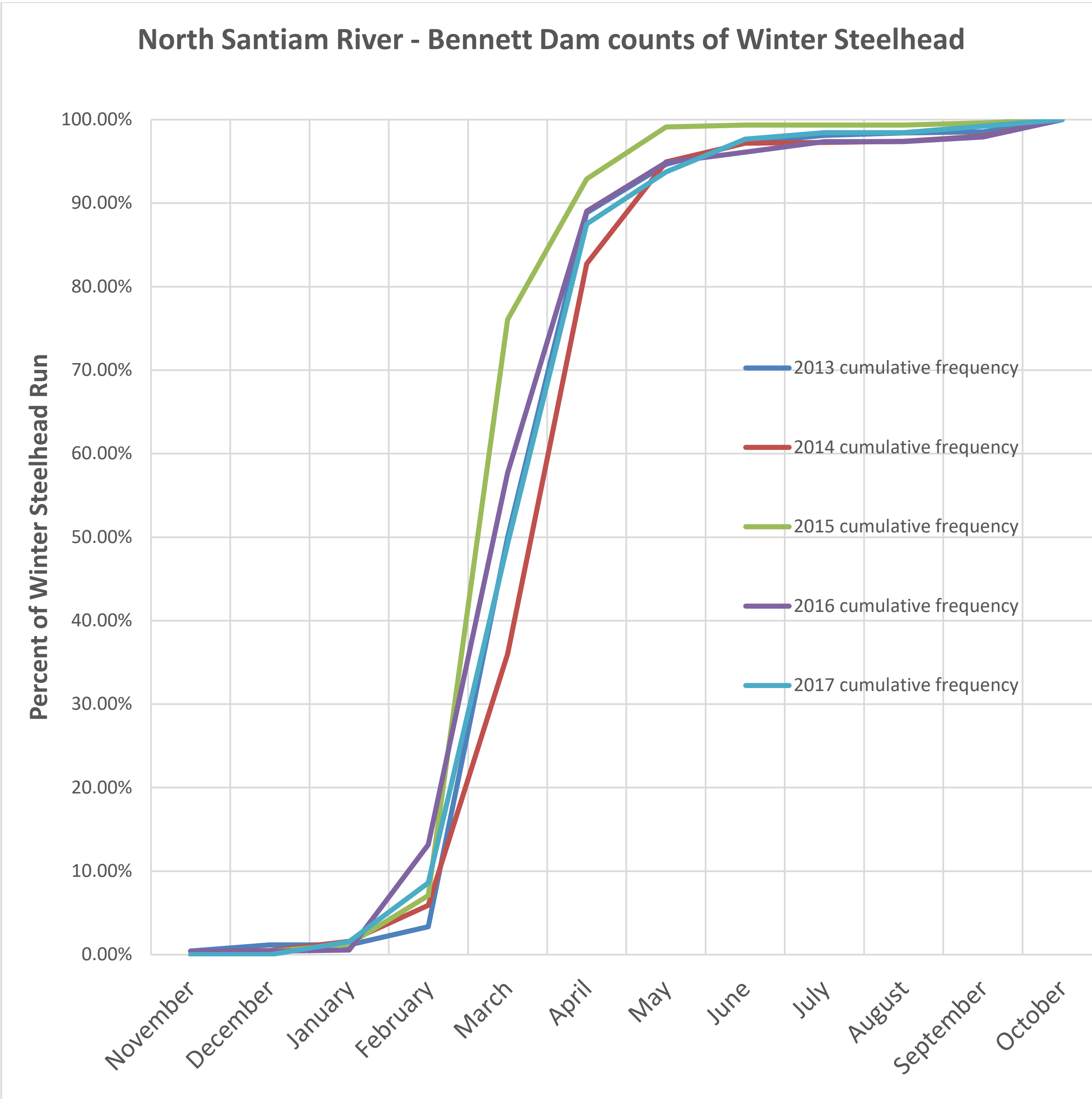


Figure 48. Run timing of winter steelhead observed at Bennett dams, North Santiam River 2013-2017.

Once winter steelhead migrated to the area where they are going to spawn, data suggests spawning occurred over a short period of time, as kelting behavior (moving back downstream after spawning) has been observed within weeks upon entering the tributary areas (Table 24). Since the migration timing of winter steelhead entering the North Santiam, South Santiam, and Calapooia rivers is later than other populations lower in the UWR (i.e. Clackamas, spawn timing for these populations is also later. Jepson et al. (2015) showed mean spawn timing in the North Santiam, South Santiam, and Calapooia to occur principally in April (Table 24). Mapes et al. (2017) observed the peak of winter steelhead spawning in the South Santiam River in April through May (Figure 49). Data related to the historic hatchery winter steelhead program in the North Santiam River that was terminated in 1997, is also available showing the spawn timing of winter steelhead broodstock in the 1990's (Figure 50). The hatchery winter steelhead broodstock was spawned principally from mid-April through early-May. All of this information suggests the spawn timing of winter steelhead to be principally in April through May in the North Santiam and South Santiam rivers.

Table 24. Mean entry dates, exit dates, and residence times of winter steelhead in 2014. Data taken from Table 9 of Jepson et al. (2015).

Tributary	Mean entry date	Mean exit date	Mean Residence time (+/- one standard deviation)
Tualatin	March 13th	April 19th	37 days (20)
Molalla	March 27th	April 27th	31 days (19)
Yamhill	April 1st	April 17th	16 days (5)
North Santiam	April 1st	April 30th	26 days (26)
South Santiam	March 29th	April 28th	30 days (31)
Santiam (lower)	April 20th	April 27th	7 days (NA)
Calapooia	March 28th	April 16th	19 days (8)

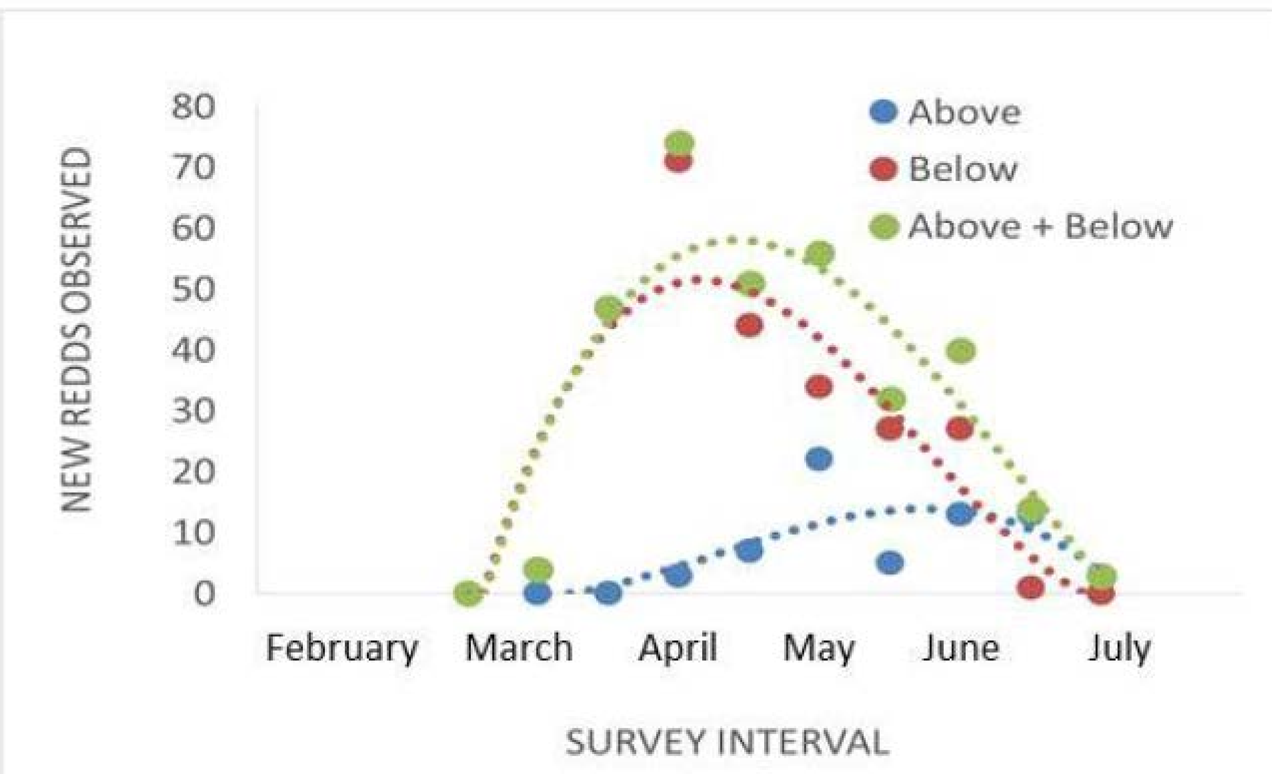


Figure 49. Winter steelhead redds observed by survey interval in the South Santiam subbasin above and below Foster Dam, 2015-2016. Figure taken from Mapes et al. (2017).

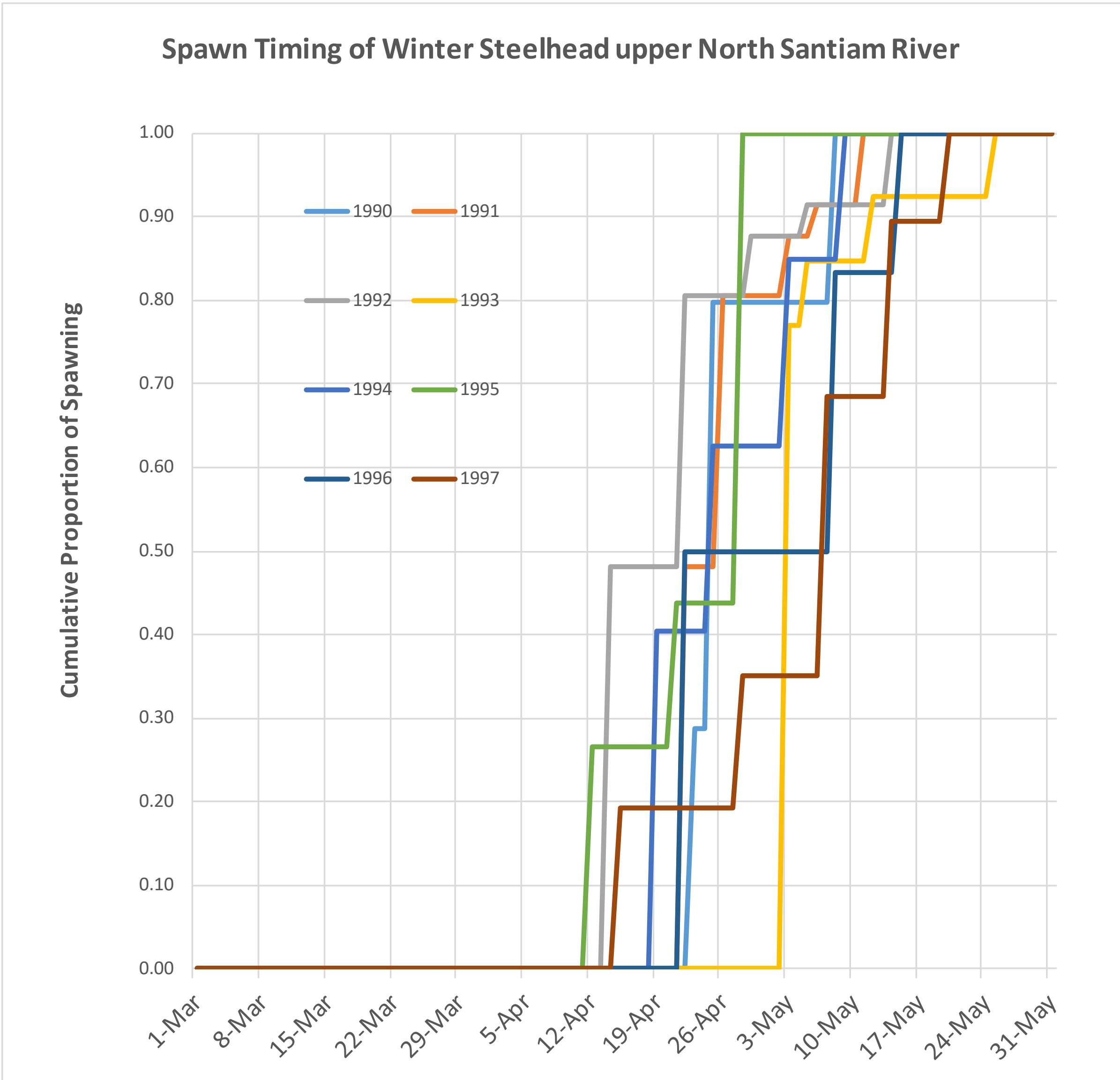


Figure 50. Spawn timing of hatchery winter steelhead broodstock at Minto dam, North Santiam River, 1990-1997, before the hatchery winter steelhead program was terminated. Data from G. Grenbemer, ODFW, April, 2018.

For hatchery summer steelhead returning to the UWR, the migration pattern and spawn timing are completely different than winter steelhead. Hatchery summer steelhead are observed migrating upstream at Willamette Falls principally from early May through early July (Jepson et al. 2015). Hatchery summer steelhead have been observed homing back to the river where they were released as smolts (Figure 51). From 2012-2104, not a single hatchery summer steelhead was observed entering any of the westside tributaries to the Willamette River (i.e. Tualatin, Yamhill, Luckiamute rivers, or Rickreal Creek). One radio-tagged hatchery summer steelhead did enter the Molalla River in 2014, which was less than 1% of the estimated summer steelhead return (Jepson et al. 2015).

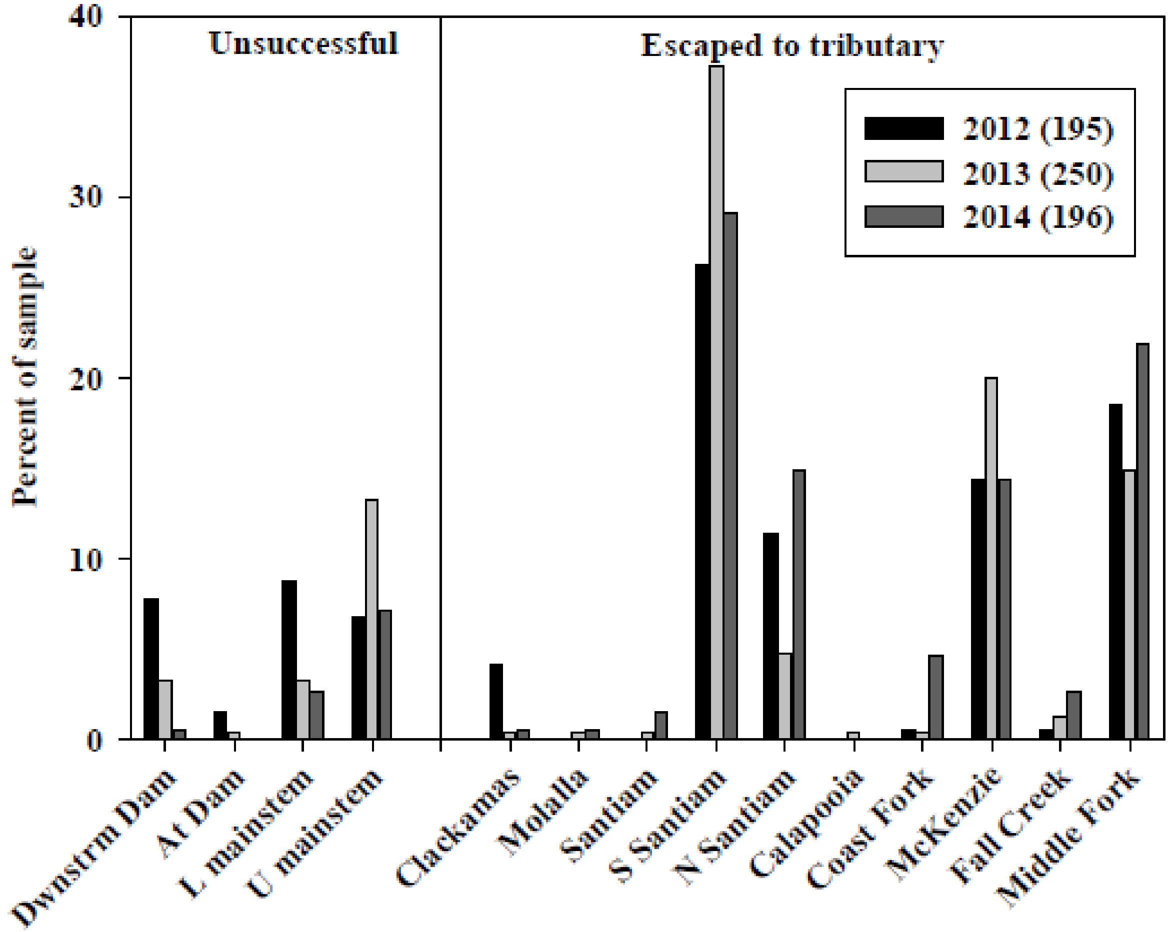


Figure 51. Percent of hatchery summer steelhead observed throughout the UWR based upon radio telemetry study (Jepsen et al. 2015). The majority of hatchery summer steelhead return to the point where they were released as juveniles (i.e. North Santiam, South Santiam, McKenzie, and MF Willamette). "Unsuccessful" category means summer steelhead died before entering the tributaries of the mainstem Willamette River.

Once hatchery summer steelhead enter the tributaries of the mainstem Willamette River, they reside there throughout the entire summer. Most of the hatchery steelhead migrate upstream to the upper most extent of volitional migration and are collected at Minto and Foster dams where they were released as smolts. During this migration, a proportion of hatchery fish are harvested in sport fisheries. The remaining proportion of hatchery summer steelhead that are not harvested nor collected at dam collection facilities continue to reside in the river until fall and early winter to spawn. Jepson et al. (2015) reported behaviors from a few of these hatchery summer steelhead that were not harvested or collected and observed their natural behaviors through the summer, spawning, and kelting period (post-spawn). Table 25 shows the results from six hatchery summer steelhead that returned to the North Santiam or South Santiam rivers and were observed at radio telemetry sites during the winter period suggesting these hatchery steelhead survived through spawning. These hatchery summer steelhead migrated up the Santiam River in May and June and then were subsequently detected in the mainstem Santiam River the following year in January and March. Overall, the proportion of hatchery summer steelhead that observed kelting behavior (indicating the fish probably survived and spawned naturally in the wild) ranged from 2.5% to 1.5% in 2012 and 2013, respectively. In comparison, ESA-listed winter steelhead (which are not removed at any location and suppose to spawn in the wild), kelting behavior was observed in 58% to 62% of the tagged steelhead (Jepsen et al. 2015).

Table 25. Hatchery summer steelhead exhibiting kelting behavior (post-spawning) in the North Santiam and South Santiam from the radio tagging studies conducted by Jepson et al. (2015). Data taken from Table 14 of Jepson et al. 2015.

Holding and Spawning		**Post-spawn (kelts)**	
Tributary entry date	**Spawning tributary**	**Exit date**	**Exit Location Where Observed**
5/14/2012	Little North Santiam	3/28/2013	Santiam River- mainstem
5/23/2012	North Santiam	3/1/2013	Santiam River- mainstem
5/15/2012	South Santiam	3/20/2013	Santiam River- mainstem
6/12/2012	North Santiam	3/21/2013	Santiam River - mainstem
5/13/2012	South Santiam	1/25/2013	South Santiam River- lower
5/30/2013	North Santiam	1/15/2014	Santiam River - mainstem

Additional information on the spawn timing of hatchery summer steelhead is available from spawning ground surveys for summer steelhead in the UWR. These surveys are difficult to conduct because they have to occur during the winter when streamflows are high and the water is turbid making it difficult to observe spawning steelhead. Therefore, these surveys were conducted periodically. In 2003-2005, Schroeder et al. (2006) observed peak spawning of summer steelhead throughout all populationss in the UWR in January through February (Figure 52). More recently in 2017, Mapes et al. (2017) observed summer steelhead spawning in the South Santiam River from late December through January (Figure 53).

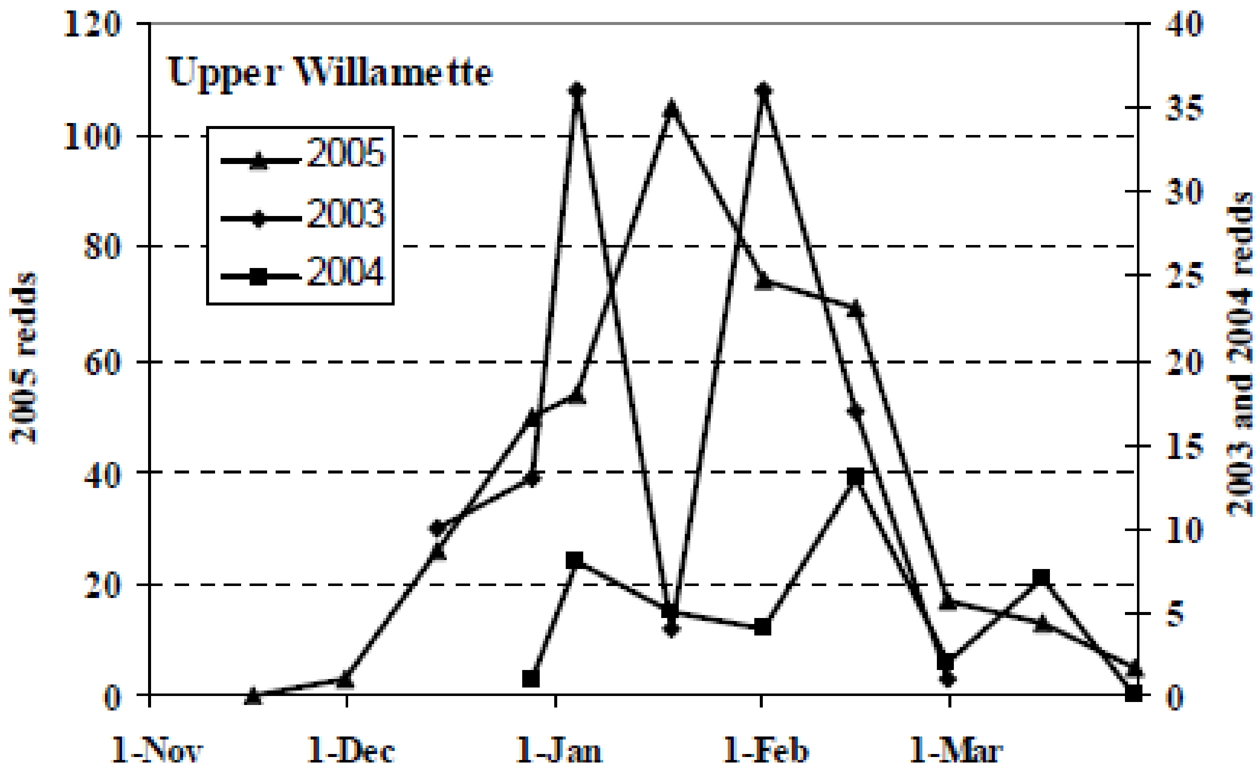


Figure 52. Spawn timing of summer steelhead, 2003-2005. Figure taken from Schroeder et al. (2006).

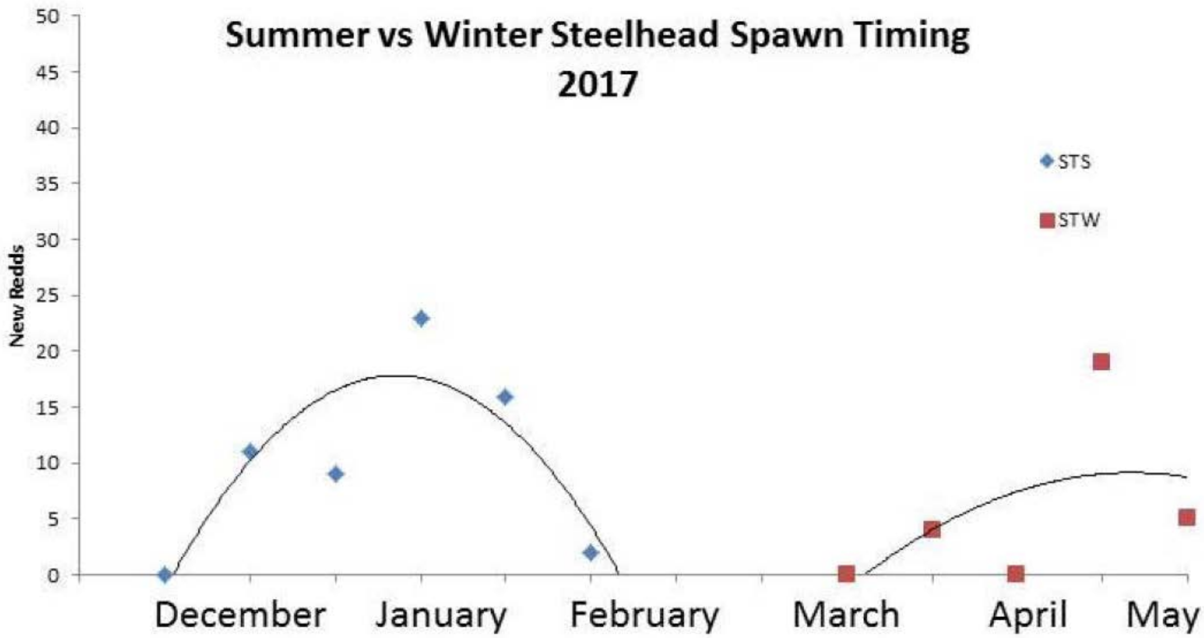


Figure 53. Spawn timing of summer steelhead and winter steelhead in the South Santiam River, 2016-2017. Figure taken from Mapes et al. (2017).

Additional spawn timing data is available from South Santiam hatchery where returning summer steelhead are spawned as broodstock for the release program. Since spawn timing is a heritable trait in steelhead (Abadia-Cardoso et al. 2013), this data provides relevant information on the spawn timing for hatchery summer steelhead in the wild. Figure 54 shows the hatchery broodstock spawn timing at South Santiam hatchery for the summer steelhead program over the last 12 brood cycles. Broodstock are spawned in December and January, and thus returning offspring would be expected to exhibit similar spawn timing. Over the last generation, a management change has occurred to shift the spawn timing of hatchery summer steelhead even earlier in order to further separate the spawn timing of summer steelhead from winter steelhead. This management change appears to have been effective, with the majority of summer steelhead now exhibiting a December spawn timing. Over the last six cycles (2013-2018), an average of 66% of the broodstock was spawned in December, compared to 31% for years 2006-2012 (Figure 55). The shift to a higher percentage of summer steelhead spawning in December versus January will reduce the probability of overlap between summer and winter steelhead (Figure 44). Beginning in 2016 returning summer-run spawn timing should begin to reflect this significant hatchery management change to earlier spawn timing. The proposed action will continue to advance the spawn timing of this hatchery program in order to further separate timing with ESA-listed winter steelhead.

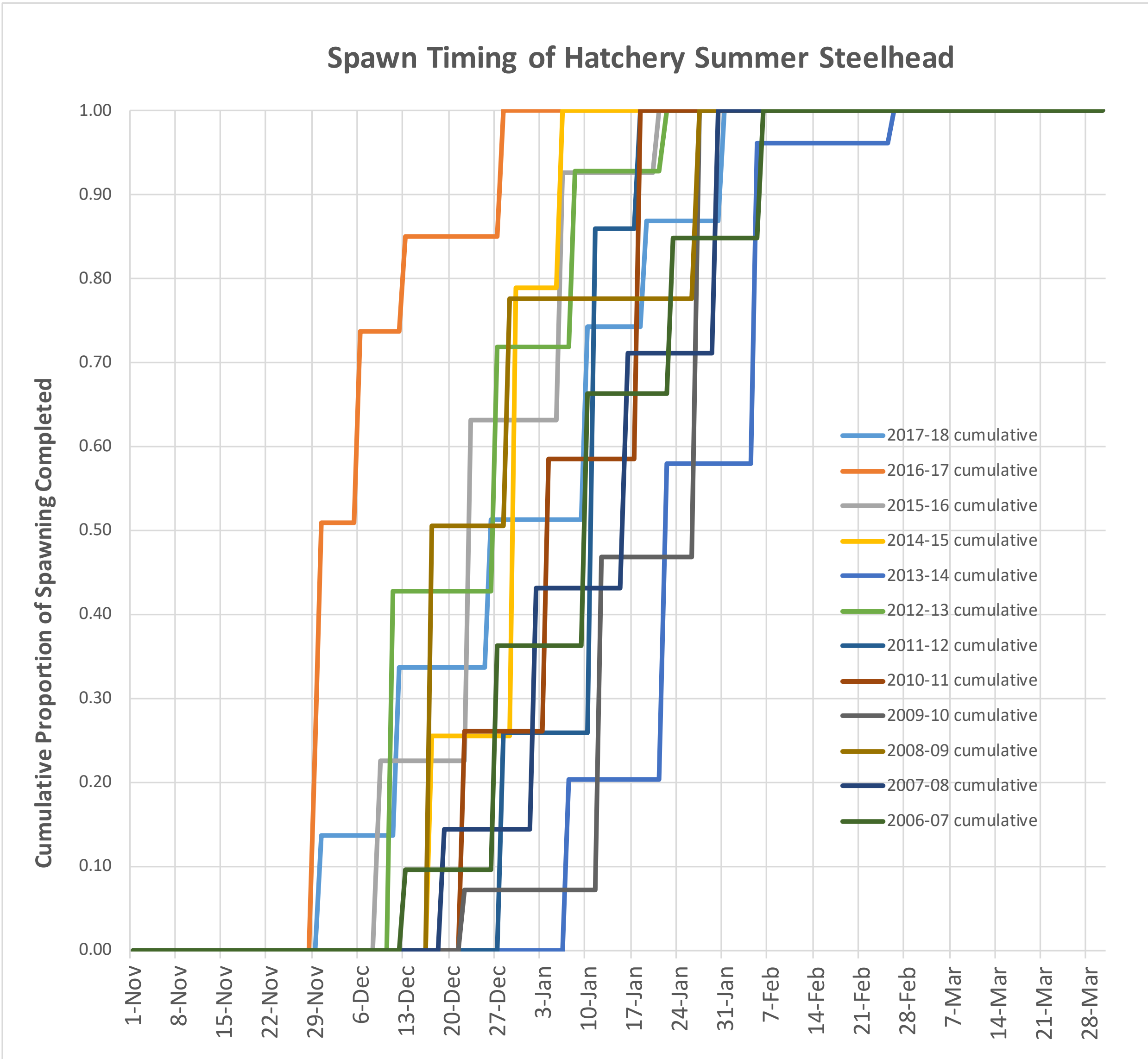


Figure 54. Spawn timing of hatchery summer steelhead broodstock at South Santiam hatchery, 2006-2018. Data from B. Boyd, ODFW, April 2018.

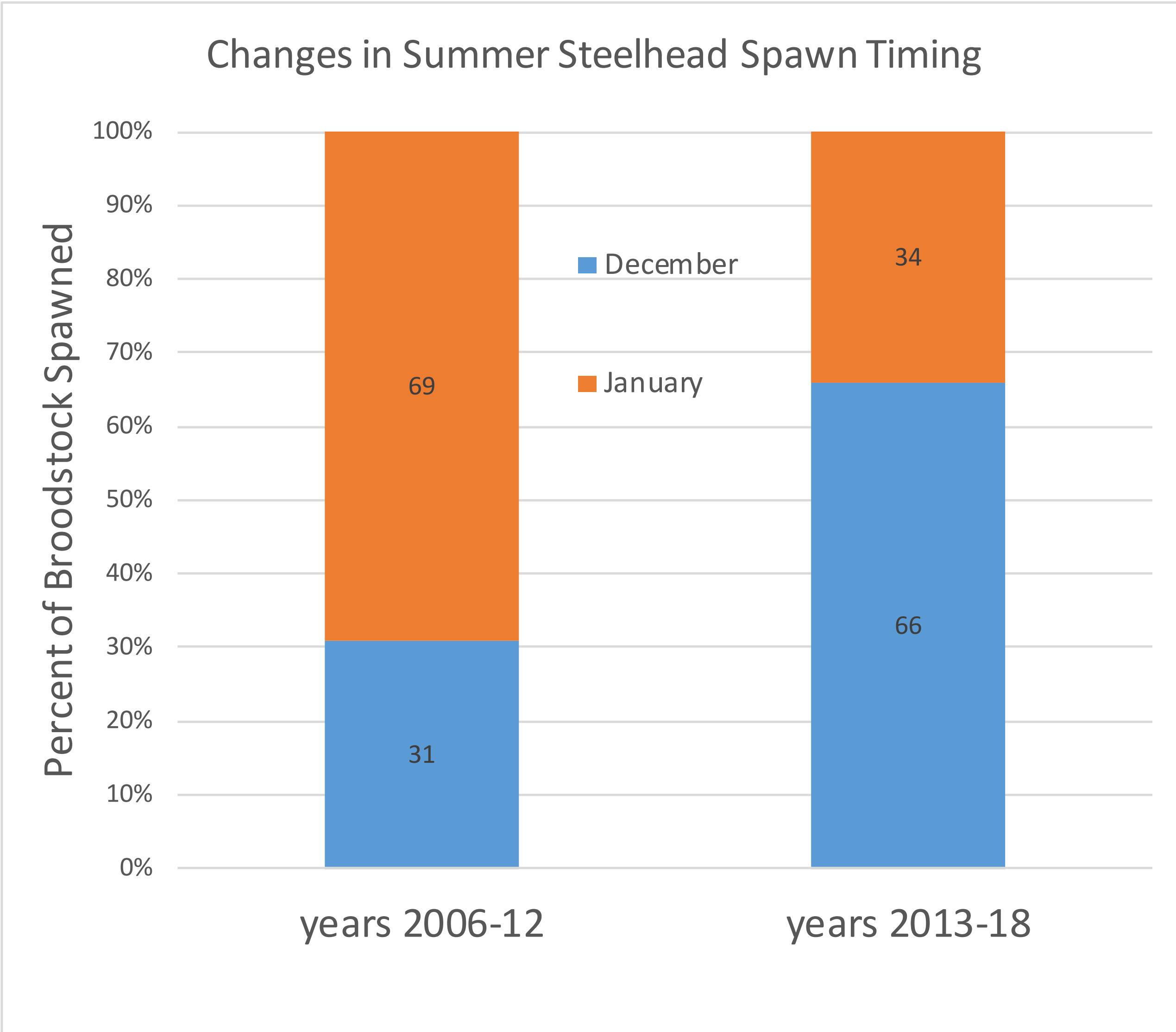


Figure 55. Percent of summer steelhead broodstock spawned by month at South Santiam hatchery over two time periods, 2006-2012 and 2013-2018. Years refer to the beginning of spawn season in December. Data from ODFW.

Jepson et al. (2015) compiled the results of their radio tagging studies to compare the potential overlap in time between the presence of summer steelhead and winter steelhead in the UWR. Figure 56 shows data on the timing of summer steelhead kelts overlapping with winter steelhead upstream migrants. It is important to note the data does not represent actual spawn timing but the date when these fish were detected passing receivers. Thus, these overlap periods represent the widest range of overlap between the runs, using limited numbers of summer steelhead observed. Given this data, it is possible for a hatchery summer steelhead male to spawn and then reside in the wild until winter steelhead females begin spawning and potentially interbreed. Only males would have this potential because female summer steelhead would be completely spawned out and not available for interbreeding between later arriving male winter steelhead. Even though the potential for hatchery males to spawn with female winter steelhead exists, the likelihood of this appears to be low given the kelting behavior observed by summer steelhead exiting the population areas (Table 25), while winter steelhead are migrating upstream to spawn (Figure 48).

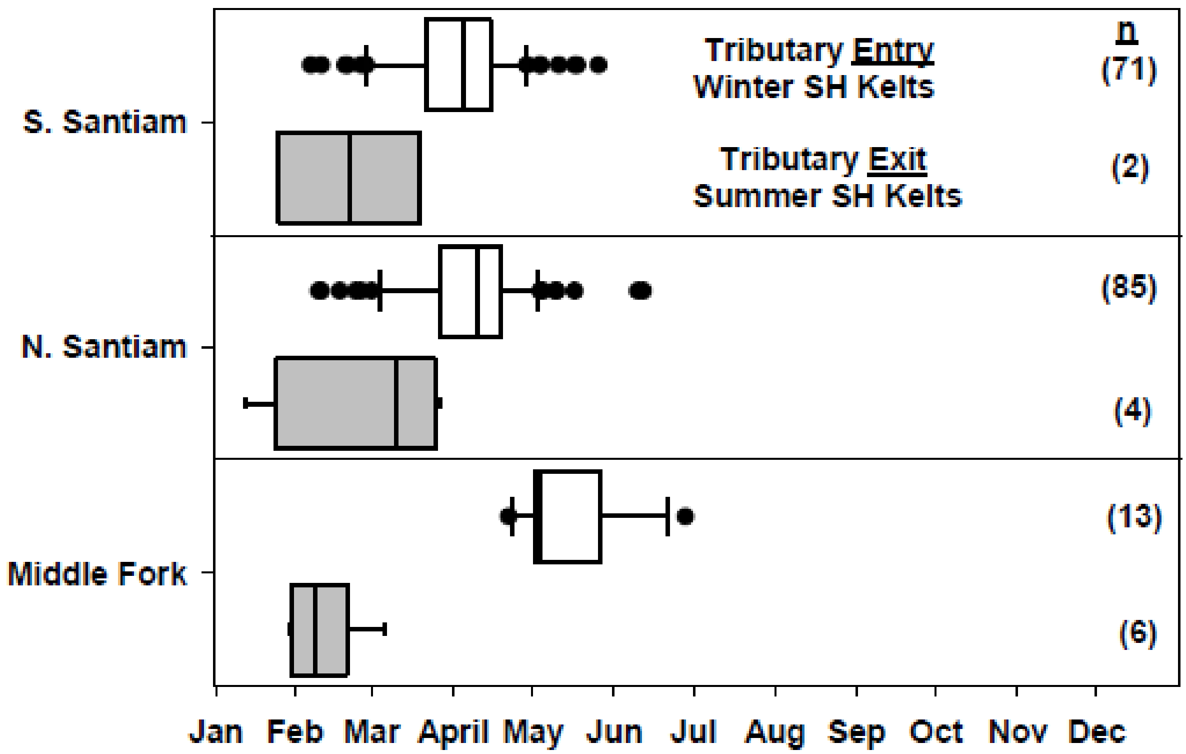


Figure 56. Potential temporal spawning overlap between summer and winter steelhead. For summer steelhead, the dates are the last recordings for kelts (post-spawn) and only these fish are shown. For winter steelhead, the dates are when the winter run entered tributaries (pre-spawn). Figure taken from Jepson et al. (2015).

The proportion of hatchery summer steelhead spawning in the wild (pHOS) is also useful information for evaluating the effect of the hatchery program on ESA-listed winter steelhead. If pHOS is high, then the risk of summer steelhead spawning with winter steelhead is greater in the overlap period when both runs may spawn together. Even though the above data shows the overlap period to be minimal, if a lot of summer steelhead are present in the wild and have the chance to spawn naturally, the risk of spawning with winter steelhead present even in low numbers is higher than if few summer steelhead are available to spawn in the wild during the overlap period. The available information on pHOS of summer steelhead is poor due to the difficulty in conducting spawning surveys for steelhead during the period when summer steelhead spawn in December and January when higher flows and turbidity make it difficult to accurately observe and enumerate spawning redds. Because of this, spawning ground surveys for steelhead are not conducted regularly. The spawning surveys conducted in 2003-2005 represent the most comprehensive surveys done during the summer steelhead spawning period (Schroeder et al. 2006). These surveys showed pHOS in December and January to be greatest in the areas where hatchery summer steelhead are released, as expected. The estimates for these years range from 2% to 14% of the steelhead observed on the spawning grounds being likely hatchery spawners (Table 26). The years when these spawning surveys were conducted were high abundances of summer steelhead due to high survival and this likely contributed to higher pHOS than observed recently in the last few years when summer steelhead returns were extremely low and pHOS was essentially zero because all returns were accounted for from collection at hatcheries and sport harvest. If returns of hatchery summer steelhead remain low, as in the last few years, it is expected pHOS will be less than 5%.

Table 26. Proportions of fin-clipped and non-fin-clipped steelhead observed in spawning ground surveys, 2003-2005. Table taken from Schroeder et al. (2006).

Area	Fin-clipped	Non fin-clipped	Percent fin-clipped	Unknown	Percent known
Mid Willamette					
Molalla	0	52	0	44	54
N. Santiam	19	117	14	196	41
S. Santiam	2	113	2	59	66
Total	21	282	7	299	50

Another proxy for summer steelhead pHOS is calculated from knowing the total count of hatchery summer steelhead migrating past Willamette Falls and then applying survival estimates, harvest estimates, and known collections of hatchery steelhead at hatcheries to derive an estimate of the number of summer steelhead that cannot be accounted for, and thus may be left in the rivers and able to spawn naturally. NMFS has analyzed this, applying a range of estimates for survival and harvest, and there is a considerable amount of uncertainty and potential error associated with these estimates. For example, extensive research has been conducted on Chinook salmon prespawning mortality in the same habitats where summer steelhead co-occur. Prespawning mortality may be low or high depending upon the year, water conditions, and specific river reach. Similarly, this greatly influences the estimates of pHOS for summer steelhead. Also, sport harvest of hatchery steelhead varies annually. If harvest is high, fewer hatchery fish remain in the wild and spawn; whereas if harvest is lower, then the potential for higher pHOS exists if fish are not collected at the hatcheries. Summer steelhead were also recycled back through the fishery after being captured at collection facilities (up to the dates specified in NMFS (2008)) and that contributed to summer steelhead being left in the river and possibly spawning in the wild. The proposed action suspends the recycling of hatchery summer steelhead in the North and South Santiam rivers until further information is obtained on the risks to winter steelhead. This will greatly reduce the number of summer steelhead left in the river and potentially spawn in the wild. Collection of summer steelhead at the newly rebuilt Minto fish collection facility is very high (~90%) and few fish are left in the river with no recycling.

There is also a strong positive correlation between run size and unaccounted for hatchery steelhead (proxy for pHOS). As stated above, a variety of factors influence this relationship; pre-spawning mortality is also related to the density of salmon holding in the river (Bowerman et al. 2018). Conversely, in years when the abundance of hatchery summer steelhead is very low (2017), nearly all of the hatchery steelhead can be accounted for under reasonable assumptions, and pHOS is clearly low (0 to 10%) under these circumstances. In conclusion, there is a lot of uncertainty in the estimates of pHOS; but it remains useful information for evaluating the effect of the hatchery program on ESA-listed winter steelhead. The genetic effects analysis below assesses the potential effects of pHOS in greater detail.

Current Genetic Effects of Summer Steelhead in the UWR

As explained in Section 2.5.1, evaluation of outbreeding effects is very difficult. In situations where there is no selection nor genetic drift, the best existing management guidance for avoiding outbreeding effects remains the conclusion of the 1995 straying workshop (Grant 1997) that gene flow among populations (measured as immigration rates) should be limited to less than 5%. The HSRG (2009) generally recommended that for primary populations (those of high conservation value like the North and South Santiam populations) affected by isolated hatchery programs, that the proportion of natural spawners consisting of hatchery-origin fish (pHOS) not exceed 5%, and more recently (HSRG 2014) has suggested that perhaps this level should be reduced further. While not addressing them specifically in their guidelines, the HSRG earlier discussed risks posed by highly diverged hatchery populations such as the hatchery summer steelhead, concluding that "…if non-harvested fish spawn naturally, then these isolated programs can impose significant genetic risks to naturally spawning populations." Indeed, any natural spawning by fish from these non-native steelhead may be considered unacceptable because of the potential genetic impacts on natural populations (HSRG 2004, Appendix B).

A distinction needs to be made between pHOS and gene flow, because the two can easily be confused. Genetic impacts from hatchery programs are caused by gene flow (introgression) from hatchery fish into the naturally spawning population. By contrast, pHOS represents the census count of hatchery-origin spawners divided by the total number of spawners throughout the entire period of spawning for summer and winter steelhead, but pHOS makes no assumptions regarding the relative reproductive success of hatchery-origin fish. Thus, if hatchery-origin fish are equivalent to natural-origin fish in reproductive success, pHOS represents the maximum proportionate contribution of hatchery-origin parents to the next generation of natural-origin fish. In the absence of other information, pHOS is an estimate of maximum gene flow on the spawning grounds, and thus is a surrogate for gene flow. However, there are a variety of factors for the hatchery summer steelhead program which would make the pHOS surrogate for gene flow an overestimation of gene flow.

As discussed above, hatchery summer steelhead in the UWR spawn from late November to February; much earlier than the majority of ESA-listed winter steelhead (see previous section; Jepson et al. 2015). The environmental conditions in the UWR for summer steelhead spawning are sub-optimal (e.g. subject to high winter flows). In contrast, ESA-listed winter steelhead are adapted to spawn later in the season under more favorable environmental conditions. Therefore, there is not complete overlap in spawning between the two runs, but only a discrete period of overlap that is quantified below, so that even when pHOS seems high, it does not translate into significant numbers of hatchery summer steelhead mating with natural-origin winter steelhead. In addition, hatchery steelhead undergo domestication selection in a hatchery environment rather quickly and become dramatically less fit to spawn in the wild over the course of just one generation (3-5 years; Araki et al. 2007). Skamania stock summer steelhead have been propagated in the UWR for almost five decades, and as a result may have undergone substantial domestication. The fitness of this hatchery stock spawning in the wild has been shown to be extremely poor (RSS = 0.17; HSRG 2014). Therefore, even if hatchery steelhead do attempt to spawn in the wild in a time when natural-origin fish are present, the likelihood of these fish producing offspring is low. Taken together, these factors help explain why an elevated pHOS may not translate into high rates of genetic introgression.

In discussing gene flow from hatchery programs, it is important to distinguish the Skamania Hatchery summer steelhead program from most other hatchery programs. Although some divergence from natural life history traits can be expected over time in hatchery programs, the Skamania stock represents a situation in which the fish have been subjected to intensive artificial selection over many years for a life history divergent from naturally produced populations. The prospect of gene flow from such highly domesticated stocks seems intuitively risky, as is reflected in the cautionary statement by the HSRG (2014). Studies have only recently begun to compare the impact of highly domesticated stocks hybridizing with natural populations, such as those considered in this opinion, with those that are less domesticated. A modeling effort by Baskett and Waples (2013) demonstrated that the introgression effects of hatchery programs using broodstocks genetically different from the natural population could be quite different than those from genetically similar programs, and depending on the circumstances, could pose more or less risk. The key element in determining risk level is an understanding of the impact of potential gene flow on fitness.

The proposed action includes a standard of less than 2% gene flow from summer steelhead into any winter steelhead population in the DPS. The broodstock spawn timing is also proposed to be advanced even further than in recent years; with all of the broodstock spawned by the first of January for the 2018-2019 summer steelhead brood year. As progeny from these earlier spawnings return, it is expected the separation of spawn timing between summer and winter steelhead will be even greater.

In attempting to understand the risks posed by hatchery summer steelhead spawning in the wild, three distinctive characteristics of this phenomenon must be considered: 1) whether hatchery-origin fish are known to have low reproductive success in the wild relative to natural-origin fish; 2) whether hatchery-origin fish comprise a small portion of the spawning population; and 3) whether a level of temporal and spatial isolation exists between hatchery-origin and natural-origin spawners, resulting in hatchery-origin and natural-origin fish mating among themselves at higher levels than expected under random mating. We know of no empirical information that is applicable to the fitness consequences of natural spawning of hatchery summer steelhead in this situation. Similarly, we also know of no modelling that adequately simulates the phenomenon of summer steelhead spawning in the wild, although elements of existing models, such as those of Ford (2002) and Baskett and Waples (2013) would be useful in modeling this situation. Therefore, we decided to apply gene flow models used by NMFS to evaluate hatchery steelhead effects in Puget Sound (NMFS 2016) for the UWR where data is available.

Estimate of Demographic Loss of Winter Steelhead

A concern that has often been raised in connection with these isolated steelhead hatchery programs is that, due to the low expected reproductive success of hatchery summer steelhead (Skamania stock) spawning in the wild, the reproductive potential of natural-origin fish that spawn with hatchery-origin fish (hybridize) would be reduced or wasted. Reductions in the reproductive output of natural-origin winter steelhead thus reduces the size of the spawning population, and therefore the genetically effective size of the winter-run population. Figure 44 shows the spawn timing distribution of hatchery-origin summer steelhead and natural-origin winter steelhead based upon known run and spawn timings of steelhead described in the previous section. Due to the earlier spawn timing of hatchery summer steelhead, summer steelhead predominately spawn with each other. However, there is the potential for latest spawning summer-run to spawn with the earliest spawning winter-run when they co-occur in space and time (labeled as “region of overlap” in Figure 44). Apart from this brief overlap, winter steelhead are not at risk of genetic interactions with summer steelhead

Assuming random mating[14], the expected proportion of different mating types can easily be determined. In this case, since the only matings that are of interest are those that occur in the overlap region where both runs spawn together (Figure 44), and of those, only the matings in which hatchery summer steelhead mate with winter steelhead are of interest. The expected proportion of summer steelhead actually mating with winter steelhead is given by Equation 1 (NMFS 2016):

$$\frac{\mathrm{pHOS} * \mathrm{O_N} * \mathrm{O_H}}{\mathrm{pHOS} * \mathrm{O_H} + (1 - \mathrm{pHOS}) * \mathrm{O_N}}$$

where pHOS is the proportion of natural spawners (throughout the entire spawning of both summer and winter steelhead) that are of hatchery origin. The pHOS estimate is then multiplied by the proportions of summer and winter steelhead that actually spawn together in the overlap zone (Figure 44). O_N represents the proportion of winter steelhead and O_H is the proportion of summer steelhead in the overlap zone. Based on the information presented in the previous section on the life history, run timing, and spawning timing of hatchery summer steelhead and ESA-listed winter steelhead, the proportion of the winter steelhead spawners involved in HxN[15] matings can be calculated.

The expected proportion of winter steelhead matings with hatchery summer steelhead ranges from 0 to 1.15% depending upon the population area throughout the DPS (

[14] Random mating is assumed in a number of basic population genetic models for mathematical simplicity. The models in this section are based on simple population genetic models, and use the random mating assumption for the same reason. Mating dynamics of steelhead and salmon is complex and in fact non-random (Seamons et al. 2004), but attempting to include all the deviations from random mating would be a major modelling exercise in itself. We assume that the results of our modeling are robust to the typical deviations from random mating found in nature. This is, therefore, a more conservative assumption than what is likely to occur.

[15] The HxN notation is meant to include matings in which a hatchery-origin male mates with a natural-origin female, and vice versa.

Table 27). For the North Santiam and South Santiam populations, a range of pHOS estimates (10-30%) were used in these calculations (Table 27). Our estimates are based upon recent spawn timing data for hatchery summer steelhead spawned for the program at South Santiam hatchery, which shows 39% of summer steelhead are spawned in January. This estimate of O_H is the best representation of the spawn timing of summer steelhead currently returning to the UWR, since there have been management actions to shift the summer steelhead broodstock to an earlier spawn timing (see Figure 55). Determining the O_N for winter steelhead is more difficult because this metric is the spawn timing of winter steelhead. The best available indicator for winter steelhead in the actual spawning areas comes from the radio tagging results of Jepson et al. (2015) described in the previous section, regarding Bennett Dam counts of winter steelhead passing in the lower North Santiam River, and counts at Minto and Foster dams. There are no other equivalent counting facilities in the Calapooia and Molalla rivers. The most thorough dataset comes from Bennett Dam counts where the entire winter steelhead run for multiple years has been monitored. For Bennett Dams, the percentage of the run of winter steelhead passing the dam from November through January is calculated as 1.23% (average). Based upon radio telemetry, these fish are likely to spawn from one to three weeks afterwards, so this represents a conservative estimate of spawn timing for O_N.

Since upper river populations (North Santiam, South Santiam, and Calapooia winter steelhead) are known to have later run timing when entering the tributaries than lower river populations (Jepson et al. 2015), a higher percentage of the run was expected to enter into these populations by the end of January. For the lower river populations (Molalla, Tualatin, Yamhill, Luckiamute) with known earlier returning winter steelhead, it was assumed O_N for these population areas would be 5% of the run spawning by the end of January (Table 27).

Sensitivity analyses were performed on the estimates of O_H and O_N and effects on demographic mortality loss estimates (Figure 58; Figure 59). Values of O_H had little effect on the final estimates of mortality. The value of O_N is more sensitive and influenced the mortality estimates to a greater degree than $O_{H.}$ However, the sensitivity was when O_N was in the range of 5% to 30% (winter steelhead overlap with summer steelhead), which is much higher than any estimated range for the North Santiam or South Santiam. Further details on the sensitivity of estimates can be found below in the analysis using the Scott-Gill gene flow model.

After calculating the percentage of summer steelhead by winter steelhead matings in the overlap zone, analyses can be performed on the effect of these matings on ESA-listed winter steelhead productivity in the UWR DPS. If it is assumed the reproductive output of a winter steelhead mating with a hatchery summer steelhead is a complete loss (zero fitness), the impact to the populations in the North Santiam and South Santiam rivers in terms of demographic and effective population size loss would be less than 1.15% (

Table 27; an alternative assumption, where these matings produce viable offspring, is analyzed in the next section below). In the other population areas within the DPS (i.e. Calapooia, Molalla, westside tributaries), the loss is expected to be zero. In the North and South Santiam rivers, this loss would be expected to occur repeatedly, but the effects would not be cumulative. In this respect, the demographic impact would be the same as a loss due to fishery harvest or an adverse ecological interaction. In previous population viability analyses, mortality rates in the range of 0 to 1.15% would not result in a measurable decrease in the viability of the DPS (NMFS 2001b; Falcy 2017). Under the assumption of all summer steelhead by winter steelhead crosses being non-viable (i.e. zero fitness by contributing no offspring), the demographic loss to the DPS would be very low and have no effect on the viability of the DPS (Falcy 2017).

Table 27. Expected proportion (expressed as %) of natural-origin winter steelhead escapement involved in matings with hatchery summer steelhead (HxN crosses) for winter steelhead populations affected by the proposed action. Data are based upon specific information for each population as described in this section.

	Tributary Populations in DPS						
Metric/Data	**Molalla**	**North Santiam**	**South Santiam**	**Calapooia**	**Tualatin**	**Yamhill**	**Luckiamute**
O_N (Nov-Jan)[1]	5%	1.23%	1.23%	1.23%	5%	5%	5%
O_H (Jan)	39%	39%	39%	39%	39%	39%	39%
Recent pHOS (Nov-May)	3%	10-30%	10-30%	0%	0%	0%	0%
Expected proportion of natural-origin fish mating with hatchery-origin fish	0.97%	0.96%-1.15%	0.96%-1.15%	0%	0%	0%	0%

[1] Winter steelhead return to the Molalla, Tualatin, Yamhill, and Luckiamute earlier than upriver populations (Jepson et al. 2015). Therefore, NMFS calculated O_N at 5% for these tributaries (no monitoring is available to quantify this precisely). Information for the North Santiam at Bennett Dam (1.23%) was used also for South Santiam and Calapooia because of similar run timing.

Even though a substantial amount of data has been used to derive the region of overlap in spawning of hatchery summer steelhead and winter steelhead, there is still considerable inter-annual variability. Averages were used for this analysis, and there is some variability in the data depending upon the year. In some years, summer steelhead have completed spawning before any winter steelhead have been observed in the tributaries where they spawn. . In other years, summer steelhead spawning is prolonged and the overlap region may be higher than reported in Table 27. However, overall we believe the averages reflect spawn timing over a range of environmental conditions and represent actual effects on the ground. With recent changes to broodstock management proposed in the HGMP, we expect the impacts to decrease. We present a simple evaluation of the effects of this uncertainty in Figure 57, which shows the proportion of natural-origin fish (winter steelhead) participating in HxN matings as a function of pHOS and overlap.

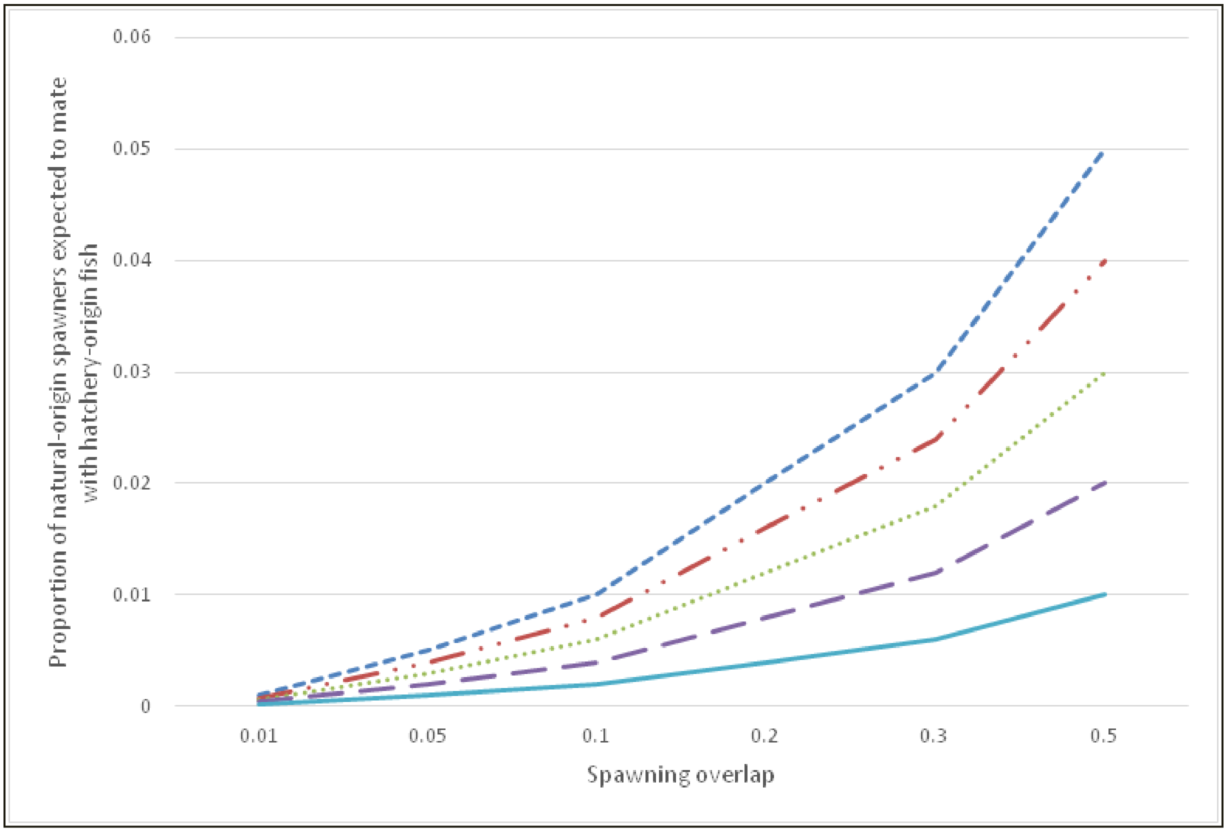


Figure 57. Proportion of natural-origin fish expected to be involved in HxN matings as a function of pHOS, and proportion of spawners in overlap zone. For simplicity we have assumed that the overlap is the same for natural-origin and hatchery-origin fish; e.g., for the 0.05 level, $O_N=O_H=0.05$. Isopleths represent pHOS=0.1 (small dashes), 0.08 (dots and dashes), 0.06 (dots), 0.04 (large dashes), and 0.02 (solid).

A potential limitation of this "overlap region" approach to determine demographic loss due to hatchery summer steelhead matings to the DPS is that it assumes that all the spawners are returning anadromous adults. Resident *O. mykiss* (rainbow trout) and precocious residual hatchery juveniles may also be involved, both of which would not have been counted as part of the escapement. McMillan et al. (2007) noted both types of males participating in mating in the later part of the spawning season in an Olympic Peninsula stream. Residual males accounted for less than 1% of the observed mating attempts, and were observed only late in the season. Measurable reproductive success of non-anadromous male *O. mykiss* was noted in another Olympic Peninsula stream that has no hatchery program (Seamons et al. 2004). In the UWR, the relative abundance of anadromous and non-anadromous *O. mykiss* is not well known in most streams, and residualism rates for hatchery summer steelhead is probably less than 10% (Harnish et al. 2014). A recent meta-analysis of steelhead programs throughout the Pacific Northwest found an average residualism rate of 5.6%, ranging from 0 to 17% (Hausch and Melnychuk 2012). Commonly, the largest fish are most likely to residualize and mature sexually while residing in freshwater. Although residualism per se may have ecological consequences, residual males are not a genetic concern unless they are sexually mature. Applying these residual rates, both the demographic and genetic influence of these fish would be low in the reaches where hatchery summer steelhead residualize (below the hatchery facilities in the North and South Santiam rivers). Winter steelhead may co-occur in these reaches, but it is not the primary rearing area for juvenile winter steelhead.

Estimates of Gene Flow From Summer Steelhead to Winter Steelhead

Accurately measuring gene flow presents a number of challenges. Firstly, gene flow from hatchery fish into natural populations is referred to in many NMFS documents and elsewhere as interbreeding or hybridization. This is an oversimplification as gene flow operates through two processes: hatchery-origin fish spawning with natural-origin fish and hatchery-origin fish spawning with each other. The reproductive success of hatchery fish determines the rate at which genes from the hatchery population are incorporated into the natural population. The importance of including the progeny of HxH matings as a potential "vector" for gene flow is supported by the finding that hatchery-origin fish (i.e., the progeny of HxH matings) may have a considerably longer and later spawning season than first generation hatchery-origin fish (Seamons et al. 2012). An appropriate metric for gene flow needs to measure the contributions of both types of mating to the natural population being analyzed. Another consideration is temporal scale. Although there may have been effects from gene flow from earlier more intensive and widespread hatchery activities, for the purposes of analyzing these proposed programs what must be considered is the current rate of gene flow, which is best represented as the proportion effective hatchery contribution (PEHC) of the current naturally produced progeny gene pool:

$$\text{Gene flow} = (2\mathrm{f(HH)} + \mathrm{f(NH)})/2 \, ,$$

Where *f(HH)* is the proportion of naturally produced progeny produced from HxH matings, and *f(NH)* the proportion of progeny produced by NxH[16] matings.

NMFS has estimated gene flow using either genetic data or demographic and life history data (NMFS 2016). In the UWR, genetic data is not available to estimate gene flow from summer steelhead to ESA-listed winter steelhead; however, sufficient information is available to calculate gene flow from the demographic information presented in this opinion. Scott and Gill (2008) developed a demographic model to calculate gene flow that has been used by NMFS to evaluate hatchery steelhead programs (NMFS 2016). We report the results of hatchery steelhead gene flow to ESA-listed winter steelhead using the Scott and Gill (2008) method (referred to Scott-Gill method).

It is important to understand that the Scott-Gill method estimates the current rate of gene flow and expected rate of gene flow, not cumulative gene flow. In other words, the effects analysis addresses how much gene flow is occurring or will occur, not how much may have occurred in the past, nor what the cumulative genetic contribution of hatchery summer steelhead to winter steelhead populations has been. Our analysis thus assumes that natural-origin fish may have some level of hatchery ancestry. In the case of the Scott-Gill method, the natural-origin fish considered in the equation may include the progeny of HxH or HxN matings.

The Scott-Gill method for estimating gene flow using demographic and life history data is based on the schematic diagram presented in Figure 21. The method assumes random mating within mating region, and uses estimates of the proportion of spawners that are of hatchery origin (pHOS[17]), the proportion of

[16] As in earlier usage in this document, this is meant to represent both matings between natural-origin females and hatchery-origin males, and vice versa/

[17] Symbolized by *q* in the equation in WDFW documents.

hatchery-origin and natural-origin spawners in region B, and the RRS of the HxH and NxH mating types to compute the proportion of the offspring gene pool produced by hatchery-origin fish.

Table 28. Demographic gene flow generated from the Scott-Gill method for UWR winter steelhead DPS.

Metric Data	Tributary Populations in DPS						
	Molalla	**North Santiam**	**South Santiam**	**Calapooia**	**Tualatin**	**Yamhill**	**Luckia-mute**
O_N	5%	1.23%	1.23%	1.23%	5%	5%	5%
O_H	39%	39%	39%	39%	39%	39%	39%
Recent pHOS (Nov-May)	3%	10-30%	10-30%	0%	0%	0%	0%
Expected proportion of natural-origin fish mating with hatchery-origin fish	0.97%	0.96%-1.15%	0.96%-1.15%	0%	0%	0%	0%
Demographic Gene Flow	0.8%	1.8%-5.7%	1.8%-5.7%	0%	0%	0%	0%

Sensitivity analyses were performed on the Scott-Gill equation with respect to input values used for UWR winter steelhead in Table 28. The demographic gene flow rates are relatively insensitive to changes in O_N and O_H (as in previous demographic mortality estimates). If the proportion of overlap is increased beyond reported values, the calculated gene flow only increased slightly. The most sensitive input value for the gene flow calculation is pHOS. As reported in Table 28, a range of pHOS values from 10% to 30% were used to calculate gene flow; corresponding to a range of conditions observed naturally. As previously described, pHOS is greater when the returns of summer steelhead to the UWR are greater and pHOS is lower when the abundance is lower. Given this, the corresponding gene flow rates increased from 1.8% to 5.7% for the North Santiam and South Santiam populations, depending upon pHOS. This parameter has major consequences for the expected gene flow calculation, and there is a tremendous amount of uncertainty associated with the monitoring of pHOS, given the difficulties of determining steelhead spawning rates throughout the UWR during the winter. A variety of methods were used to determine likely pHOS values on an annual basis and the most defining trend was the overall run size of summer steelhead counted at Willamette Falls. There seems to be a reasonable relationship between the abundance of summer steelhead returning to the UWR and subsequent pHOS. For example, in 2017 when the return of hatchery summer steelhead was very low (2,182), nearly all of the hatchery steelhead returning to the North and Santiam rivers could be accounted for in angler harvest and hatchery broodstock collections at Minto dam and Foster dam. There were few summer steelhead unaccounted for that could potentially spawn in the wild (i.e. pHOS). Consequently, pHOS was very low in 2017 (near zero). In contrast, in 2004 when the summer steelhead return was very high (33,440), pHOS was higher due to the number of hatchery fish unaccounted for (Table 26; Schroeder et al. 2006).

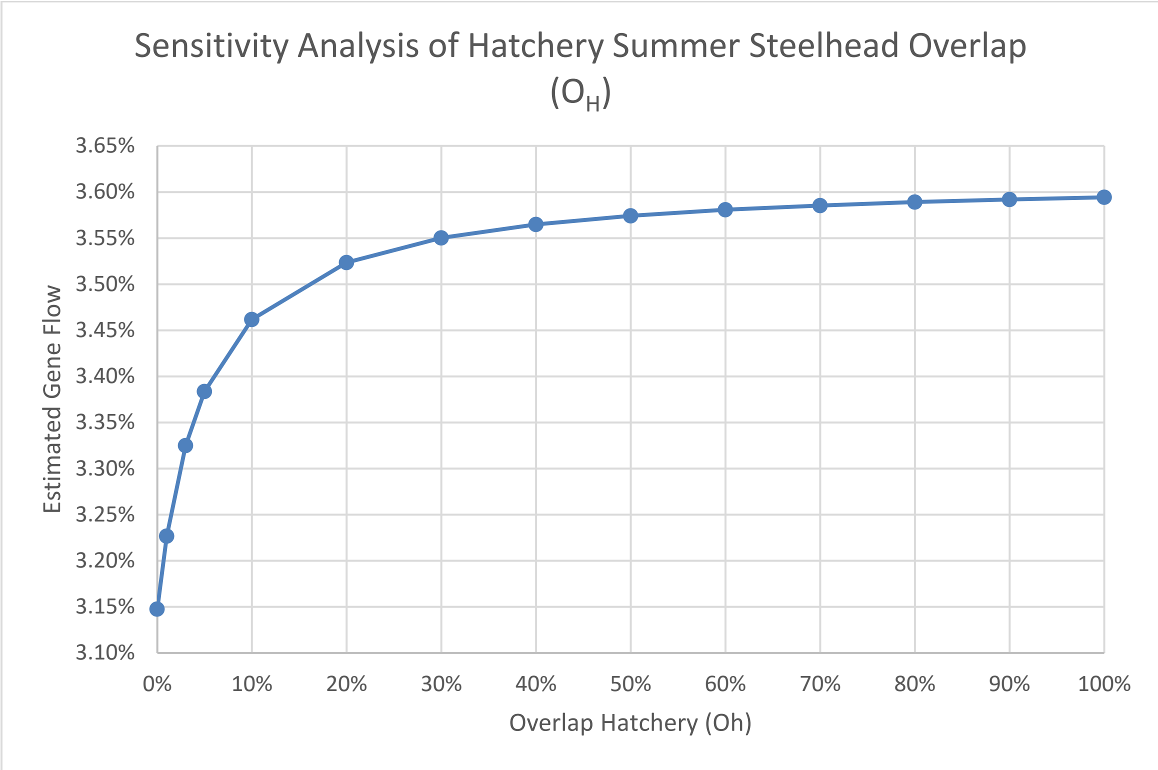


Figure 58. Sensitivity of the O_H estimate value on calculated gene flow.

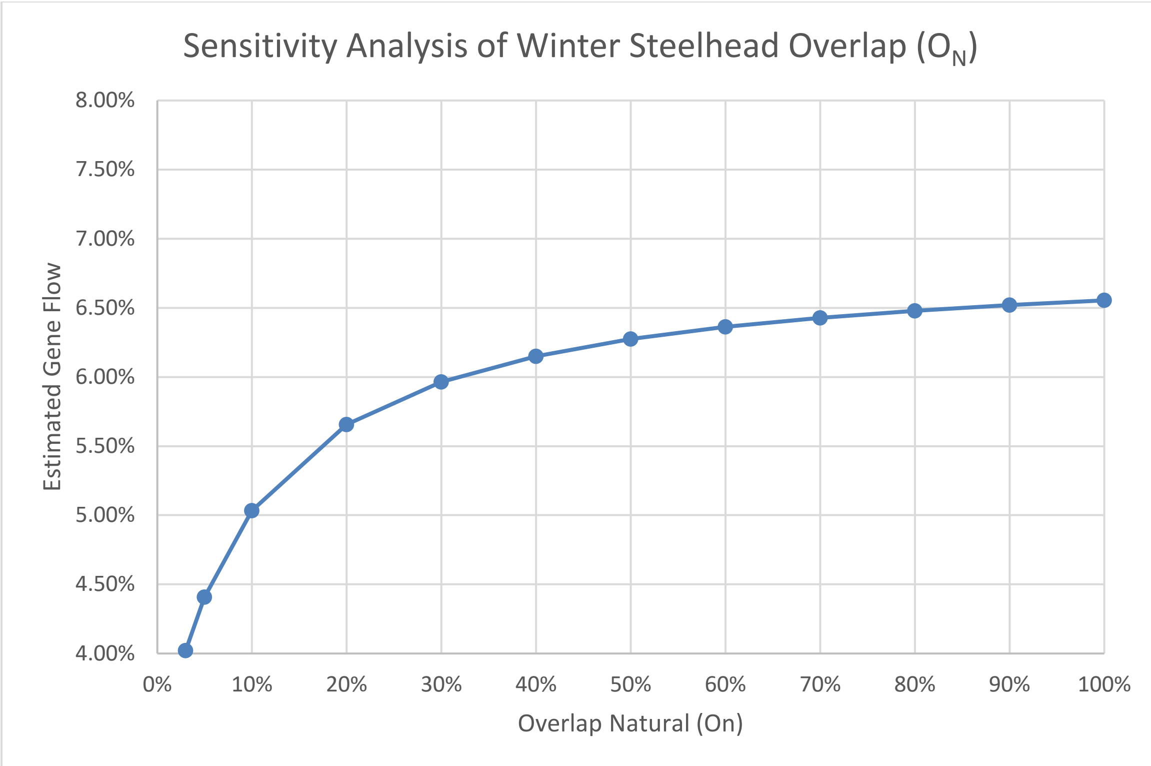


Figure 59. Sensitivity of the O_N estimate value on calculated gene flow.

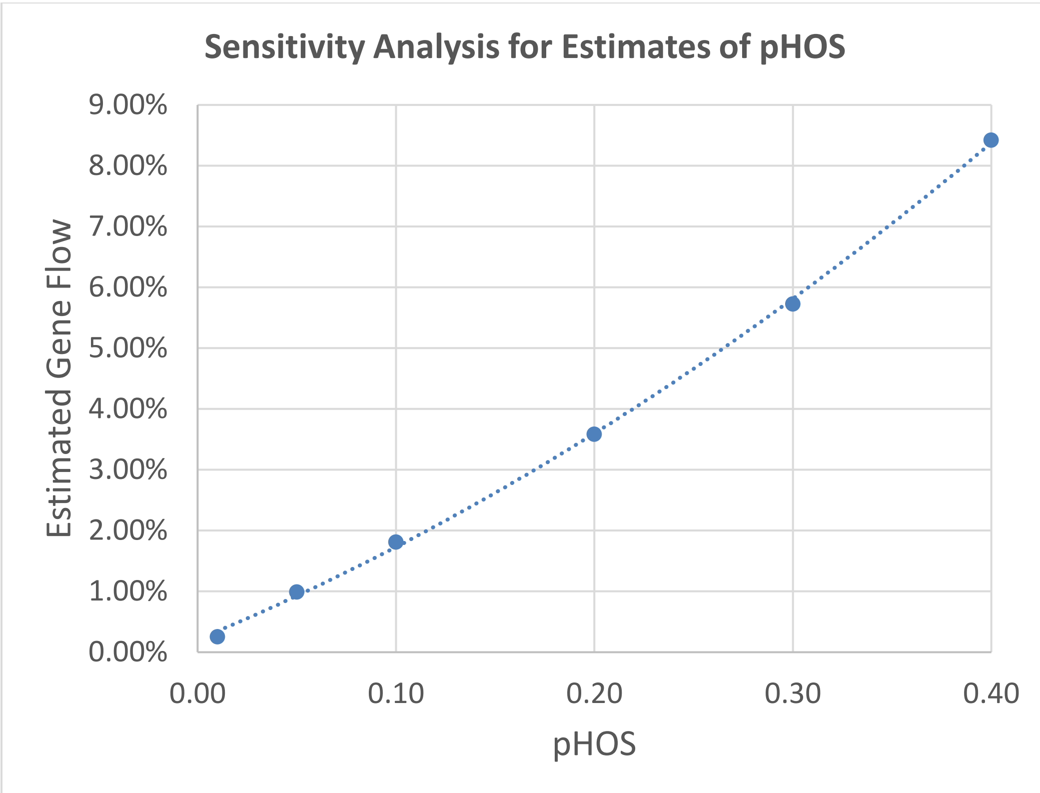


Figure 60. Sensitivity of the pHOS estimate value on calculated gene flow. O_H= 0.39, O_N= 0.0123. Relative reproductive success of HxN matings is assumed to be 0.54 and that of HxH matings is assumed to be 0.13.

Related to pHOS in the North Santiam population area, the proposed action includes acclimation of hatchery summer steelhead at Minto FFC prior to release as smolts and continued collection of all summer steelhead at the trap. This is important because in recent years the returns of steelhead to the rebuilt Minto FFC has been more effective than in the past (Figure 61). A high percentage of summer steelhead returning to the North Santiam River are actually collected and not available to spawn naturally and thus the proposed action substantially reduces the risks of pHOS. For 2016-2018, the years when collection efficiency at Minto FFC was greatly improved, the number of hatchery summer steelhead not collected was 752, 52, and 199 fish, respectively. Even though a combination of actions are likely responsible for the very high collection rates observed recently, the proposed action continues the management actions that lead to high collection of returning summer steelhead (e.g. acclimation of smolts at Minto FFC, continuation of using the rebuilt Minto FFC).

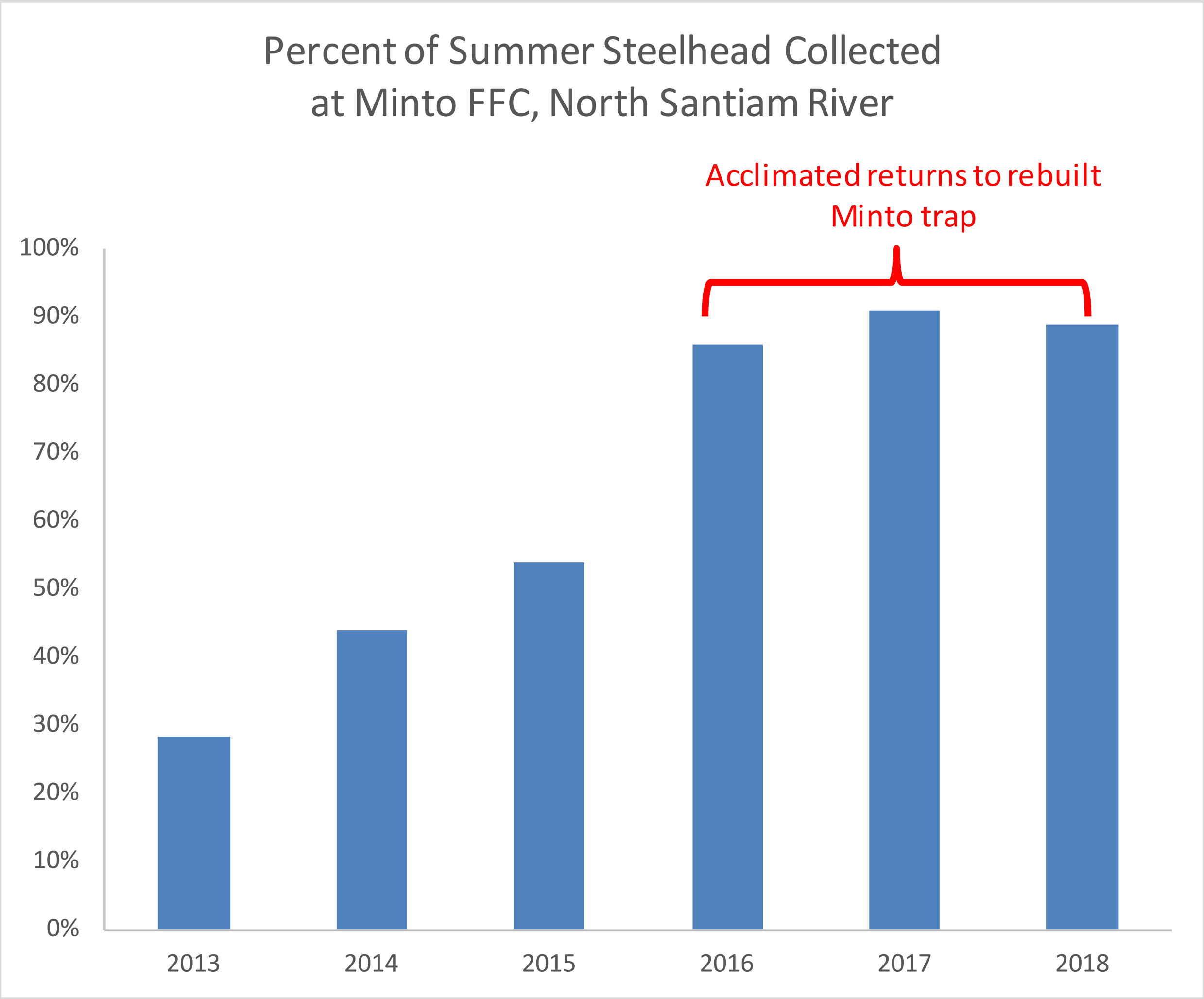


Figure 61. Percentage of hatchery summer steelhead collected at Minto FFC, North Santiam River, 2013-2018. Acclimated summer steelhead began returning in 2016. Metric calculated as the number of summer steelhead collected at Minto FFC divided by the number of summer steelhead counted at Bennett dams.

Another method for calculating gene flow rates from the hatchery summer steelhead program into ESA-listed winter steelhead populations is using a simple island-continent migration model. This model provides another useful measure of gene flow that is based upon the one-way gene flow from a donor population (in this case summer steelhead) to a receiving population (winter steelhead), where the genetic make-up of the receiving population will become more like the donor population depending upon the rate of gene flow through time (Figure 62). This estimate of gene flow is from the following equation (Hedrick 1983):

$$Gene\ flow(m) \ = 1 - (1 - pR)^{\frac{1}{t}}$$

Where *pR* is the average proportion of the genome originating from summer steelhead and *t* is the number of generations over which the program has been in operation.

Genetic information is available from Johnson et al. (2013) to calculate the expected gene flow from summer steelhead to winter steelhead using the proportions of the genome assigning to summer steelhead and eastside winter steelhead in the North Santiam and South Santiam populations. For the North Santiam population, 15.7% of the sampled genome assigned to summer steelhead. For the South Santiam population, 7.4% of the sampled genome assigned to summer steelhead. Since the summer steelhead program has been in operation for 48 years in the Upper Willamette River, this would equate to 12 generations assuming a fixed 4 year life cycle for winter steelhead. Even though winter steelhead have multiple age classes returning to spawn in a given year, on average four years represents an overall mean (age 2 smolts, 2 salt residence) that is sufficient for the gene flow estimate. Using these assumptions provided an annual gene flow estimate of 0.6% and 1.4% for the South Santiam and North Santiam winter steelhead populations, respectively (Figure 63). The more recent samples (after 2000) had a lower average summer steelhead assignment in both the North Santiam and South Santiam compared to samples collected before 2000. This suggests hatchery management reforms implemented since ESA-listing may be reducing the impacts of the hatchery program on ESA-listed winter steelhead populations.

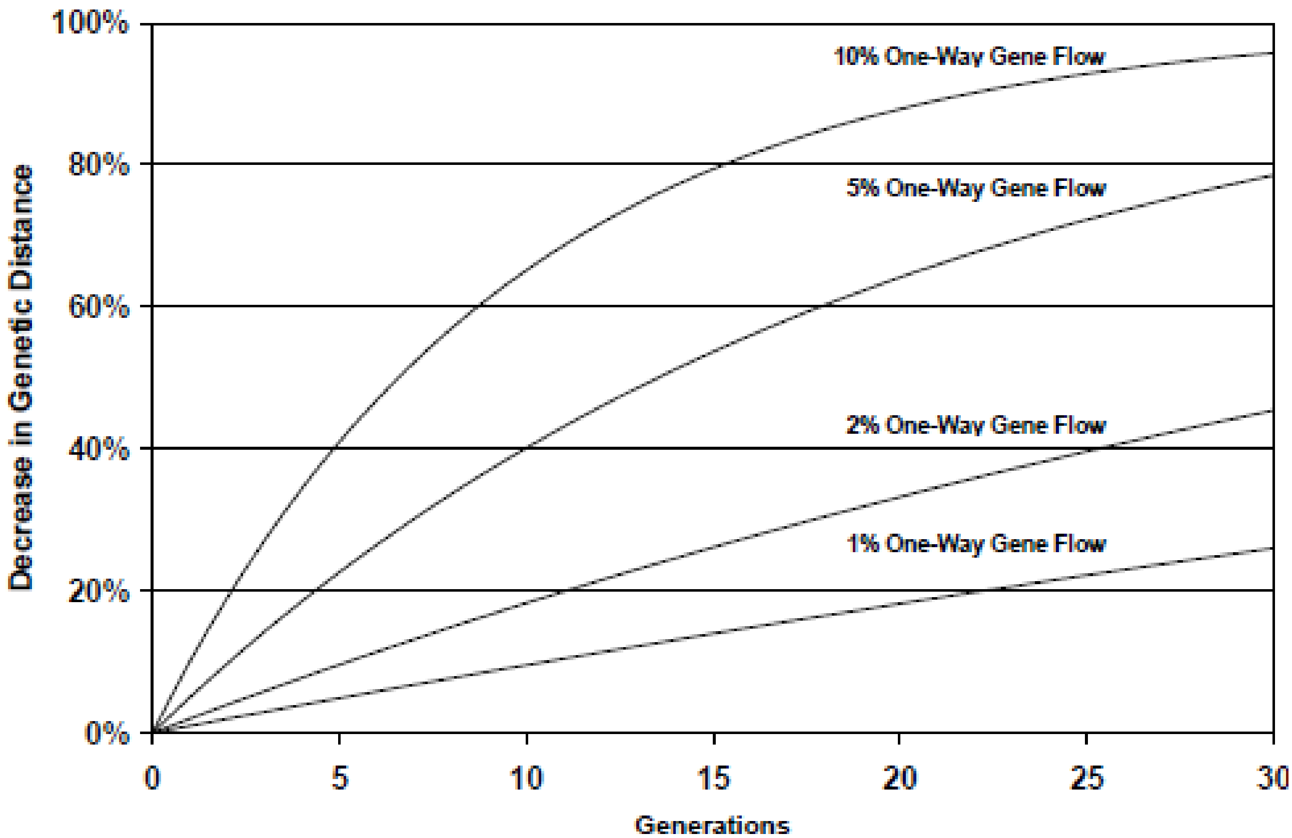


Figure 62. Decay of selectively neutral genetic differences between a donor and recipient population under varying levels of one-way gene flow. Figure taken from Scott and Gill (2008).

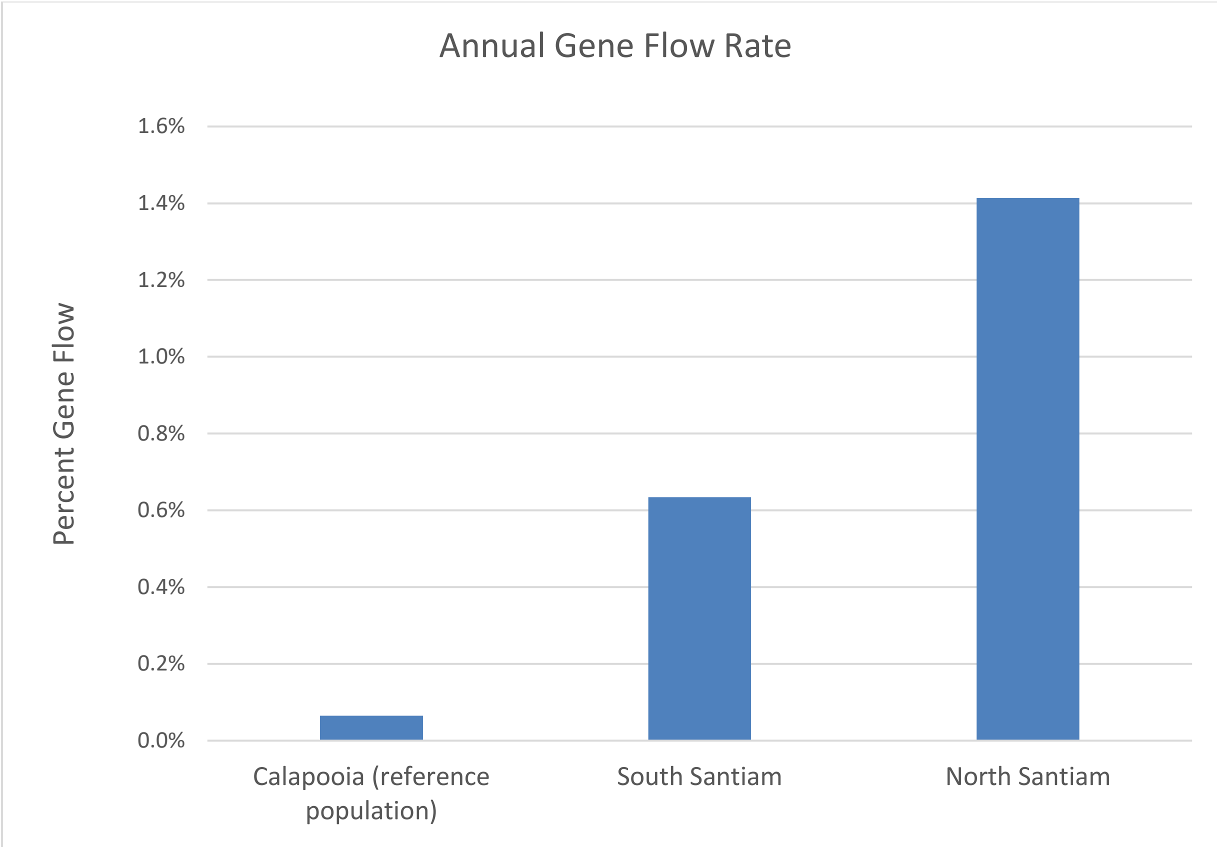


Figure 63. Annual island-model gene flow estimates from hatchery summer steelhead to winter steelhead populations over 12 generations (48 years), based upon the island model (Hedrick 1983). The data used for this assessment is included in the appendix of Johnson et al. (2013). The Calapooia winter steelhead population is also shown for reference purposes, as those samples were the purest eastside tributary winter steelhead samples assessed in Johnson et al. (2013).

In conclusion, we have calculated gene flow rates from hatchery summer steelhead to winter steelhead using three independent assessments. We have applied a range of pHOS values in the modeling for the South Santiam and North Santiam populations; given the uncertainty in the actual pHOS rate due to monitoring not being feasible on an annual basis. All three methods calculate gene flow in the range of zero to 1.8% assuming 10% pHOS. Gene flow increased to 5.7% in one model when pHOS was assumed to be 30%. In recent years, pHOS has been near zero and known to be much higher in 2004-2006. Therefore, assuming pHOS rates of 10% to 30% in the above analyses likely overestimates the gene flow observed in the recent past. We expect pHOS to be reduced in the future under the proposed action and the Terms and Conditions specified in Section 2.9.4.

Relationship of Genetics and Habitat for Steelhead

In the previous sections, the genetic structure, life history characteristics, and gene flow were evaluated to determine the genetic impacts of hatchery summer steelhead spawning in the wild with ESA-listed winter steelhead in the UWR. This section transitions to an ecological perspective of freshwater habitat and the genetics of steelhead in the UWR and the broader Willamette/Lower Columbia ecoregion. The purpose of this ecological assessment is two-fold: 1) to describe the relationship of the hatchery summer steelhead stock used in the UWR in the context of the ecoregion, and 2) to describe new information showing the role of freshwater habitat features correlated with steelhead genetic structure. Both of these aspects help inform the evaluation of hatchery steelhead programs (past and present) and provides another interpretation of the current genetic structure of steelhead in the UWR.

The genetics of steelhead are based upon large-scale habitat features throughout their range (Busby et al. 1996). Steelhead populations in close proximity to each other are genetically more similar than distant populations in the Columbia River Basin (Blankenship et al. 2011; Matala et al. 2014). This is attributable to similar habitat features (e.g. precipitation, temperatures) and the likelihood of nearby populations interacting (straying) with each other (Grant 1997; Hard and Heard 1999; Quinn 2005). The Willamette/Lower Columbia River ecoregion is a distinct habitat region where steelhead occupying this area are more similar to each other than steelhead populations occupying adjacent ecoregions in the Middle Columbia region or Oregon and Washington coast regions. Recent information shows a relationship between Clackamas River steelhead (Lower Columbia River DPS) and stocks residing in the UWR DPS through straying and from being in close proximity to each other (Jepsen et al. 2015; NWFSC 2015). For spring Chinook, the Clackamas River population is included in the UWR ESU. In addition, the Clackamas River originates in the Cascade Mountain Range (Figure 64). The Molalla, North Santiam, South Santiam, and Calapooia rivers also originate to varying extents in the Cascade Mountain Range. It would make sense ecologically that all of these steelhead populations resemble each other genetically due to similar habitat features (Matala et al. 2014; PNWERC 2016). The hatchery summer steelhead stock currently being propagated in the UWR was originally from Skamania hatchery on the Washougal River. Even though this stock is summer-run and not part of the UWR steelhead DPS, the stock shows genetic similarity to other nearby summer and winter steelhead because the stock originated from the Willamette/Lower Columbia River ecoregion (Johnson et al. 2013; Matala et al. 2015). Weigel et al. (2019) reported the fixation index (F_{ST}) between summer steelhead and winter steelhead in the UWR to be 0.057 (if Q=0.8) to 0.065 (if Q=0.9); indicating very similar genomes. This is not to say the non-native, Skamania stock used in the UWR poses negligible risk, but that this stock is highly related to other steelhead populations in the ecoregion. There are still known epigenetic changes that have occurred with this stock being reared in a hatchery environment (domestication selection) that pose risks to the ESA-listed winter steelhead populations in the UWR. However, it is noted the degree of risk is lower in using this Skamania stock (even though out of the DPS) compared to propagating a hatchery stock that is not in the ecoregion (e.g. a non-native stock from Puget Sound, Snake River, or Oregon Coast). The genome of some known Skamania hatchery steelhead in the UWR have been assigned as natural-origin winter steelhead in genetic classifications; showing the relatedness of these two stocks of steelhead.

In a related matter, recent genetic studies conducted on steelhead in the UWR show somewhat differing results on the degree of summer steelhead introgression into winter steelhead populations of the UWR (Johnson et al. 2018; Weigel et al. 2019). In our opinion, these and other recent UWR studies attribute effects of hatchery steelhead programs on the DPS that are difficult to support given the available information. Weigel et al. (2018) found relatively high introgression of summer steelhead into the genome of winter steelhead returning to the westside tributaries (e.g. Tualatin, Yamhill), even though no summer steelhead have ever been stocked there (Busby et al. 1996; NMFS 2008) and there is no recent evidence for summer steelhead straying there (Jepsen et al. 2015). Johnson et al. (2018) classified these same winter steelhead as likely descendants of an early returning Big Creek hatchery winter steelhead stock that had been released in some areas prior to 1998. However, other westside tributary rivers that have never been stocked with Big Creek hatchery fish show similar genetic structure to adjacent tributaries (Blankenship et al. 2011; Matala et al. 2015). There is a presumptive cause and effect relationship that westside tributary steelhead are descendants of Big Creek hatchery stock because their genetic structure is similar to the Big Creek hatchery stock. However, similarity to Big Creek hatchery stock does not prove they are descendants. This characterization dates back prior to the 1990's when hatchery steelhead were not externally marked and could not be easily differentiated from natural-origin steelhead. The adult returns from Big Creek hatchery stockings in the UWR were unquantified at the time and the run of steelhead was divided February 15th at Willamette Falls with the early returning steelhead presumed to be mostly hatchery steelhead and the later returning steelhead presumed to be predominately the native, winter steelhead. Because improvements to the fish ladders occurred during the same period of hatchery stockings, it was uncertain whether native steelhead were passing earlier or if the increases were from hatchery stockings (Clady 1971). Since the termination of all winter steelhead hatchery releases in the UWR (Big Creek and native stocks), it is known natural-origin steelhead pass Willamette Falls from December through May; with the majority of all natural-origin steelhead passing in February and March (Jepsen et al. 2015). Historically, natural-origin winter steelhead occupied westside tributaries of the UWR prior to hatchery stockings (e.g. Yamhill and Tualatin (Fulton 1970)); although the numbers of fish in these areas were far fewer than observed in the eastside tributaries (Molalla, Santiam) and likely represented dependent populations.

It is likely natural-origin winter steelhead occupying the westside tributaries of the UWR (Luckiamute, Rickreal, Yamhill, Tualatin) exhibit similar genetic structure because they occupy similar habitat. It is our opinion that because Big Creek is also located in the similar habitat of the Coast Mountain Range downstream of the Willamette River, that this stock exhibits similar genetic structure as other nearby populations of winter steelhead. The similarity of genetic structure among these populations is not likely due to previous hatchery stockings, but similarity in freshwater habitats (Figure 64; Blankenship et al. 2011; Matala et al. 2015). The habitat differentiation between westside tributaries and eastside tributaries of the UWR (Coast Range vs Cascade Range) and differences in steelhead genetics is similar to findings in other DPS's of the Columbia Basin. For example within the Snake River steelhead DPS, Matala et al. (2015) found climate to differentiate steelhead genetic structure among the Clearwater, Grande Ronde, and Imnaha populations, which occur in close proximity to each other yet experience greatly different temperature and precipitation patterns. The same case could be made for the UWR that environmental variables among areas in the UWR are affecting steelhead genetics and the present structure is not an artifact of previous hatchery management.

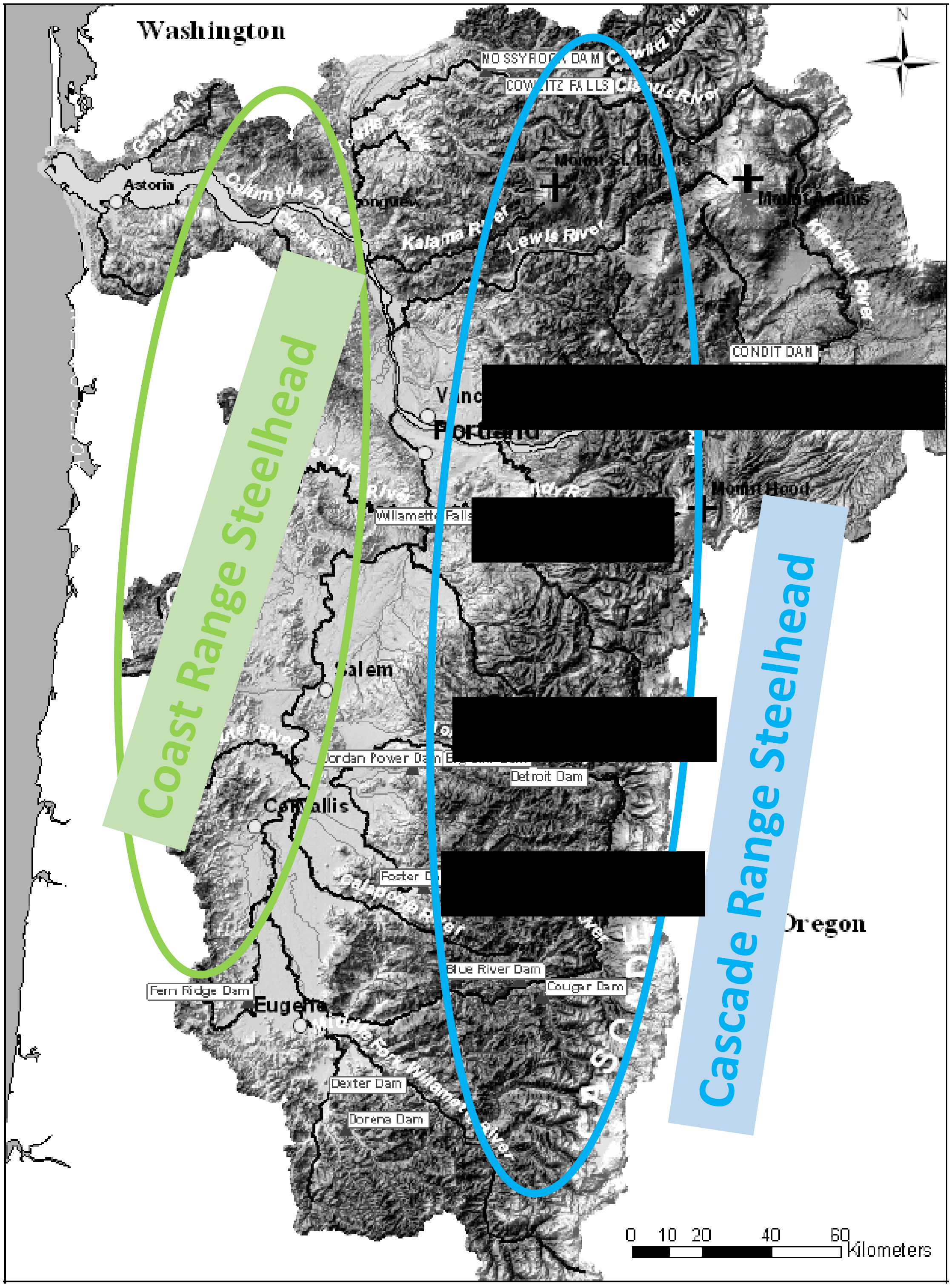


Figure 64. Geographic ecoregions in the Lower Columbia/Willamette recovery domain highlighting the Coast Range and Cascade Mountain Range EPA level IV ecoregions, with Washougal (Skamania hatchery summer steelhead), Clackamas, North Santiam, and South Santiam populations noted.

Matala et al. (2014) found Skamania stock summer steelhead (taken from returns to the Clackamas River) to be most similar to Willamette winter steelhead populations (i.e. Clackamas, North Santiam, South Santiam, Luckiamute) when evaluating allele frequencies of nine non-neutral single nucleotide polymorphism (SNPs). This is a significant finding because previous genetic studies cited above analyzed neutral genes not under active selection. However, in Matala et al. (2014), the nine SNPs genes were under active selection, and therefore, offer insight on the relationship between Skamania summers and Willamette winter steelhead. These findings are supported ecologically, as both Skamania summers and UWR winters have adapted to environmental conditions of the Willamette Valley and Cascade ecoregions (Figure 64).

Co-occurrence of Summer and Winter Steelhead in Same Populations

Summer steelhead and winter steelhead co-occur in many populations throughout California, Oregon, Washington, and British Columbia (Busby et al. 1996). This information is important because it provides further insight on the temporal and spatial interactions between summer and winter runs in the natural environment. In these populations, if gene flow between the populations was substantial, the distinct summer-run and winter-run life history types may not exist in these populations. This information provides support for the previous evaluations above in the UWR related to life history and genetic interactions between summer and winter runs. Summer and winter steelhead occur sympatrically in the following rivers in western Oregon: Rogue, North Umpqua, Siletz, and Hood. Historically, these rivers produced both summer and winter steelhead and continue to produce natural-origin returns today. In some cases there is a physical habitat feature that helps separation the two different run types within the population area, but not always. In all cases, the temporal separation between spawning periods effectively isolates the run types and does not allow interbreeding to occur for the majority of the spawning.

In addition, hatchery summer steelhead have been introduced into other rivers in western Oregon including the Nestucca, Wilson, Clackamas, and Sandy rivers. Winter steelhead in these populations still exist in high abundances even though summer steelhead have been present in the same population areas for several decades. The occurrence of summer and winter steelhead naturally in many rivers in western Oregon lends support for the analyses in the UWR showing temporal separation between the life history types and low levels of interactions on the spawning grounds.

Recent genetics work evaluating the differences between summer and winter steelhead in the same population areas has highlighted the importance of the summer life history type in steelhead populations (Prince et al. 2017). Summer steelhead have a unique early run timing and unique gene complexes (i.e. GREB1 loci) not found in winter steelhead. The unique genes found only in summer steelhead, and not winter steelhead, has recently caused some debate in the conservation of steelhead and other species exhibiting premature migration life histories (Waples and Lindley 2018). These recent findings are important to include here because hatchery summer steelhead are non-native in the UWR. From a conservation biology perspective, this hatchery program is less risk on ESA-listed winter steelhead than if the situation was reversed, with the unique life history of summer steelhead needing protection instead of winter steelhead. This aspect of steelhead genetics is also considered in our risk evaluation of the hatchery summer steelhead program in the UWR.

The Willamette River Basin has been drastically altered over the last century which has changed the characteristics for the migration of salmon and steelhead into this watershed. Historically, Willamette Falls in the lower river was favorable for passage of salmon and steelhead during a select time period throughout the year; primarily in late winter and spring before river flows decreased to a point where upstream passage was blocked due to insufficient flows. These characteristics promoted the life history patterns currently found in native, ESA-listed winter steelhead and spring Chinook salmon. In 1946, a fish ladder was built at Willamette Falls that essentially allowed upstream migration throughout the entire year instead of during select seasons. In addition, improvements to the fish ladder in the late 1960's also improved upstream passage (Clady 1971). This increase in accessibility coupled with increased flows from the federal dams during the summer and fall compared to natural flow regimes has greatly modified the habitats now available to salmon and steelhead throughout the Willamette basin. Natural colonization by non-native coho salmon (and fall Chinook salmon to much less extent) has occurred. The possibility also exists for summer steelhead to naturally stray and migrate above Willamette Falls from the Columbia River. Even though counts of unmarked summer steelhead (presumed of natural-origin) has been relatively low at Willamette Falls, the possibility for natural straying still exists. Of particular note is the finding by Johnson et al. (2018) showing relatively high influence of summer steelhead in the Molalla River, even though no hatchery summer steelhead have been released in this river for more than 20 years and straying by marked hatchery steelhead very low (Jepsen et al. 2015). Since the hybrids observed in Johnson et al (2018) were recent crosses with winter steelhead (F1, F2, etc.) seems to support there may be some level of colonization by natural-origin summer steelhead in this population and/or legacy effect of past hatchery releases. This would be consistent with the pattern observed for natural-origin coho salmon in the Molalla River and rest of the UWR. The effect of natural colonization of the UWR by salmonids needs to be considered because it is not related to current hatchery management but the result of past land management decisions (e.g. laddering Willamette Falls, flow management from federal dams, etc.) and past hatchery practices that have ceased for decades. We do not rule out the effect of natural colonization entirely in contributing non-local genetic effects to the UWR steelhead DPS.

Summary of Effects of Summer Steelhead on the Spawning Grounds

The above analyses is the most extensive, up to date assessment of the effects of the hatchery summer steelhead program on UWR winter steelhead conducted by NMFS. There are four factors considered in evaluating the genetic risk of this hatchery program on winter steelhead: within population diversity, inbreeding depression, outbreeding depression, and hatchery induced selection (domestication). Since this program is not native to the DPS and provides no conservation benefit, the first three factors do not apply. Hatchery induced selection (domestication) is the primary risk factor for this particular hatchery program. In summary, the best available information shows separation in the spawn timing of summer and winter steelhead that has minimized the potential of interbreeding. The proposed action will continue to advance the spawn timing of summer steelhead which will make the separation of spawning even more pronounced. Estimates of the gene flow from hatchery steelhead into ESA-listed winter steelhead populations is relatively low, even under assumptions that would overestimate the impacts of the program. Over the long-term (the entire period of time the hatchery program has been conducted), average gene flow ranges from 0.65% to 1.4% for the South Santiam and North Santiam winter steelhead populations, respectively. The proposed action includes production reductions in the South Santiam releases, broodstock spawn timing advances, and acclimation in the North Santiam River that are expected to reduce impacts of the hatchery steelhead program to the lowest levels ever observed.

Recent genetic studies show the UWR winter steelhead DPS to be genetically distinct from hatchery steelhead. These genetic structure results help validate the findings in this opinion that the current effects of the hatchery summer steelhead are currently low and will be even lower in the future as the proposed action (and terms and conditions of this opinion) are implemented.

2.5.2.2.2.2 Hatchery Rainbow Trout

The hatchery rainbow trout program releases fish for recreational fisheries in various ponds, reservoirs, and rivers throughout the UWR. The only locations where hatchery trout may interact on the spawning grounds with ESA-listed winter steelhead is above and below Foster Dam on the South Santiam River and below Big Cliff Dam on the North Santiam River. No winter steelhead are passed upstream of Detroit and Green Peter dams due to low survival of winter steelhead through these projects. The hatchery rainbow trout program uses a non-local *O. mykiss* broodstock that spawns in the fall and all progeny are sterile when released. The sterilization of hatchery trout (triploid) eliminates the risk of genetic interactions with *O. mykiss* (and the steelhead life form) in the UWR through interbreeding. Winter steelhead spawn predominately from February through May (see previous section). Therefore, the period of overlap in spawn timing between these stocks is negligible. In addition, hatchery rainbow trout are a highly domesticated stock that does not reproduce well in the wild (but sterilized before release). Stocked rainbow trout would have to successfully emigrate downstream through the dams and reservoirs (with very high mortality rates due to their larger size) below Big Cliff and Foster dams to be in the same area as winter steelhead, or migrate upstream in the South Santiam River above Foster reservoir. Genetic analyses of *O. mykiss* samples throughout the UWR have not shown hatchery trout (of the Cape Cod stock) to reproduce in the wild (M. Johnson, ODFW, personal communication, April, 2018). Given the likelihood of interaction on the spawning grounds between hatchery trout and winter steelhead is extremely unlikely, the effect is negligible.

2.5.2.3 Hatchery fish and the progeny of naturally spawning hatchery fish in juvenile rearing areas (tributaries, mainstem, estuary, and ocean)

2.5.2.3.1 UWR spring Chinook salmon: Negative effect

2.5.2.3.2 UWR winter steelhead: Negligible effect

2.5.2.3.3 Lower Columbia Chinook Salmon, Coho Salmon, and Steelhead: Negative effect

2.5.2.3.4 Columbia River Chum Salmon: Negative effect

2.5.2.3.5 Snake River Spring/Summer Chinook Salmon: Negligible effect

The ecological effects of the hatchery programs on juvenile salmon and steelhead in the UWR are assessed below. This section is divided into two focus areas: ecological interactions in areas where hatchery fish occur in the UWR Basin, and ecological interactions in the lower Columbia River and estuary below the mouth of the Willamette River. These two areas of evaluation were chosen because the ecological conditions change substantially below the Willamette River related daily tidal changes, species composition, abundance of hatchery fish, river temperatures, and other aspects for natural-origin salmon and steelhead rearing and emigrating in these habitats.

The ecological interactions between hatchery juvenile salmonids (all species) and natural-origin spring Chinook salmon and winter steelhead is an important effect to consider fully, yet information in many population areas is sparse or non-existent. In an effort to better understand juvenile salmonid interactions, NMFS has quantified the spatial and temporal overlap of juvenile hatchery fish and natural-origin salmon and steelhead (as described in the following sections). NMFS is unaware of any additional assessments of ecological interactions at this fine of a scale for the UWR. This analysis relies on the best available information to assess the risks posed by the presence of juvenile hatchery fish in the action area. In addition, much work has been conducted on the ecological interactions between hatchery fish and juvenile salmon in other areas. Many of the results of these studies have been included here in the assessment, as appropriate for juvenile salmon and steelhead ecological interactions.

There are three primary types of effect considered here: competition between hatchery and natural salmon and steelhead, predation by hatchery fish on juvenile salmon and steelhead, and transfer of disease pathogens from hatchery fish to juvenile salmon and steelhead. Each effect is a function of both spatial and temporal overlap; the effect can only take place when hatchery and natural-origin salmon and steelhead encounter each other or are rearing together.

In order to evaluate the effects of competition, predation, and disease on juvenile salmon and steelhead, this opinion considers the following spatial and temporal factors:

- Establish the area of potential overlap between releases of hatchery fish and co-occurring juvenile natural-origin salmon and steelhead in the same area.
- Establish when hatchery fish from each program are released, and thus available to interact with juvenile natural-origin salmon and steelhead.
- In the area and time when hatchery fish and juvenile natural-origin salmon and steelhead co-exist, model the effects of these interactions using PCDrisk model (Pearsons and Busack 2012). Evaluate the likely competitive and predatory interactions between hatchery fish and juvenile natural-origin salmon and steelhead.
- Summarize the relative magnitude of PCD results at the ESU/DPS in terms of juvenile and adult equivalent mortalities.

We used the PCD Risk model (Pearsons and Busack 2012) to simulate predation and competition on natural-origin salmon and steelhead juveniles from the release of hatchery salmon and steelhead included in the proposed action, from their release sites to the mouth of the Columbia River (tips of the jetties). Although these simulations should not be considered estimates of the actual predation and competition impact on natural-origin salmon and steelhead from hatchery-origin juveniles, they are useful in that they give an indication of the magnitude of interactions that could occur under a certain set of assumptions. Many of these assumptions will need to be refined, but NMFS used the best data that it could obtain at the time the model was run for releases of hatchery fish in the UWR. PCD Risk was not used for the hatchery trout releases because the model does not apply to resident (non-migratory) fish species nor releases in standing water bodies (i.e. reservoirs).

It is important at the outset of this discussion to emphasize that the PCD Risk model is not by any means a total simulation of ecological interactions between hatchery and wild fish. Competition is dealt with in the model as a direct interaction between hatchery-origin and natural-origin fish; the model does not include the effects of density dependence on food availability, for example. The model also does not include predation or competition from other fish species such as bass or non-fish species such as piscivorous birds. It also does not account for the possible beneficial effects of juvenile hatchery-origin fish releases, mainly in the form of prey for natural-origin salmon and steelhead. Another limitation in our modeling is that neither species grows during the simulation; in reality, of course, fish growth could greatly change competition dynamics and susceptibility to predation. Finally, and perhaps most relevant, PCD Risk runs are limited to evaluating interactions between one hatchery-origin species and one natural-origin species under specified conditions in a limited area over a limited time. The model was originally intended for evaluating effects in tributaries or independent streams with direct access to the ocean. In this case, two specific locations were modeled: 1) from point of release of hatchery fish to the mouth of the Willamette River, and 2) from the mouth of the Willamette River in the Columbia River downstream to the tips of the jetties where the river enters the ocean.

Simulated predation and competition interactions in PCD Risk must be interpreted very differently. Within the parameter values chosen and the mechanisms for interactions coded into the model, a predation event is an actual loss of a fish: the fish is removed from the simulated population. Competition events in the PCD model have quite different consequences than predation events. Whereas a predation event denotes a mortality, a competition event means that a fish does not eat for a day, and suffers some weight loss as a result. The same fish could suffer another competition event the next day, and possibly one each day of the interaction period. Thus at the end of a seven-day interaction period (set as the residence time parameter), a particular natural-origin fish could have sustained anywhere between 0 and 10 competitive interactions that will have resulted in weight loss. Ten interactions are expected to result in a weight loss of approximately 10- 15%. In reality, a weight loss of this magnitude is unlikely to directly result in death, but could result in increased susceptibility to disease (Pearsons and Busack 2012), or perhaps to further interactions, neither of which mechanism is included in the model. The model reports instead, “competition equivalent” deaths, which are computed as how many fish would die if the cumulative weight loss of all the natural-origin fish due to competitive interactions were concentrated into individual fish to reach lethal levels (typically programmed at 50% weight loss). In other words, if an individual fish suffering 20 competitive interactions dies from weight loss, then if 5,000 total competitive interactions occurred in a run of the model, this would result in 250 competition equivalent deaths, even if no fish in the simulation truly suffered 20 interactions. Detailed analysis of model runs done for this consultation have revealed that even with substantial time periods over which for interactions to occur, a substantial proportion of fish may not suffer any competitive “hits,” and maximally affected fish suffer only a few. However, because we believe that the model underestimates the effects of competition, we aggregated the competitive interactions so that they all happened on the same natural-origin fish until that fish died (i.e., competition equivalent deaths). Although this is not a realistic scenario in the natural environment, it allowed us to put an upper bounds on potential mortalities.

The current version of this program (version 2.3) is a 2017 modification by Busack of the original described in (Pearsons and Busack 2012). The modification was done to increase ease of use, reliability, supportability, and expandability. The current version lacks two operational prominent operational features of the original: disease effects and probabilistic output. The calculation of disease effects in the original version was deleted for the time being upon the advice of fish-disease experts who felt that the disease effects modeling was uninformative. Probabilistic output can be obtained with the current version by multiple runs of the model in which the parameters of interest are varied.

Parameter values used across multiple model runs are shown in Table 29. Hatchery program specific parameter values are detailed in Table 30. For our model runs, we evaluated the effects of UWR hatchery releases on ESA-listed spring Chinook salmon and steelhead in the interaction zones within the UWR. We evaluated the effects of UWR hatchery releases once the hatchery fish entered the Columbia River below the mouth of the Willamette River on all ESA-listed salmon and steelhead in the Columbia River.

Table 29. Parameters from the PCD Risk model that are the same across all programs.

Parameter	**Value**
Habitat complexity	0.1
Population overlap	1.0
Habitat segregation[1]	0.3 for intraspecific pairings; 0.6 for interspecific pairings
Dominance mode	3
Piscivory rate[1]	0.002 for yearling Chinook salmon on Chinook salmon, sockeye, coho, chum 0.0023 for steelhead on Chinook salmon, sockeye, coho, chum 0.0189 for coho on Chinook salmon, sockeye, coho, chum
Maximum encounters per day	3
Predator:prey length ratio for predation[2]	0.25

[1] Values from HETT (2014).
[2] Daly et al. (2014).

Table 30. Input values used in PCDrisk modeling for the hatchery programs in the UWR.

Hatchery Program		Numbers of smolts released	Length at release (CV)	Water temperature at release ©	Days for interaction (Willamette Basin, Lower Columbia)
Chinook Salmon	Middle Fork Willamette	2,200,000	176 (0.15)	7.8	6, 6
	McKenzie	605,000	165 (0.15)	6.0	6, 6
	South Santiam	704,000	170 (0.15)	6.8	4, 6
	North Santiam	1,021,000	165 (0.15)	4.8	4, 6
	Molalla	100,000	165 (0.15)		2, 6
Steelhead	Middle Fork Willamette	157,000	231 (0.15)	7.8	6, 6
	McKenzie	108,000	224 (0.15)	7.4	6, 6
	South Santiam	121,000	231 (0.15)	7.8	4, 6
	North Santiam	121,000	224 (0.15)	5.5	4, 6

2.5.2.3.5.1 Spatial Overlap Between Hatchery Fish and Juvenile Natural-Origin Salmon and Steelhead

First, it is necessary to establish the area of potential overlap between hatchery fish and juvenile natural-origin salmon and steelhead. As a result of the proposed action, hatchery fish (of any species) are released in the Middle Fork Willamette, McKenzie, South Santiam, North Santiam, and Molalla population areas in the UWR. The specific reaches in each of these population areas where hatchery fish occur from the point of release to the ocean are shown in Figure 65, Figure 66, Figure 67, and Figure 68. In all cases (except the Molalla River), hatchery fish are released at the hatchery facilities below the federal dams and/or in the lower river. These areas are not the primary rearing habitats for age-0 juvenile Chinook salmon and winter steelhead. Overall, 27 percent of critical habitat (total river miles) for the UWR spring Chinook salmon ESU is affected by hatchery fish. Most of this interaction area in the mainstem Willamette River and lower Columbia River. For the winter steelhead DPS, the affected area is less. The principal habitat areas affected by hatchery fish are the mainstem tributaries, mainstem Willamette River, and lower Columbia River.

For the hatchery rainbow trout program, the spatial overlap between natural-origin salmon and steelhead and hatchery trout is even more limited. Hatchery trout are released into sections of the McKenzie River where juvenile spring Chinook salmon may be present. All of the other areas where juvenile salmon and steelhead may be present are above the federal dams in reservoirs and upriver reaches. Hatchery trout are released above Detroit Dam, Foster Dam, and Fall Creek Dam where natural-origin salmon may be present. Hatchery trout are released above Dexter Dam and Hills Creek Dam, but no natural-origin salmon are present. The only area where winter steelhead may be present with stocked hatchery trout is Foster Reservoir.

2.5.2.3.5.2 Temporal Overlap Between Hatchery Fish and Juvenile Natural-Origin Salmon and Steelhead

In addition to the geographic extent of hatchery fish released within a natural population area (i.e., space), another aspect of the interaction between hatchery fish and natural-origin juvenile salmon and steelhead is the season and period of time affected by the presence of hatchery fish in the rivers. For the UWR, six natural population areas are affected by hatchery fish released from February through mid-April (Table 31). The time of release varies depending upon the species of hatchery fish, and this is specifically assessed below by program and species. Hatchery spring Chinook salmon are released in the winter (February-March) and hatchery steelhead in the beginning of April, and rainbow trout in the spring and summer. Given the time frame when hatchery fish are released throughout the entire action area (February-July), there is a tremendous amount of variability in the interactions with juvenile salmon and steelhead depending upon the specific area of interaction. Some natural-origin populations do not have any hatchery fish present; whereas other populations have hatchery fish released for several months of the year. The specific details for each population area where hatchery fish are released is assessed below.

The target release size for hatchery fish in the UWR is the smolt life stage for all steelhead and salmon. Hatchery rainbow trout are typically released at a legal size for fisheries (>8 inches). Depending upon the species, average fork length ranges from seven inches (~170 mm) for spring Chinook salmon (the smallest) up to eight inches (~220 mm) for summer steelhead (the largest). Given that hatchery fish are released as smolts and in lower river areas below the dams and hatcheries, the interaction period is short-lived because the hatchery fish are actively emigrating to the estuary and ocean (with the exception of hatchery rainbow trout released in the reservoirs). The physiological condition of the hatchery smolts triggers their desire to emigrate. In the UWR, emigration to below Willamette Falls from the uppermost hatchery release (the furthest distance) occurs rapidly. Most hatchery smolts emigrate below Willamette Falls within one week (Schreck et al. 1994). In all cases, the potential interaction time for hatchery smolts with natural-origin salmon and steelhead residing in freshwater is likely in the range of one to two weeks total. However, there is also the potential for a remnant of the smolts released from the hatchery to not emigrate and residualize near the hatchery facility. Hatchery steelhead have a tendency to exhibit this behavior and this is specifically assessed below. For Chinook salmon, this type of behavior is not common in the UWR.

Table 31. Assessment of hatchery fish releases (CHS- spring Chinook, STS-summer steelhead) and risk of interaction with natural-origin salmon and steelhead in freshwater areas throughout the UWR basin.

Population Area where Hatchery Fish Released	Time Period for Hatchery Fish Releases	Potential Area of Overlap between Hatchery and Natural Salmon and Steelhead	Relative Magnitude of Potential Hatchery Fish Interaction with Natural-origin Salmon and Steelhead
Molalla (Trout Creek)	CHS- Feb to March	Molalla/Trout Creek confluence downstream to Willamette River (27 miles)	Low
North Santiam (Minto FF)	CHS- Feb to March STS- April	Minto FF downstream to Willamette River (53 miles)	Medium
South Santiam (Foster Dam)	CHS- Feb, Mar, Oct STS- April	Foster Dam downstream to Willamette River (48 miles)	Medium
McKenzie (hatchery and Leaburg Dam)	CHS- Jan to March STS- April	Leaburg Dam downstream to Willamette River (34 miles)	Medium
Middle Fork Willamette (Dexter FF)	CHS- Feb to April STS- April	Dexter FF downstream to Willamette River (27 miles)	High
Coast Fork Willamette (dam)	CHS- Feb	Cottage Grove dam downstream to Willamette River (29 miles)	Low
Willamette (Eugene)	STS- April (CHS – from tributaries)	Eugene to Columbia River (174 miles)	Low (for STS at Eugene) to Very High (as hatchery fish accumulate from tributaries)

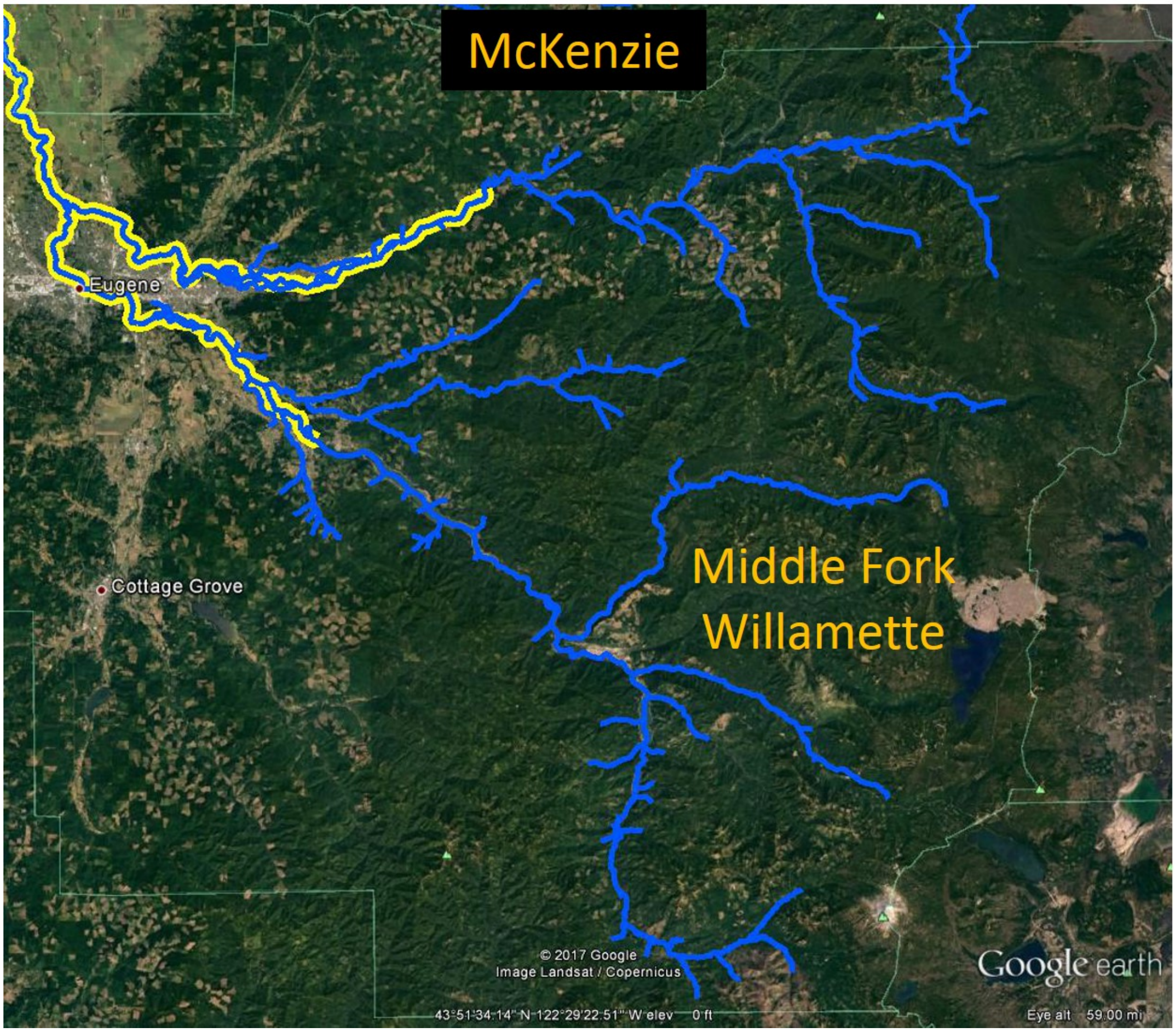


Figure 65. Geographic extent of the interaction area between hatchery fish and natural fish in the upper Willamette region. Hatchery fish are released in the McKenzie and Middle Fork Willamette rivers. The reaches where hatchery fish are released are the yellow lines. Stream reaches designated as critical habitat for UWR spring Chinook salmon and winter steelhead are identified as the blue colored lines.

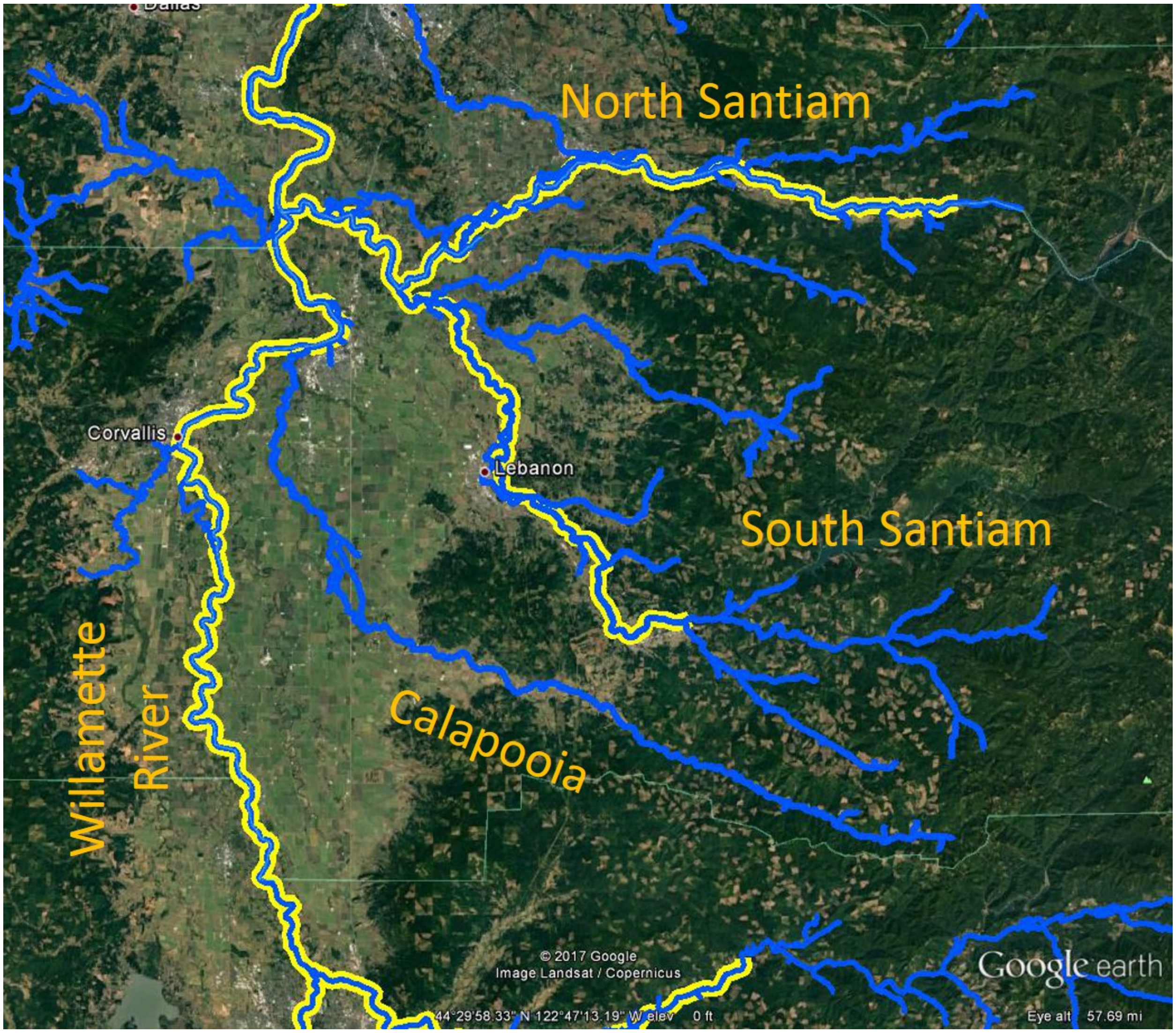


Figure 66. Geographic extent of the interaction area between hatchery fish and natural fish in the mid-Willamette region. Hatchery fish are released into the North Santiam and South Santiam rivers. The reaches where hatchery fish are released are the yellow lines. Stream reaches designated as critical habitat for UWR spring Chinook salmon and winter steelhead are identified as the blue colored lines.

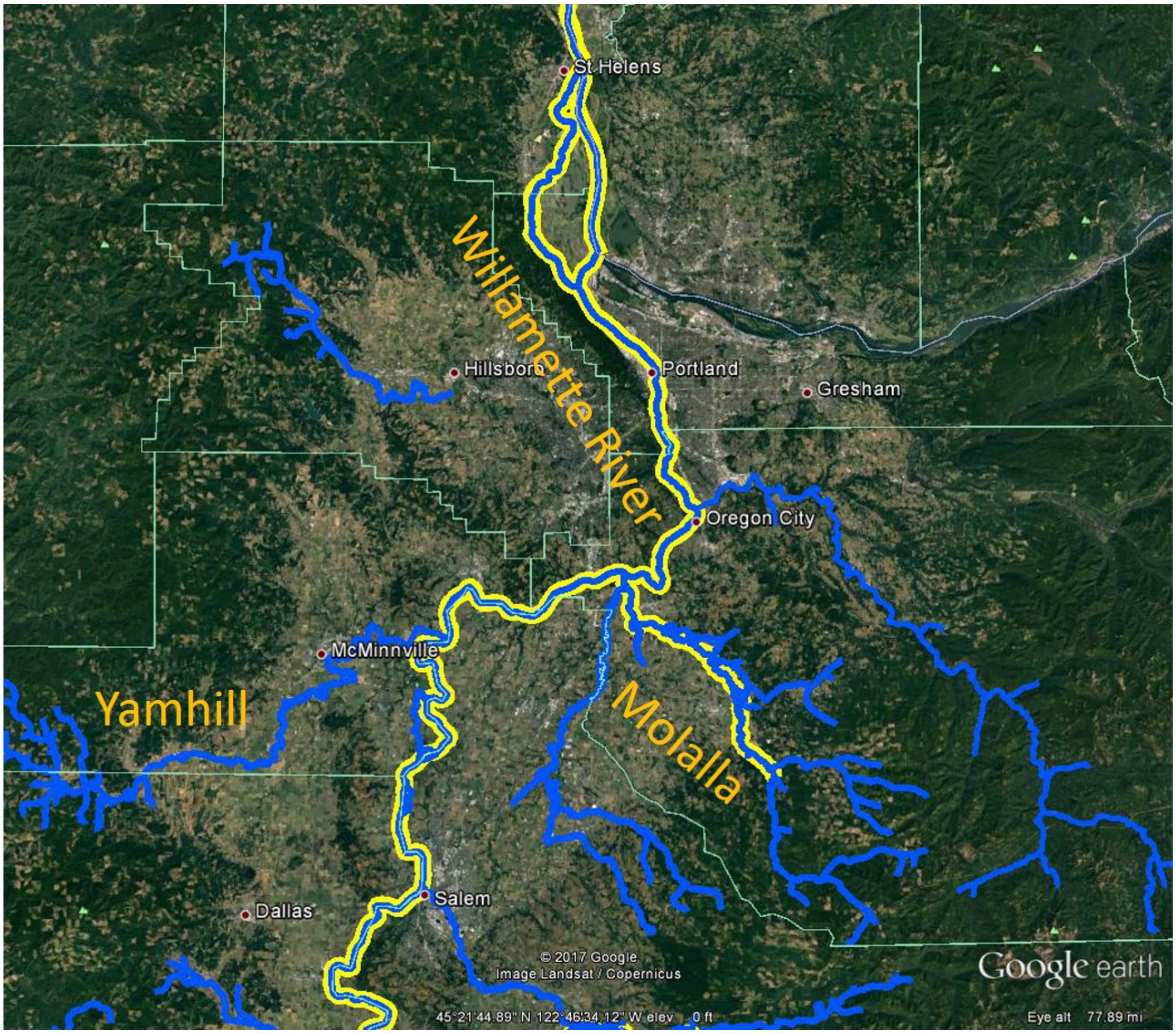


Figure 67. Geographic extent of the interaction area between hatchery fish and natural fish in the Lower Willamette region. Hatchery spring Chinook salmon are released into the mainstem Molalla River. The reaches where hatchery fish are released are the yellow lines. Stream reaches designated as critical habitat for UWR spring Chinook salmon and winter steelhead are identified as the blue colored lines.

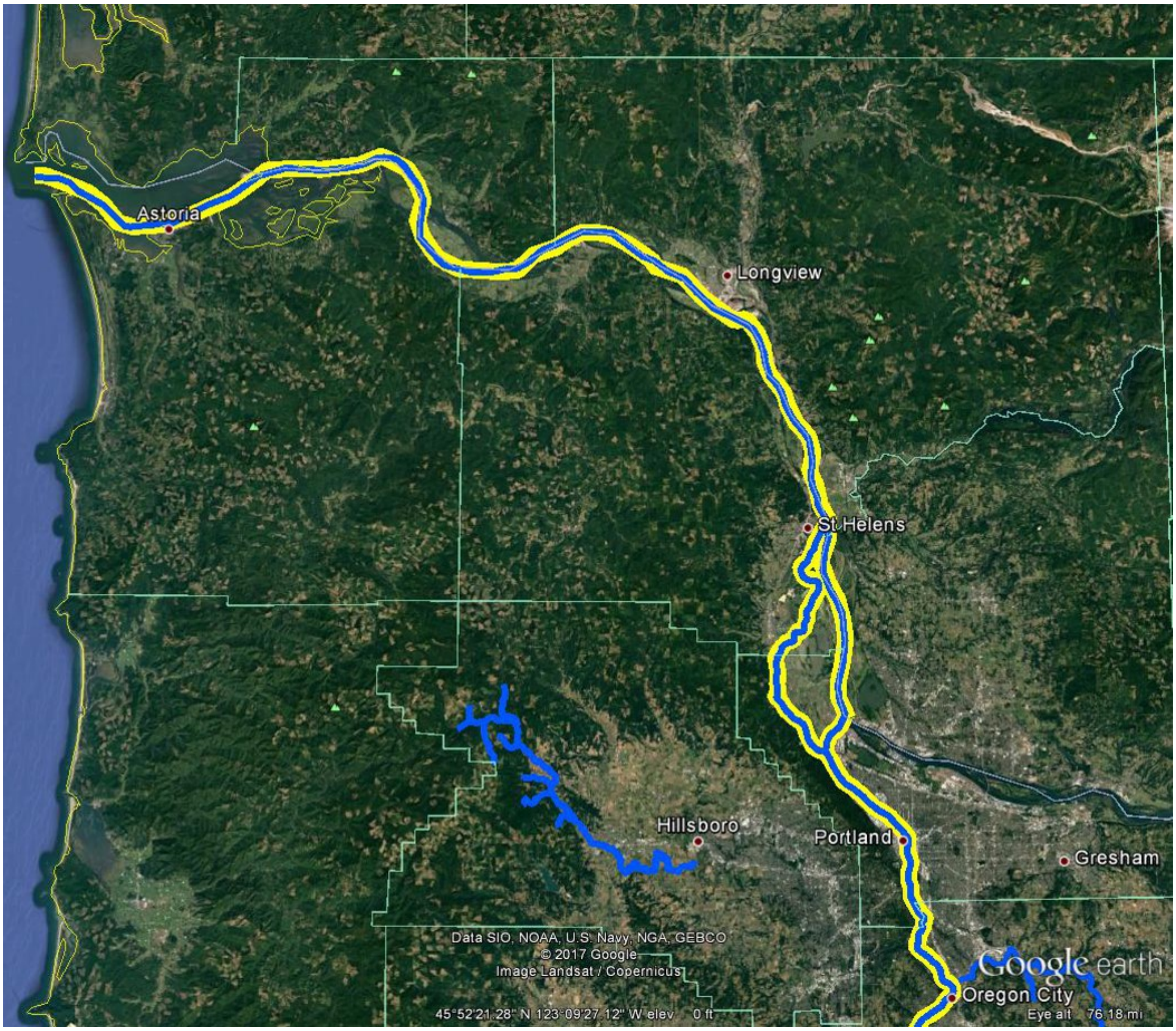


Figure 68. Geographic extent of the interaction area between hatchery fish and natural fish in the Columbia River region. The reaches where hatchery fish (from UWR releases) occur are the yellow lines. Stream reaches designated as critical habitat for UWR spring Chinook salmon and winter steelhead are identified as the blue colored lines.

2.5.2.3.5.3 Ecological Interactions in the Willamette River Basin

The primary habitat areas where hatchery smolts potentially interact with natural-origin juvenile salmon and steelhead is below the federal dams where hatchery fish are released into the mainstem tributary rivers (Figure 65; Figure 66; Figure 67; Figure 68). Hatchery Chinook salmon are released in February and March from the hatchery facilities as smolts. These fish actively emigrate downstream in the thalweg of the river and so ecological interactions with age 0 and age 1 natural-origin Chinook salmon is minimal. Age 0 Chinook salmon during this period of time are rearing in shallow water habitats near the margins of streams and rivers as winter refugia. Age 1 salmon are rearing in similar slow-water habitats until they are physiologically ready to emigrate as smolts, typically a couple months after the hatchery salmon are released. Smolt monitoring at Willamette Falls show hatchery salmon to emigrate rapidly from the hatchery to the falls, with the majority of hatchery smolts emigrating downstream of Willamette Falls within seven to ten days (Schreck et al. 1994). Interaction of hatchery and natural-origin fish in the tributary mainstem rivers is expected to last three to 10 days. The vast majority of the hatchery smolts emigrate. However, a low percentage (<5%) of salmon may residualize and not emigrate to the ocean; taking up residence in freshwater habitats before the hatcheries. However, this behavior is uncommon for hatchery Chinook salmon in the UWR (Harnish et al. 2014).

The results of our model simulations are found in Table 32. Again, these results should not be considered estimates of the actual predation and competition impact on natural-origin salmon and steelhead from hatchery-origin juveniles because, as described earlier, the PCD Risk model is not a total simulation of ecological interactions between hatchery and wild fish. Nonetheless, they are useful in that they give a sense of the magnitude of interactions that could occur under a certain set of assumptions. Based on these simulations, it appears that ecological impacts from the release of hatchery-origin fish included in the proposed action may be greatest on Lower Columbia Chinook salmon and Columbia River chum salmon The hatchery spring Chinook program exerted the greatest impact on age-0 Chinook salmon due to their smaller size compared to hatchery fish. Hatchery steelhead had the greatest impact on age-0 Chinook salmon as well due to their size differences. The situation for hatchery steelhead interacting with natural-origin salmon and steelhead below the hatcheries is greater because hatchery steelhead are larger in size (greater predation risk) and released later in the year (April) when water temperatures are higher and metabolism is also higher resulting in the need for greater food consumption. Most of the ecological effects on natural-origin ESA-listed salmon and steelhead occurred via competition. Our model runs did not result in any predation on Snake River fall Chinook and sockeye salmon and steelhead, Upper Columbia River spring Chinook salmon and steelhead, and Middle Columbia steelhead.

Table 32. Simulated natural-origin mortalities when PCD Risk model was run under the assumptions outlined in this opinion. Actual predation and competition impact on natural-origin salmon and steelhead from hatchery-origin juveniles are likely to be less, due to the conservative nature of the assumptions used in over-estimating effects. However, they are useful in that they give an example of the magnitude of interactions that could occur under a certain set of assumptions for each species.

Species (ESU/DPS)		Simulated losses of juvenile fish from competition and predation by hatchery fish	Simulated losses of adult fish equivalents (assuming recent average SARs)
Chinook Salmon	Upper Willamette River	7,495	44
	Lower Columbia River	42,151	131
	Snake River spring/summer	1,183	2
	Snake River fall	no effect	0
	Upper Columbia spring	no effect	0
Steelhead	Upper Willamette River	1,130	34
	Lower Columbia River	918	28
	Mid-Columbia River	no effect	0
	Snake River	no effect	0
	Upper Columbia River	no effect	0
Lower Columbia coho		9,396	188
Lower Columbia chum		18,152	36
Snake River sockeye		no effect	0

The hatchery summer steelhead program has risk with smolts residualizing below the point of release and never emigrating as smolts to the ocean. This is due to the natural tendencies of rainbow trout (*O. mykiss)* from the diversity of life history types including resident and anadromous life forms. In many cases, a substantial proportion of rainbow trout do not emigrate to the ocean, regardless of their parental origin. For hatchery steelhead, there is a critical threshold, where releasing the fish too early will result in higher rates of residualism, and releasing the fish too late also resulting in higher rates of residualism. Management of the hatchery steelhead program strives to release fish that are physiologically smolting and will actively emigrate. However, even under this management approach, there is always a proportion of fish that do not emigrate. The proposed action continues to volitionally release hatchery steelhead over an extended period of time, with non-migrants removed from the hatchery facilities and stocked into standing water bodies where interactions with natural-origin salmon and steelhead will not occur.

However, even under this proposed action it is still expected residualism of hatchery steelhead will occur at a low level, with densities being highest near the hatchery facility and decreasing further downstream. Harnish et al. (2014) observed 4% of the *O. mykiss* occurring in sampled sites throughout the summer in the South Santiam River being hatchery steelhead. The remaining 96% of observed *O. mykiss* were natural-origin. The hatchery steelhead were larger than their natural-origin counterparts of the same age class. Hatchery steelhead were observed emigrating from South Santiam hatchery to Willamette Falls over a period of two to four weeks. However, only 25% (approximately) of the radio tagged hatchery steelhead were detected at Willamette Falls, which raises concerns about the efficacy of the methods used to derive the estimates. A much greater proportion of hatchery steelhead should have been observed emigrating. It is expected the greatest ecological interactions between hatchery steelhead and natural-origin salmon and steelhead occurs near the hatchery facilities, where the densities of hatchery steelhead are greatest. The actual fish densities in these areas are not known, but likely to be less than habitat carrying capacity. If this is the case, competition among the species is not likely; especially since hatchery steelhead are larger in size and would prefer different microhabitat types (Kruzic 1998).

The proposed action includes the stocking of hatchery trout into many reservoirs and in some rivers for recreational fisheries. There is the possibility of negative ecological interactions between hatchery trout and natural-origin Chinook salmon and winter steelhead. Juvenile Chinook salmon are potentially present in the headwater habitats and reservoirs in the North Santiam, South Santiam, McKenzie, South Fork McKenzie, Fall Creek, and Middle Fork Willamette rivers. Winter steelhead are only present in the South Santiam above Foster Dam. No winter steelhead are outplanted above Detroit Dam. It is difficult to determine potential competitive interactions between these species in these areas due to limited information. However, available information suggests adverse ecological interactions may occur due to differences in the size of hatchery trout compared to juvenile salmon and steelhead, but competition for limited space and resources is not likely due to the amount of habitat available and current juvenile rearing densities. The number of adult salmon (and steelhead above Foster Dam) outplanted above the dams into these headwater habitats is far below the estimated carrying capacity of the rivers and reservoirs; and thus rearing densities are low.

In the rivers where hatchery trout occur, stocking typically occurs throughout the summer when the trout season is open and fishing effort is highest. The majority of Chinook salmon have emigrated to the reservoirs by early summer, and thus the interaction between juvenile salmon and hatchery trout is minimal. In the upper South Santiam River, juvenile steelhead could be present throughout the summer. Some overlap in space and time occurs for juvenile steelhead. In the reservoirs, juvenile salmon and steelhead are definitely present with high numbers of stocked hatchery trout. Given the amount of rearing habitat available in the reservoirs, it is not known if density dependent interactions are occurring, which would indicate some level of competition. The available information shows poor passage of juvenile salmon and steelhead in most reservoirs and multiple age classes reside in the reservoirs. Growth rates of juvenile salmon have been tremendous, with age-0 salmon reaching smolt size at a much earlier age than salmon rearing in the upper rivers above the reservoirs. The condition factor of reservoir-reared salmon suggests the salmon are very healthy. If competition among fish species in the reservoirs were a significant limiting factor, growth, size, and condition factor metrics would not be as great as have been observed. Therefore, it is not likely hatchery trout are resulting in adverse competitive interactions with salmon and steelhead in the areas where these trout are stocked.

Predation

Predation effects are a risk to both UWR Chinook and steelhead, but to varying degrees. The following analysis attempts to estimate the extent of the risk for each species from all of the proposed hatchery programs combined. The greatest risks from predation are from hatchery steelhead on salmon fry. Risks to winter steelhead fry (age-0) are negligible due to their later emergence timing in late spring-early summer after hatchery fish have emigrated to the ocean.

Specific studies on predation of natural-origin salmonids by hatchery fish within the UWR are very limited. Two studies have been conducted to evaluate predation by hatchery trout on natural-origin salmon and steelhead in the McKenzie River and Foster Reservoir. Hatchery trout can and do predate upon age-0 salmon and steelhead. However, the highest predation rates occurred by a few hatchery trout in areas where predation was effective. Overall, predation by hatchery trout was very low throughout the population area. Schroeder et al. (2006) captured hatchery rainbow trout and steelhead in the McKenzie River to determine the extent of predation of hatchery rainbow trout on spring Chinook salmon fry (the life stage at highest risk from rainbow trout). Juvenile salmonids were found in approximately 1.0% of the hatchery rainbow trout stomachs collected from the lower McKenzie River and Leaburg Canal intake. In Leaburg Lake and the upper McKenzie River, approximately 0.2% of the hatchery rainbow trout sampled had salmonids in their stomach. Most of the salmonids were thought to be Chinook salmon fry.
The extent of predation on Chinook fry by hatchery steelhead or rainbow trout was not estimated because of data uncertainties about digestion rates, consumption rates, sampling timing, species composition of predated fish and hatchery fish population abundance (Schroeder et al. 2006). However, it is clear the vast majority of hatchery trout did not eat other salmonids.

Naman and Sharpe (2012) reported a wide range of predation impacts from hatchery fish on natural-origin salmonids when they reviewed studies along the West Coast. Predation rates were greatest when the number of hatchery fish released was high and the release coincided with the presence of natural-origin salmonids. In most cases, predation was low overall, however, in specific circumstances and locations, hatchery fish predation could be substantial (i.e., loss of tens of thousands juvenile salmonids).

The difference in body size between the predator and prey is a reasonable indicator of predation risk between hatchery fish and natural-origin juvenile salmon and steelhead. Some reports suggest that hatchery fish can prey on fish that are up to 1/2 their own length (Pearsons and Fritts 1999; HSRG 2004) but other studies have concluded that salmonid predators prey on fish 1/3 or less their length (Horner 1978; Hillman and Mullan 1989; Beauchamp 1990; Cannamela 1992; CBFWA 1996). Hatchery fish may also be less efficient predators as compared to their natural-origin conspecifics, reducing the potential for predation impacts (Sosiak et al. 1979; Bachman 1984; Olla et al. 1998).

For the UWR, predation by hatchery fish on natural-origin salmonids does occur but the magnitude of the impact depends upon the specific circumstances. Hatchery steelhead predation upon age-0 Chinook salmon fry during April through May is likely to be the greatest threat in the UWR. Age-0 steelhead are still incubating in redds in the gravel during the period of hatchery steelhead release and thus are not susceptible to predation. For hatchery Chinook salmon, these fish are not as large as hatchery steelhead and are more similar in size to their natural-origin counterparts, which greatly reduces the risk of predation.

Cannamela (1993) evaluated predation by hatchery steelhead on Chinook salmon fry in the Snake River. This work provides consumption rates of fry by hatchery steelhead during the period of spring release with water temperatures in the range found for western Oregon streams and rivers during the same period. Using Cannamela's consumption rate calculation, we applied the following equation to estimate predation of salmon fry by hatchery steelhead for the areas where hatchery fish are released:

*Total number of Chinook salmon fry eaten = 0.000645(Cannamela's number of fry consumed by hatchery steelhead per day) *(number of hatchery steelhead released) * 7(number of days exposed to predation)*

Applying this equation provides the following estimates of predation losses of fry by hatchery steelhead in the four populations:

- North Santiam – 546 salmon fry consumed by hatchery steelhead
- South Santiam – 729 salmon fry consumed by hatchery steelhead
- McKenzie – 488 salmon fry consumed by hatchery steelhead
- Middle Fork Willamette- 397 salmon fry consumed by hatchery steelhead
- Willamette River – 2,161 salmon fry consumed by hatchery steelhead
- Total of 4,322 salmon fry consumed by hatchery steelhead in mainstem and tributary habitats

It is important to reiterate that the temporal and spatial overlap between the release of hatchery steelhead and co-occuring juvenile age-0 Chinook salmon are the reaches below the point of release from the hatcheries (Figure 65; Figure 66; Figure 67; Figure 68). Depending upon the population, the risk may be very low or moderate. In the Middle Fork Willamette, the risk of predation on juvenile Chinook is low due to few salmon occupying reaches below Dexter Dam during the time period when hatchery steelhead are released. Salmon may be present, but the vast majority of the juvenile salmon are still above Lookout Point Dam during this time period. In the McKenzie, South Santiam, and North Santiam populations, the occurrence of age-0 Chinook salmon is likely to be much greater and therefore these areas are at greater risk from predation by hatchery steelhead. However, as assessed in the previous section, the temporal overlap is likely to be short and in the range of one to two weeks exposure time, where 95% of the hatchery would have emigrated during this time period. There are significant differences in the behavior and habitat use of age-0 Chinook salmon and hatchery steelhead smolts that make the risk of predation short lived.

For perspective on the number of age-0 Chinook fry estimated to be consumed by hatchery steelhead, the number of juvenile salmon estimated to be produced from adult outplanting efforts above the federal dams ranges in the hundreds of thousands of fry produced per year. The production of fry below the federal dams where hatchery steelhead are released is unknown, but in most cases the number of salmon spawning in the overlap reach exceeds spawning above the dams (that produced the above juvenile fry estimates) by a large degree. Therefore, it is likely the production of fry produced below the federal dams could be equivalent to the number of fry produced above the federal dams. The exception is the Middle Fork Willamette River, where pre-spawning mortality rates are very high and spawning below Dexter Dam has been more limited than above the federal dams in this population area. Given the production of age-0 salmon fry below the hatchery release sites, the estimated levels of predation by hatchery steelhead are likely to have minimal impacts on the natural populations.

It is estimated that less than 26% of the juvenile Chinook salmon habitat (as indexed by ESA designated critical habitat) is exposed to hatchery steelhead releases and thus the risk of predation. From April through May, water temperatures are relatively low (45-60 F) and consequently consumption rates by steelhead are lower and the fish do not require as much food compared to higher water temperatures. If the exposure time of salmon fry to hatchery steelhead predation is less than one week in duration in tributary habitats, the estimated loss of 4,322 salmon fry to hatchery steelhead predation seems reasonable. This loss is spread across four populations of Chinook salmon. In no population would the predation loss of Chinook fry be more than one adult equivalent in each natural population (range of 0.4 to 0.7 assuming 30% conversion of fry to smolt and 0.3% smolt to adult survival).

Even though most hatchery steelhead smolts emigrate to the ocean, there is a percentage of residual hatchery steelhead that do not emigrate and reside in the mainstem tributaries for an extended period of time. These residual steelhead can continue to prey upon age-0 salmon and steelhead fry. Typically, natural habitat segregation occurs in order to minimize predation risk, with larger salmon and trout occupying riffle/glide habitat instead of slower water habitats preferred by age-0 fish (Kruzic 1998). Predation losses of fry by residual hatchery steelhead is unquantifiable at this time, but expected to be very low because of the low proportion of available habitat affected by residual steelhead below the hatchery facilities. Worst case, residual steelhead predation over an extended period of time through the spring and summer is equivalent to the emigrating smolt predation described above, which would equate to the equivalent of less than one adult salmon in each of the four Chinook populations.

Fish disease pathogen transfer and amplification

The hatchery programs will be operated in compliance with regional fish health protocols pertaining to movement and monitoring of cultured fish which helps minimize risks associated with hatchery fish (IHOT 1995). When egg-to-release survival rates are high for fish propagated in the hatchery programs that are part of the proposed action, this indicates that protocols for monitoring and addressing the health of fish in hatcheries have been effective at limiting mortality. In addition, hatchery fish from these programs emigrate to the ocean relatively quickly, limiting exposure time and/or pathogen shedding in freshwater. Although fish are monitored monthly during rearing, there are situations where fish that may be infected with pathogens are released into the watershed. Sometimes this may occur as a measure to mitigate the spread of disease further in a hatchery environment. However, this practice also may contribute to increased pathogen levels in the natural environment if the disease does occur. This is rare occurrence and used only when preventive measures do not mitigate the outbreak.

Although a variety of pathogens have been detected in Oregon hatcheries over the last few years, no novel or exotic pathogens have been found and no devastating outbreaks have occurred in UWR hatchery programs in recent years. However, it is important to note that detection of a pathogen does not mean that disease was observed. It indicates the number of epizootics (20-30 per year) occurring from some pathogens is much less than the number of pathogen detections 3,000-4,000 per year. In addition, many of the epizootics are curable using treatments approved for use in fish culture such as formalin, hydrogen peroxide, and various antibiotics.

The low frequency of epizootics from native pathogens, in combination with frequent monitoring and treatment options under current fish health policies suggest that the amplification of pathogens during rearing of fish in hatcheries on natural-origin salmon and steelhead is likely indiscernible from natural pathogen levels in the natural environment.

2.5.2.3.5.4 Ecological Interactions in the Lower Columbia River and Estuary

This section evaluates the releases of hatchery fish in the UWR and effects on salmon and steelhead co-occurring in the lower Columbia River (from the mouth of the Willamette River) downstream to the ocean. The estimated losses of salmon and steelhead in this area is described in Table 32.

The greatest likelihood for ecological interactions and competition between hatchery fish and natural-origin juvenile salmon and steelhead is in the lower Columbia River and estuary. All of the hatchery fish concentrate in this area as they emigrate to the ocean from all areas in the Columbia Basin. Hatchery Chinook salmon are released from UWR hatcheries in February through March. This period of time is earlier than natural-origin salmon and steelhead smolts emigrate to the lower Columbia River. Natural-origin fish emigrate predominately from April through June. Hatchery steelhead from UWR hatcheries are released in April and May which would overlap with natural-origin smolt emigrations. Consequently, hatchery steelhead pose the greatest risk for ecological interactions with natural-origin fish from the UWR below Willamette Falls. By this time, hatchery Chinook smolts should have already emigrated downstream and be making the transition to the ocean.

The greatest risk of adverse ecological interactions with natural-origin salmon and steelhead produced from the UWR does not come from hatchery fish released in the Upper Willamette River. UWR hatchery fish releases comprise less than 5% of the hatchery releases throughout the Columbia River Basin (Figure 29). Releases from hatchery programs that are part of the environmental baseline contribute the greatest likelihood of adverse ecological interactions because of their abundance, density, and emigration timing. Due to hatchery production reductions throughout the Columbia Basin, it is expected ecological interactions will diminish for natural-origin fish as further reform efforts are implemented. Overall hatchery production in the Columbia River Basin has been reduced from approximately 200 million fish released annually to 144 million fish released annually. This 25% reduction in releases will further reduce impacts to natural-origin fish rearing and emigrating in the Lower Columbia River and estuary.

In the areas below the Willamette River where natural-origin salmon and steelhead may be present, hatchery steelhead represent the greatest risk for predation due to their larger size. However, due to the differences in habitat preference and behavior, it is expected predation by hatchery steelhead will be limited and of short duration until steelhead smolts make the transition into saltwater.

In the area below the Willamette River, there are no additional identifiable risks from the diseases of hatchery fish on natural-origin salmon and steelhead associated with the proposed action. As the river flows downstream, the same risks would occur below the Willamette River. There are no additional impacts expected compared to the environmental baseline.

2.5.2.4 Hatchery Research, monitoring, and evaluation

The HGMPs describe hatchery-related research, monitoring, and evaluation (RME) that occurs in the population areas of the hatchery programs throughout the UWR. The primary purpose of this RME is to evaluate the effects of the hatchery program on natural-origin salmon and steelhead and the success of the hatchery program for conservation and fisheries purposes. Typical activities associated with hatchery RME include spawning ground surveys to determine the abundance and percentage of hatchery- and natural-origin spawners, genetic pedigree analyses of hatchery fish reintroduced above federal dams, evaluation of hatchery broodstocks and incorporation of natural-origin fish, creel surveys to determine harvest of hatchery fish and bycatch of natural-origin fish including catch-and-release mortality, smolt trapping to determine outmigration abundance of hatchery- and natural-origin fish, and juvenile population surveys. Most of these activities would have no (or minimal) effects on ESA-listed juvenile and adult natural-origin fish throughout the UWR. In most cases, the take of ESA-listed salmon and steelhead is incidental and all fish are released unharmed after capture.

2.5.2.4.1 UWR spring Chinook salmon: Negligible effect

2.5.2.4.1.1 Hatchery Spring Chinook Salmon

RME associated with the hatchery salmon programs occur throughout the populations to evaluate and assess the success of the reintroduction efforts using hatchery fish above the federal dams and to evaluate the effects of hatchery fish. Activities occur both out in the field and in the hatchery facilities. Most of the sampling of salmon at the hatchery facilities occurs in conjunction with regular activities. Most of the sampling in the field is incidental take where salmon may be observed and/or sampled, before being released unharmed.

For all of the RME, the information is essential to help inform management decisions related to the hatchery programs and the status of the recovery of natural populations. Activities such as genetic pedigree sampling and analyses is used to determine the success of reintroduction efforts above the federal dams and contribution of fish produced above and below the dams. Without pedigree analyses, there is no way to ascertain with confidence where natural-origin salmon are produced. In recent years, funding of this work has been terminated by the Action Agencies, even though this work is vital for measuring progress towards recovery. There is also uncertainty as to whether funding will occur to allow collection of finclip samples from salmon outplanted above and below the dams for future analyses. Discontinuing this work would inhibit pedigree analyses because it takes 4-5 years to gather enough sampling years to determine the pedigree of returning salmon.

Spawning ground surveys also occur above and below the federal dams to measure pre-spawning mortality, spawning escapement, and pHOS. These surveys are a measure of spawning success because dams counts do not factor in high pre-spawning mortality rates. Take that occurs from spawning ground surveys is in the form of harassment. Because the fish’s response to surveys is within the range of normal fish behaviors (e.g., startling, movement to a temporary location), we will not assign any take to this take pathway.

Many RME activities also occur at the collection facilities and hatchery facilities to evaluate various aspects of the hatchery program including: broodstock composition, age at return, spawn timing, survival rates, and juvenile production. In some years, specific research projects can also occur, but these activities typically span no more than three years.

For all of these RME activities, the effects on natural-origin salmon are low. Most of the effect is from observation of fish, capture and handling for sampling, and then releases unharmed. In limited circumstances, natural-origin salmon may be taken for further study, but these activities typically are evaluated on a case-by-case basis and authorized if the hatchery RME fits within the scope of the hatchery program's ESA authorization at that time.

2.5.2.4.1.2 Hatchery Summer Steelhead

No specific RME activities are proposed for the summer steelhead program that would directly affect spring Chinook salmon. All of the existing RME activities associated with this hatchery program occur as regular on-going management at the hatchery collection facilities and hatcheries. If future RME for this program is proposed, the activities will be evaluated on a case-by-case basis and authorized if the activity fits within the scope of the hatchery's ESA authorization at that time.

2.5.2.4.1.3 Hatchery Rainbow Trout

No specific RME activities are proposed for the hatchery trout program that would directly affect spring Chinook salmon. If future RME for this program is proposed, the activities will be evaluated on a case-by-case basis and authorized if the activity fits within the scope of the hatchery's ESA authorization at that time.

2.5.2.4.2 UWR winter steelhead: Negligible effect

2.5.2.4.2.1 Hatchery Spring Chinook Salmon

Related to RME activities, there is very little overlap between hatchery salmon and winter steelhead at the hatchery collection facilities and in the field. Late arriving winter steelhead may be present at fish collection facilities at Minto Dam or Foster Dam when spring Chinook salmon begin to be collected, but effects are solely from collection and handling and no adverse effects are expected from hatchery operations. All of the other RME associated with hatchery salmon occur after winter steelhead have spawned. Incidental impacts from harassment and displacement from researchers being in the water may occur on juvenile steelhead from snorkeling surveys and wading in streams during Chinook spawning surveys. Overall, these effects are negligible.

2.5.2.4.2.2 Hatchery Summer Steelhead

The primary RME activity for this program that may affect winter steelhead is spawning ground surveys during the late fall through spring. All of the effect would be incidental from researchers being present in the water and no mortality or handling is expected. Therefore, the effect on winter steelhead is negligible.

2.5.2.4.2.3 Hatchery Rainbow Trout

Occasionally RME may occur for this program to evaluate the effects of hatchery trout on juvenile steelhead and Chinook salmon in reservoirs or in rivers where hatchery fish are released. Typically the effect is incidental with all juvenile steelhead and salmon captured released unharmed. No RME is proposed. However, any future studies will be evaluated on a case-by-case basis to determine if the RME activity is within the scope of the ESA authorization for the program at that time.

2.5.2.5 Operation, maintenance, and construction of hatchery facilities

The operation, maintenance, and construction of hatchery facilities can impact ESA-listed spring Chinook salmon and winter steelhead and their habitat. No new construction of hatchery facilities is proposed in the HGMPs; just continued operation and maintenance of existing hatchery collection facilities and rearing facilities as specified in the environmental baseline. Most of the hatchery facilities are associated with the federal dams and interconnected with water sources and operation of fish ladders.

Each facility that is required to operate under a NPDES permit currently has the permit. Effluent from each facility is monitored weekly to ensure compliance with permit requirements. Any sediment from the maintenance of instream structures at hatchery facilities would be localized and temporary and would not be expected to affect ESA-listed fish.

2.5.2.5.1 UWR spring Chinook salmon: Negligible effect

2.5.2.5.1.1 Hatchery Spring Chinook Salmon

Several of the fish collection facilities have been rebuilt to lessen impacts on natural- and hatchery-origin salmon. The remaining hatchery facilities are adequate to provide protection of salmon, with the exception of the broodstock holding pond at Willamette Hatchery. At this facility, adult mortality is excessive in most years (>30%) due to the high holding densities in this small pond. Since the hatchery program is needed for conservation/reintroduction efforts in the Middle Fork Willamette population for the foreseeable future, these losses of ESA-listed hatchery and natural salmon is unacceptable. From an economic standpoint, there are additional costs associated with collecting, loading, and transporting additional numbers of broodstock up to the hatchery to account for the mortality losses.

2.5.2.5.1.2 Hatchery Summer Steelhead

Operation of the hatchery facilities for the summer steelhead program will continue to be the same as currently set forth in the environmental baseline. All operations will continue in the proposed action. There are no additional impacts expected, and current impacts are negligible.

2.5.2.5.1.3 Hatchery Rainbow Trout

There are no known issues related to raising hatchery trout for release in the UWR. Presently, the hatchery trout are raised at Desert Springs hatchery (an isolated private hatchery on spring water in central Oregon with no native fish present). The trout are transported and released directly into stocking locations. This hatchery facility does not affect spring Chinook salmon.

2.5.2.5.2 UWR winter steelhead: Negligible effect

2.5.2.5.2.1 Hatchery Spring Chinook Salmon

Operation of the hatchery facilities for the spring Chinook salmon program will continue to be the same as currently set forth in the environmental baseline. All operations will continue in the proposed action. There are no additional impacts expected, and current impacts are negligible.

2.5.2.5.2.2 Hatchery Summer Steelhead

Operation of the hatchery facilities for the summer steelhead program will continue to be the same as currently set forth in the environmental baseline. All operations will continue in the proposed action. There are no additional impacts expected, and current impacts are negligible.

2.5.2.5.2.3 Hatchery Rainbow Trout

There are no known issues related to raising hatchery trout for release in the UWR. Presently, the hatchery trout are raised at Desert Springs hatchery (an isolated private hatchery on spring water in central Oregon with no native fish are present). The trout are transported and released directly into stocking locations. This hatchery facility does not affect spring Chinook salmon.

2.5.2.6 Fisheries

Hatchery programs in the UWR produce fish for harvest. As discussed earlier, these fisheries are approved under the ESA through a separate ESA authorization (NMFS 2001a; NMFS 2001b). The effects of fisheries on ESA-listed salmon and steelhead are described in the environmental baseline. There are no changes to those baseline effects as a result of the proposed action, and effects identified in the baseline (incidental mortality associated with catch and release fishing) are expected to continue at similar levels.

2.5.2.7 Effects of the Action on Critical Habitat

2.5.2.7.1 UWR Spring Chinook Salmon: Negligible effect

2.5.2.7.2 UWR Winter Steelhead: Negligible effect

2.5.2.7.3 Lower Columbia Chinook Salmon, Coho Salmon, and Steelhead: No effect

2.5.2.7.4 Columbia River Chum Salmon: No effect

2.5.2.7.5 Snake River Spring/Summer Chinook Salmon: No effect

All of the hatchery facilities and associated fish collection facilities are currently in existence and no new building activities are included in the proposed action. The impacts of the hatchery facilities on critical habitat are specified in the environmental baseline. Therefore, no additional effects are anticipated with the implementation of the proposed action on critical habitat.

2.6 Cumulative Effects

"Cumulative effects" are those effects of future state or private activities, not involving Federal activities, that are reasonably certain to occur within the action area of the Federal action subject to consultation (50 CFR 402.02). The Federal action in this case is NMFS' issuance of an exemption from the prohibition against taking threatened species pursuant to limit 5 of the 4(d) rule for the proposed hatchery programs. Future Federal actions that are unrelated to the proposed action are not considered in this section because they require separate consultation pursuant to section 7 of the ESA.

Reasonably foreseeable future actions include actions related to forest management, land use and development, habitat restoration activities, and climate change. Hatchery programs, fisheries, federal forest management, and the operation of the Willamette Project are not included here because all of these have, and will continue to be, subject to federal section 7 ESA consultations. Many plans, regulations, and laws are in place at the local, state, and federal levels within the UWR to continue economic benefits while minimizing and/or reducing environmental degradation. However, it is unclear if these plans, regulations, and laws will be successful in meeting their environmental goals and objectives. In addition, it is not possible to predict the magnitude of effects from future timber harvest, human development, and habitat restoration with complete certainty for several reasons: (1) the activities may not have yet been formally proposed, (2) mitigation measures specific to future actions may not have been identified for many proposed projects, and (3) there is uncertainty whether mitigation measures for these actions will be fully implemented and successful. However, when combined with climate change, a general trend in expected cumulative effects can be estimated for each resource.

Because of the large geographic scope of this analysis, it is not feasible to conduct a detailed assessment of all project-level activities that have occurred, are occurring, or are planned in the future for the cumulative effects analysis area. However, this cumulative effects analysis captures the essential effects related to the range of activities occurring in the Action Area by qualitatively assessing the overall trends in cumulative effects considering past, present, and reasonably foreseeable future actions, and describing how the alternatives contribute to those trends. It should be noted that many of the actions in the Action Area which affect the listed salmon and steelhead are those actions discussed in the Environmental Baseline.

The Willamette River Basin Planning Atlas (see http://oregonstate.edu/dept/pnw-erc/; accessed November 28, 2017) evaluated the long-term, large-area perspective on the combined effects of the multiple policies and regulations affecting the quality of the environment and natural resources within the Willamette River Basin. The process[18] produced a suite of alternative potential scenarios for the future expressed as maps of land use and land cover that reflected the possible outcomes of the scenarios. The alternative evaluation included characterizing the current and historical landscape, development of two or more alternative scenarios for the future landscape that reflected varying assumptions about land and water use and the range of stakeholder viewpoints, and the likely effects of these landscape changes and alternative futures on ecological and socio-economic endpoints. Three future alternatives were evaluated; one represented the expected future landscape should current policies be implemented as written and recent trends continue, another reflected additional conservation measures to protect habitat to a greater degree, and the last loosened current policies to allow freer rein to market forces across all components of the landscape, but still within the range of what stakeholders considered plausible. The results of this analysis forms the basis for the discussion below concerning forest management and land use effects.

2.6.1 Forest Management

The modeling results of Hulse et al. (2002) suggested that under the scenario where current practices and trends continued, there would be older aged forests, primarily on federally managed lands, and the area of conifer forest that was greater than 80 year in age was reduced by 19% relative to 1990. Under the potential scenario that relaxed current land use practices, there was a greater amount of clear-cutting and less stream and riparian protection. The area of conifer forest greater than 80 years in age declined by 22% relative to 1990. Under the additional conservation measures scenario, private forestry lands included a 30-meter or wider riparian buffers on all streams, a gradual decrease in the average clear-cut size, and retention of small patches of legacy trees. The modeled result suggested that there would be a 17% increase in the area with conifer forests aged 80 years and older, relative to 1990. Still, the extent of older age conifer forest would be less than half of what occurred prior to Euro-American settlement, and result in ongoing impacts to stream habitat restoration and recovery.

2.6.2 Land Use and Development

The number of people living in the Willamette River Basin is expected to nearly double between the early 2000s and 2050 (Hulse et al. 2002). The modeling results of Hulse et al. (2002) suggested that under modeled scenarios where current practices and trends continued, new development occurred only within designated urban growth boundaries and existing rural residential zones. As a result, population density within urban areas almost doubled relative to ca. 1990 (from 9.4 residents/ha in ca. 1990 to 18.0 in 2050), while the amount of urbanized land plus land influenced by rural development increased by

[18]The Willamette Restoration Initiative was established in 1998 to develop a basin-wide strategy to protect and restore fish and wildlife habitat, increase populations of declining species, enhance water quality, and properly manage flood-plain areas – all within the context of human habitation and continued basin growth (http://www.oregonwri.org).

less than 25 percent. Surface water consumption increased by 57%, reflecting a 20% increase in diversions for municipal and industrial uses and 65-120% increase in diversions for irrigated agriculture. Demands for water for municipal, industrial, and domestic uses were met in most areas; however, stream flows declined.

Under the scenario where land use regulations were relaxed, population densities within urban growth boundaries increased by 55% (to 14.6 residents/ha) relative to 1990. Urbanized areas expanded by almost 50% and the area influenced by rural structures by 68%. Most of this new development occurred on agricultural lands. Furthermore, the location of urban growth boundaries, a consequence of historical settlement patterns, predisposes urban expansion to occupying higher quality soils and particularly valuable agricultural resource lands. Twenty-four percent of 1990 prime farmland was lost. In this scenario, water consumption for out-of-stream uses increased markedly, by 58% relative to ca. 1990.

Under the scenario with greater priority on ecosystem protection and restoration, Hulse et al. (2002) found that there was relatively little (2%) conversion of agricultural lands to urban or rural development. Yet, 15% of ca. 1990 prime farmland was still lost, converted in this scenario mostly to natural vegetation. Conservation strategies on agricultural lands included 30-meter or wider riparian buffers along all streams, conversion of some cropland to native vegetation (in particular natural grasslands, wetlands, oak savannah, and bottomland forests) in high priority conservation zones, establishment of field borders and consideration of wildlife habitat as a factor in crop selection in environmentally sensitive areas, and a 10% increase in irrigation efficiency. Areas along the Willamette River that historically had complex, dynamic channels were targeted for restoration of river habitat complexity and bottomland forest. Under this scenario, water consumption increased relative to ca. 1990, but to a somewhat lesser degree than for the other scenarios. No water planning areas were projected to have near zero flow in a moderately dry summer, although an estimated 225 km of 2nd to 4th order streams would still go dry (70% more km than ca. 1990). Continued impacts on stream and river habitat will likely occur into the foreseeable future and affect the recovery potential for salmon and steelhead in the UWR.

2.6.3 Climate Change

The effects of climate change in the UWR will be particularly impactful on spring Chinook salmon due to their life history, distribution, and abundance (Jaeger et al. 2017). Adult spring Chinook are adapted to oversummer in cool headwater pools of the Cascade Mountain Range. Climate change effects such as the warming of river temperatures during the spring, summer, and fall will greatly affect the survival of spring Chinook salmon. Myers et al. (2018) modeled significant declines in the abundance and productivity of spring Chinook salmon below federal dams in the UWR over the next 60 years. However, for the areas above the federal dams, impacts were low or negligible, with future capacity being the same as current capacity. This emphasizes the need to reintroduce spring Chinook salmon back into historic habitats above the federal dams as another way to mitigate the effects of climate change on this ESU.

Winter steelhead in the UWR will also be impacted by climate change. However, due to their life history and distribution, effects are not likely to be as extreme as for spring Chinook. Winter steelhead also have higher temperature tolerances that will enable juvenile fish to utilize habitats that will be increasingly affected by climate change.

Within the Pacific Northwest, Ford (2011) summarized expected climate changes in the coming years as leading to the following physical and chemical changes (certainty of occurring is in parentheses):

- Increased air temperature (high certainty)
- Increased winter precipitation (low certainty)
- Decreased summer precipitation (low certainty)
- Reduced winter and spring snowpack (high certainty)
- Reduced summer stream flow (high certainty)
- Earlier spring peak flow (high certainty)
- Increased flood frequency and intensity (moderate certainty)
- Higher summer stream temperatures (moderate certainty)
- Higher sea level (high certainty)
- Higher ocean temperatures (high certainty)
- Intensified upwelling (moderate certainty)
- Delayed spring transition (moderate certainty)
- Increased ocean acidity (high certainty)

These changes will affect human and other biological ecosystems within the cumulative effects analysis area. Changes to biological organisms and their habitats are likely to include shifts in timing of life history events, changes in growth and development rates, changes in habitat and ecosystem structure, and rise in sea level and increased flooding (Littell et al. 2009; Johannessen and Macdonald 2009).

For the Pacific Northwest portion of the United States, Hamlet (2011) notes that climate change will have multiple effects. Expected effects include:

- Overtaxing of storm water management systems at certain times
- Increases in sediment inputs into water bodies from roads
- Increases in landslides
- Increases in debris flows and related scouring that damages human infrastructure
- Increases in fires and related loss of life and property
- Reductions in the quantity of water available to meet multiple needs at certain times of year (e.g., for irrigated agriculture, human consumption, and habitat for fish)
- Shifts in irrigation and growing seasons
- Changes in plant, fish, and wildlife species' distributions and increased potential for invasive species
- Declines in hydropower production
- Changes in heating and energy demand
- Impacts to homes along coastal shorelines from beach erosion and rising sea levels

The most heavily affected ecosystems and human activities along the Pacific coast are likely to be near areas having high human population densities, and the continental shelves off Oregon and Washington (Halpern et al. 2009).

2.6.4 Other Restoration and Recovery Activities

To rehabilitate the negative human-induced changes that have affected critical habitat in the action areas, habitat conservation and restoration activities are occurring in the UWR. Funding for habitat conservation and restoration is likely to continue into the foreseeable future because the majority of habitat restoration projects occurs from Federal funding to the state of Oregon's Watershed Enhancement Board to local Watershed Councils for on-the-ground implementation of projects. As funding continues for habitat restoration projects, projects that reduce the most critical limiting factors and threats within the watershed will be prioritized. These habitat restoration projects will continue to enhance the conservation and recovery of the watersheds and the fish and wildlife species within them.

The Pacific Coastal Salmon Recovery Fund (PCSRF) was established by Congress to help protect and recover salmon and steelhead populations and their habitats. The states of Washington, Oregon, California, Idaho, and Alaska, and the Pacific Coastal and Columbia River tribes, receive PCSRF appropriations from NMFS each year. The fund supplements existing state, tribal, and local programs to foster development of Federal-state-tribal-local partnerships in salmon and steelhead recovery. The PCSRF has made substantial progress in achieving program goals, as indicated in annual Reports to Congress, workshops, and independent reviews.

2.7 Integration and Synthesis

The Integration and Synthesis Section is the final step in our assessment of the risk posed to species and critical habitat as a result of implementing the proposed action. In this Section, we add the effects of the action to the environmental baseline and the cumulative effects, taking into account the status of the species and critical habitat, to formulate the agency's biological opinion as to whether the proposed action is likely to: (1) Reduce appreciably the likelihood of both the survival and recovery of a listed species in the wild by reducing its numbers, reproduction, or distribution; or (2) appreciably diminish the value of designated or proposed critical habitat for the conservation of the species. This assessment is made in full consideration of the status of the species and critical habitat and the status and role of the affected population(s) in recovery.

In assessing the overall risk of the proposed action on each species, NMFS considers the risks of each factor discussed in Section 2.5, above, in combination, considering their potential additive effects with each other and with other actions in the area (environmental baseline and cumulative effects). This combination serves to translate the threats posed by each factor of the proposed action into a determination as to whether the proposed action as a whole would appreciably reduce the likelihood of survival and recovery of the listed species.

2.7.1 Upper Willamette Spring Chinook Salmon ESU

The status of UWR spring Chinook ESU remains of concern as the viability of the constituent populations continues to decline and/or has not improved (NWFSC 2015; Falcy 2018). The lack of recovery of the McKenzie River population over the last decade is of particular concern, as this core population represents the only remaining genetic legacy for the ESU. Improvements in natural-origin salmon returns in the North Santiam, South Santiam, and Fall Creek have reduced ESU risks; although the returns to these population areas are still low in abundance. The Clackamas River, a population considered now to be a stronghold, is not included in the action area, but appears to be performing better than the McKenzie population due to recent increases in abundance and thus contributes to the viability of the ESU as a whole. The populations residing above Willamette Falls appear to have different population dynamics than other populations below the falls (Falcy 2018). The recent declines observed for most populations in the ESU since NWFSC (2015), coupled with significant viability concerns identified in the last NMFS status review, make the status of the ESU precarious.

The primary limiting factors/threats facing all populations in the action area continue to be related to the loss and degradation of freshwater habitat. In the North Santiam, South Santiam, McKenzie, and Middle Fork Willamette populations, the federal dams and reservoirs continue to pose the greatest concerns for spring Chinook salmon. A significant amount of habitat for spring Chinook is currently not in production due to inadequate downstream passage facilities for juvenile salmon by the federal reservoirs and dams. With continued climate change, the need for these headwater habitats historically available for spring Chinook salmon is even more critical. Certain measures from the Reasonable and Prudent Alternative in NMFS (2008) for downstream passage facility improvements at federal dams in the North Santiam, McKenzie, and Middle Fork Willamette is behind schedule and not yet providing the intended benefits for these salmon populations. In the Molalla and Calapooia populations, land management actions resulting in habitat degradation are the primary concerns. Management actions have been identified that will improve the survival conditions for spring Chinook salmon, but much improvement is still needed for regulatory and non-regulatory activities.

Given the continued decline of the ESU as a whole and the need to re-establish Chinook salmon back in historic habitat above the federal dams, the hatchery Chinook salmon programs are providing essential benefits to the conservation and recovery of the ESU. The abundance and productivity of some populations is increasing with hatchery supplementation and will continue to under the proposed action. The spatial structure of the ESU is improving from the outplanting of hatchery fish above the federal dams for supplementation, and also improving overall diversity of the ESU. Demographic concerns from low effective population size are improved by hatchery salmon supplementation in areas above and below the federal dams in the proposed action; with the exception being the mainstem McKenzie River production area where natural production is sufficient without additional hatchery supplementation. Hatchery salmon are increasing genetic diversity of the ESU in the proposed action by increasing the return of natural-origin fish from hatchery supplementation. However, genetic risks from hatchery supplementation in the mainstem McKenzie River represents adverse risk to the long-term fitness of this genetic legacy population and will continue to be managed to attain the pHOS targets for this population. Ecological risks from the salmon hatchery programs are minimized by releasing smolts in the lower areas of the populations with minimal interactions with naturally-occurring juvenile salmon.

The benefits of hatchery supplementation have been verified through specific genetic pedigree analyses in the North Santiam, South Santiam, McKenzie, and Fall Creek (MF Willamette). The fitness of natural-origin salmon and hatchery-origin salmon have not been significantly different (Evans et al. 2016). Hatchery-origin males typically have the lowest fitness, and hatchery and natural females are about equal in fitness with spring Chinook salmon in the UWR. The hatchery stocks also contain important genetic diversity characteristics not found in the depressed natural populations (Johnson and Friesen 2013). These benefits will continue under the proposed action. Therefore, the effects of the hatchery program have to be considered in the short- and long-term. Presently, the hatchery Chinook salmon programs are providing demographic benefits such as increases in abundance, where natural-origin returns are chronically low. The hatchery programs are helping preserve and rebuild genetic resources until limiting factors are addressed, and will continue to do so. Over the long-term, there are risks with the continual use of hatchery supplementation. However, at present the demographic risks outweigh longer term genetic risks because the natural populations are at high risk of extinction (NWFSC 2015).

Management of the hatchery salmon broodstocks to minimize genetic drift and domestication is of concern, given the low numbers of natural-origin salmon available from the populations and the low numbers that have been incorporated into the broodstocks in the recent past. Under the proposed action, incorporation of natural fish into the hatchery broodstocks will occur under specific circumstances and PNI values will increase in the near term. However, high PNI values(>0.67) are not likely to occur until recovery of the natural populations occurs. Allowing some impact on the natural populations, through broodstock collection according to the criteria specified in the salmon HGMPs, will provide genetic benefits to the population while minimizing demographic risks to the extent possible. This will decrease the risks of the hatchery programs and likely aid in the recovery of natural-origin Chinook salmon, particularly since these programs are being used for reintroduction above the federal dasm. As recovery occurs from these hatchery reforms and additional actions from other sectors, natural-origin abundance will increase and the overall impacts of collecting natural fish for broodstock purposes will also decrease (i.e. taking the same number of fish from a greater population equates to lower impacts to the population). This change resulting from the proposed action will allow natural selection to dominate in an integrated population of hatchery and natural salmon.

2.7.2 Upper Willamette Winter Steelhead DPS

The viability of the Upper Willamette winter steelhead DPS continues to be of concern, particularly given increased predation of natural-origin steelhead by marine mammals at Willamette Falls (Falcy 2017). Recent returns of winter steelhead have been low. However, the return at Willamette Falls in 2018 increased as compared to 2016-2017 returns. The latest status review confirmed a threatened ESA status (NWFSC 2015).

The primary limiting factors/threats facing all of the winter steelhead populations are related to freshwater habitat capacity and productivity. In the North Santiam and South Santiam populations, the elimination of the majority of the historic habitat has substantially decreased the habitat capacity and productivity for these populations. For these populations, implementation of NMFS (2008) RPA actions will increase the viability of winter steelhead once implemented and further reduce impacts of the proposed action. In the Molalla and Calapooia populations, land management improvements have been implemented, but further reform actions are needed to help recover the habitat used by winter steelhead. For the westside tributaries of the UWR, freshwater habitat continues to be the key limiting factor/threat.

The proposed action of implementing the hatchery programs for Chinook salmon, summer steelhead, and rainbow trout will continue to have risks for the UWR winter steelhead DPS. There are no conservation/recovery benefits of these programs for ESA-listed winter steelhead. The hatchery summer steelhead program in particular represents the greatest risks to winter steelhead from the interbreeding between hatchery fish (that are not native to the DPS) and ESA-listed winter steelhead. Gene flow from hatchery steelhead to winter steelhead populations has occurred since this program was initiated over four decades ago. It is expected the proposed program will further reduce impacts to winter steelhead to the lowest levels ever recorded since the program began. Reductions in the number of hatchery summer steelhead released in the North Santiam and South Santiam will directly reduce adverse effects on listed juvenile and adult winter steelhead from past impact levels. Additional management reforms are included in the proposed action that will reduce effects of the hatchery summer steelhead program to very low levels, such as the improved trapping facility at Minto FCF, shifts to early spawn timing of summer steelhead to further segregate from winter steelhead. Our analysis above anticipates gene flow from summer steelhead to winter steelhead in the North Santiam and South Santiam populations will be less than one percent annually in the near future from the proposed action. This low level of gene flow is in the range that likely occurs naturally from straying among different DPSs in the Columbia River Basin (Grant 1997).

In evaluating the four VSP parameters for each winter steelhead population comprising the UWR winter steelhead DPS, the proposed action only affects the North Santiam and South Santiam populations because these are the only areas where summer steelhead hatchery programs occur and have the potential for direct impacts to UWR steelhead populations. The Calapooia, Molalla, and westside tributaries do not have any releases of hatchery fish (the exception being Chinook salmon are released in the Molalla River which effects are expected to be negligible as assessed above) and radio tagging studies confirm few hatchery fish straying into these areas (Jepsen et al. 2015). The summer steelhead hatchery program affects the genetic diversity VSP parameter for the North Santiam and South Santiam winter steelhead populations. Abundance, productivity, and spatial structure parameters are not principally affected by the summer steelhead hatchery program.

For the North Santiam and South Santiam rivers, abundance, productivity, and spatial structure VSP parameters will improve once production is restored in the areas above Big Cliff/Detroit and Foster/Green Peter dams in these populations. NMFS (2008) directed reintroduction of winter steelhead above Big Cliff and Detroit dams in the North Santiam population. Reintroduction of winter steelhead above these dams has not occurred yet, due to inadequate downstream passage facilities at Detroit Dam. Since there are no hatchery winter steelhead present in this population (like for spring Chinook salmon), no natural-origin winter steelhead have been outplanted above the dams because survival is too poor. Planning is underway to implement NMFS' RPA actions of improving river temperatures below the dams and improving downstream passage survival through the reservoirs/dams in this population. Once these fixes are implemented, winter steelhead will regain access to the majority of their historic habitat and recovery will likely occur. Substantial increases in natural production of winter steelhead will improve the status of this population in terms of abundance, productivity, and spatial structure. The area above the federal dams will not have any influence of hatchery summer steelhead and will be managed exclusively for winter steelhead, with no outplanting of hatchery summer steelhead. Hatchery steelhead will not be released above the dams. The area above the dams will be natural fish sanctuary area. Impacts from hatchery summer steelhead at the population level will be substantially reduced as more natural-origin winter steelhead are produced in historic habitat above the federal dams.

For the Calapooia, Molalla, and westside tributaries, the primary issues for these population areas are related to abundance and productivity VSP parameters. Most of the habitat is still accessible for winter steelhead and no hatchery programs affect diversity of these populations. Improvements to freshwater habitat will increase the abundance and productivity of winter steelhead in these areas (ODFW and NMFS 2011). The proposed action and terms and conditions in this opinion will further reduce the impacts of this hatchery program and aid in the recovery of the DPS.

At the DPS level, all winter steelhead populations are at risk. The proposed action only represents relatively minor increases in risks to the North Santiam and South Santiam populations and these populations are at moderate risk. Therefore, the proposed action will not change the risk levels for any population in the DPS.

2.7.3 Lower Columbia River Chinook Salmon, Coho Salmon, and Steelhead

The proposed action affects LCR salmon and steelhead solely through ecological interactions in the lower Columbia River as hatchery fish released from UWR hatcheries migrate as juveniles and adults from the UWR to the ocean. Age-0 fall Chinook salmon and age-0 coho salmon are at greatest risk of predation from UWR hatchery fish if they co-occur in the mainstem Lower Columbia River during the period of emigration. Overall, impacts from predation and competition is expected to be very low due to the differences in migratory behavior and life history patterns. Any additional risks at the ESU level are likely to be minimal from the proposed action on Lower Columbia River salmon and steelhead.

2.7.4 Columbia River Chum Salmon

The proposed action affects Columbia River chum salmon solely through ecological interactions in the lower Columbia River as hatchery fish released from UWR hatcheries migrate as juveniles and adults from the UWR to the ocean. Juvenile chum salmon are particularly susceptible to predation by larger salmon and steelhead. The period of interaction between UWR hatchery and chum salmon is expected to be limited. However, predation is possible, particularly if hatchery fish emigrate along the margins of the Lower Columbia River. Any additional risks at the ESU level are likely to be minimal from the proposed action on Columbia River chum salmon.

2.7.5 Snake River Spring/Summer Chinook Salmon

The proposed action affects Snake River spring/summer Chinook salmon solely through ecological interactions in the lower Columbia River as hatchery fish released from UWR hatcheries migrate as juveniles and adults from the UWR to the ocean. The ecological risks to Snake River Chinook salmon are likely to be very low from the proposed action due to the minimal level of interaction resulting from differences in peak migration periods. In addition, given the similar size and age of UWR hatchery fish and Snake River spring/summer Chinook salmon, predation is expected to be very low. Any additional risks at the ESU level are likely to be minimal from the proposed action on Snake River spring/summer Chinook salmon.

2.7.6 Critical Habitat

Critical habitat for the ESA-listed species is described in Section 2.2.2 of this opinion. After reviewing the proposed action and conducting the effects analysis, NMFS has determined that the proposed action will not impair PCEs designated as essential for spawning, rearing, juvenile migration, and adult migration purposes. In reviewing the proposed action and after conducting the effects analysis, NMFS has determined that the proposed action will not impair PCEs designated as essential for spawning, rearing, juvenile migration, and adult migration purposes as described below. The hatchery water diversion and the discharges pose negligible effects on designated critical habitat in the Action Area. Existing hatchery facilities have not contributed to altered channel morphology and stability, reduced and degraded floodplain connectivity, excessive sediment input, or the loss of habitat diversity and no new facilities are proposed.

The only effects on critical habitat from the proposed action would occur in freshwater near the hatchery from the continued operation and maintenance of the facilities. Hatchery intakes of each hatchery facility are screened where listed salmon and steelhead occur to prevent juvenile fish from injury and impingement or permanent removal from streams. Minimum flows will be maintained between the hatchery intakes and the outfalls, thus providing for fish migration through each respective geographic location. No additional construction or disturbance of riparian or streambed habitat is proposed in the HGMPs. Any impacts in the future would be negligible and entirely related to operation and maintenance.

2.8 Conclusion

After reviewing and analyzing the current status of the listed species and the critical habitat, the environmental baseline within the action Area, the effects of the proposed action, any effects of interrelated and interdependent activities, and cumulative effects, it is NMFS' biological Opinion that the proposed action is not likely to jeopardize the continued existence of Upper Willamette River spring Chinook salmon and winter steelhead, Lower Columbia River Chinook salmon, coho salmon and steelhead, Columbia River chum salmon, and Snake River spring/summer Chinook salmon in the action area, or destroy or adversely modify any designated critical habitat for these species. NMFS has specified Terms and Conditions for the proposed action that are necessary to reduce the effects of the proposed action and continue to monitor and evaluate the programs in the future.

2.9 Incidental Take Statement

Section 9 of the ESA and Federal regulations pursuant to section 4(d) of the ESA prohibit the take of endangered and threatened species, respectively, without a special exemption. "Take" is defined as to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture or collect, or to attempt to engage in any such conduct. "Harm" is further defined by regulation to include significant habitat modification or degradation that actually kills or injures fish or wildlife by significantly impairing essential behavioral patterns, including breeding, spawning, rearing, migrating, feeding, or sheltering (50 CFR 222.102). "Incidental take" is defined by regulation as takings that result from, but are not the purpose of, carrying out an otherwise lawful activity conducted by the Federal agency or applicant (50 CFR 402.02). Section 7(b)(4) and section 7(o)(2) provide that taking that is incidental to an otherwise lawful agency action is not considered to be prohibited taking under the ESA if that action is performed in compliance with the terms and conditions of this ITS.

2.9.1 Amount or Extent of Take

NMFS analyzed five factors applicable to the proposed hatchery programs in the UWR and the associated take of ESA-listed spring Chinook salmon (natural- and hatchery-origin) and winter steelhead (only natural-origin). Take is specified here for the following activities/effects:

(1) broodstock origin and collection,
(2) hatchery fish and the progeny of naturally spawning hatchery fish on spawning grounds,
(3) hatchery fish and the progeny of naturally spawning hatchery fish in juvenile rearing areas, mainstem rivers, and estuary,
(4) research, monitoring, and evaluation (RM&E) supporting hatchery program implementation, and
(5) the operation, maintenance, and construction of hatchery facilities.

2.9.1.1 Take from Broodstock Collection

Take of listed, natural-origin fish related to broodstock collection can occur in two ways: 1) direct take of natural-origin salmon directly for broodstock, identified in Table 33 below[19], and 2) incidental handling of natural-origin winter steelhead and hatchery- and natural-origin salmon while collecting broodstock for the Chinook salmon and steelhead programs. NMFS has evaluated broodstock take up to 100% of the hatchery broodstock according to the criteria specified in the salmon HGMPs. However, in the near term, take of natural-origin fish for broodstock is most likely to be in the range of zero to 30%, with corresponding impacts to the natural population less than 5%.

[19] Direct take is mentioned here solely for clarification; only take that is incidental to the proposed action is covered by this Statement. Direct take will be authorized under limit 5 of the 4(d) Rule for the spring Chinook hatchery programs.

Table 33. Number of natural-origin Chinook salmon potentially taken for broodstock purposes according to pNOB ranging from 10% to 100%. The specific criteria for the maximum allowable impact to each natural population (and corresponding numbers of fish available for broodstock) are specified in the HGMPs. Due to current low numbers of natural-origin returns in all of the populations, pNOB will likely be in the range of 10% in the near future. The Terms and Conditions specified in Section 2.9.4 below govern the approval process for taking natural-origin fish any given year.

	pNOB (percent natural-origin salmon in broodstocks)			
Spring Chinook Salmon Hatchery Program	**10%**	**30%**	**50%**	**100%**
North Santiam	54	162	270	540
South Santiam	80	240	400	800
McKenzie	52	156	260	520
Middle Fork Willamette	140	420	700	1,400

Hatchery Chinook salmon are also collected for broodstock and are also ESA-listed because they are included in the ESU. For each program identified in Table 32, up to 10,000 hatchery salmon may be collected at the fish collection facilities and hatcheries for broodstock purposes, supplementation, and/or pHOS management. Because returns of hatchery salmon varies substantially from year to year, this statement authorizes the maximum number likely to be collected for hatchery management.

Adult winter steelhead may also be encountered at the North Santiam and South Santiam fish collection facilities when broodstock are being collected. Less than 100 winter steelhead will be handled annually while broodstock collection occurs and no mortality is expected for winter steelhead as these fish are released unharmed above the dams.

Juvenile salmon and steelhead of natural-origin may be encountered during broodstock collections if these fish volitionally migrate into the fish ladders and are collected. Any ESA-listed juvenile fish captured are released back into the river unharmed and no mortality is expected. Less than 100 juvenile salmon and steelhead are expected to be handled annually during broodstock collection activities.

2.9.1.2 Take from Hatchery Fish on Spawning Grounds

Take of UWR Chinook is caused by the proposed action in the form of genetic effects where hatchery fish occur on the spawning grounds. The extent of take cannot be quantified because the take is not observable. Therefore, NMFS will rely on a surrogate, in the form of the census pHOS rate. Specifically, the surrogate will be the census pHOS rate applied to each individual population within the ESU measured as a rolling three year arithmetic mean. The three-year rolling arithmetic mean census pHOS will be measured to gauge compliance with this extent of take. NMFS expects those pHOS rates to be no greater than those listed in Table 33. Census pHOS is an appropriate surrogate for take by genetic effects because it is rationally connected to those effects by measuring the extent to which hatchery and natural-origin Chinook salmon co-occur on the spawning grounds and have the opportunity to interbreed. Census pHOS can be reasonably and reliably measured and monitored through spawning ground surveys conducted annually in each affected population.

Table 34. Take estimates of hatchery salmon spawning naturally measured by pHOS for each specific area within the populations. Values represent proportion of natural spawning comprised of hatchery salmon. Near-term is recent pHOS with hatchery supplementation. Long-term take estimates associated with pHOS are the Recovery Plan goals after successful reintroduction above the federal dams.

Population with Hatchery Salmon Program	Specific Population Area	Take estimates (near-term) pHOS for Specific Area	Near-term Population pHOS	Take estimates (long-term) pHOS
North Santiam	Above Detroit Dam	1	0.8	0.1
	Above Minto Dam-Big Cliff Dam	<0.1		
	Below Minto Dam	<0.7		
South Santiam	Above Foster Dam	<0.3	0.65	0.3
	Below Foster Dam	<0.8		
McKenzie	SF McKenzie Above Cougar Dam	1	0.35	0.1
	Above Leaburg Dam	<0.1 - 0.35		
	Below Leaburg	<0.9		
Middle Fork Willamette	Fall Creek	<0.1	0.9	0.1
	Above Dexter Dam	1		
	Below Dexter Dam	<1		

For the hatchery summer steelhead program, take caused by genetic effects of listed UWR winter steelhead occurs in the North Santiam and South Santiam rivers, through interbreeding between the hatchery and natural-origin fish. This take cannot be quantified because it cannot be reliably observed or monitored. Therefore, NMFS will rely on a surrogate measure of the incidental take, in the form of the proportion of natural-origin winter steelhead mating with hatchery-origin summer steelhead. NMFS expects this proportion to not exceed 1.15% in every population based upon a three year arithmetic mean. This ITS authorizes the proposed action, which is less than 2%, but our recent analyses conclude less than 1.15% is most probable at this time. This surrogate has a rational connection to the form of take, since interbreeding is how the take itself, the genetic introgression, occurs. This surrogate will be monitored annually by observing counts of summer and winter steelhead throughout the UWR, observing the collection of hatchery summer steelhead at the fish collection facilities, observing spawn timing of summer steelhead at the hatcheries to derive an estimate of the proportion of hatchery steelhead mating with winter steelhead in the wild. This information will inform whether the effects of the summer steelhead program are within the scope analyzed in this opinion.

2.9.1.3 Take from Hatchery Fish in Juvenile Rearing Areas

Table 32 in section 2.5.2.3 of the analysis of effects provides an estimate of the take of salmon and steelhead associated with the ecological interactions of hatchery salmon and steelhead in rearing areas. For hatchery trout, the same model cannot be used because of the different behavioral characteristics of resident trout that do not emigrate to the ocean as smolts (i.e. salmon and steelhead). Therefore, take of ESA-listed fish from hatchery trout cannot be quantified in the same manner. Therefore, NMFS will rely on a take surrogate that relies on the ability of the program to meet several parameters, which tend to stabilize the extent of take. Take is estimated to be that which would occur from ecological interactions under the following circumstances. Except as noted, failure to meet any one of the following parameters would suggest that the take associated with the proposed action has been exceeded.

Numbers of Hatchery Fish Released

- Release of hatchery smolts in any given year that is the smolt release goal for the hatchery program plus 10% for annual variability. The effects analysis considered up to this limit annually. For hatchery trout, releases within the total poundage for any given year plus 10% included in the proposed action;
- The five-year rolling average of smolt releases (or poundage for hatchery trout) for each hatchery program does not exceed the annual smolt release goal for that program. This surrogate ensures the effects are within the scope analyzed in the opinion based upon the number of hatchery fish released, while allowing some variability for any particular year (see previous bullet);

Size of Hatchery Fish Released

- A change greater than 10% of the planned average size of fish (e.g. if the average size changed from 12 fish per pound to 10 fish per pound, a 17% decrease) released for each program in the proposed action will be considered to have exceeded the expected incidental take through ecological interactions. This standard does not apply to hatchery trout, which are intentionally released at varying sizes.

Location of Where Hatchery Fish are Released

- Any change in release location from the locations identified in the HGMPs for the programs included in the proposed action must not expand the interaction area between hatchery and natural fish (see figures in effects analysis for scope of locations). If any changes are proposed, NMFS SFD (contact below) would need to review prior to being implemented to ensure the expected incidental take through ecological interactions will not be increased from the change in release location.

This approach has a rational connection to the extent of take associated with ecological effects because the relative numbers of hatchery fish released and their physical size are commensurate with the extent of the risk, and the release location is a key factor in limiting that risk. All of these matters are reliably monitored by the co-managers annually as part of their regular hatchery monitoring and reporting to NMFS. All of these metrics are available each year for evaluation.

2.9.1.4 Take by Research, Monitoring, and Evaluation Activities

All of the hatchery programs conduct research, monitoring, and evaluation (RME) periodically to evaluate program performance, the effects of hatchery fish, and the status of natural-origin populations. These activities involve primarily incidental take by observation of salmon and steelhead, but may also occasionally collect fish for sampling (e.g. genetic pedigree sampling in the wild). The majority of the expected take of natural-origin salmon and steelhead is non-lethal from observation, harassment and/or collection, where natural-origin fish may be incidentally captured, handled, and then released alive. Any mortality of salmon and steelhead would be inadvertent and accidental, unless the RME specifically needs natural-origin salmon or steelhead (e.g. direct take) for study.

Table 35 specifies the estimated take of natural-origin juvenile and adult salmon and steelhead associated with research, monitoring, and evaluation of hatchery programs authorized in this ITS. These estimates were derived from the proposed action. There may be other activities conducted in the future related to hatchery program evaluation that can be permitted as long as the maximum levels specified in Table 35 are not exceeded.

Table 35. Authorized take of natural-origin salmon and steelhead associated with annual research, monitoring, and evaluation of hatchery programs. The incidental mortality estimates are calculated as adult equivalents (juvenile and adult take combined).

Natural Population Area	Research, Monitoring, and Evaluation	Spring Chinook		Winter Steelhead	
		Harm (observe, capture, release)	Incidental (unexpected) Mortality (maximum)	Harm (observe, capture, release)	Incidental (unexpected) Mortality (maximum)
Molalla	Hatchery program monitoring, prespawning/spawning ground surveys, juvenile surveys, genetic pedigree sampling	100	2	1000	1
North Santiam		800	16	1000	1
South Santiam		1000	20	1000	1
McKenzie		3000	20	NA	NA
Middle Fork Willamette		500	10	NA	NA

2.9.1.5 Take from Operation of Hatchery Facilities

Only the take associated with the ongoing operation and maintenance of the hatchery facilities needs to be authorized in the ITS of this opinion. No new construction or modification of the hatchery facilities is included in the proposed action.

Take associated with the use of water to operate the hatchery facilities and discharge of water from the hatchery facilities is unquantifiable because it cannot be meaningfully observed. The effects on salmon and steelhead are sub-lethal, with effects primarily resulting in changes to the behavior of salmon and steelhead in the adjacent areas where the water is used and thus, cannot be measured directly.

Since take cannot be quantified, NMFS will use two surrogates for the use and discharge of water associated with the operation of the hatchery facilities and effects on ESA-listed salmon and steelhead. For take due to water quality issues, take will be considered to have been exceeded if the hatchery facilities are out of compliance with their water use permits and NPDES discharge permits. For take due to water being removed from the stream, take will be considered to have been exceeded if the use of water by the hatchery programs is in greater amounts than authorized by the hatchery's water rights permit. Each of these standards is rationally connected to the incidence of take, since take occurs in direct proportion with the amount of pollutants discharged and water withdrawn, and the water quality and the water quantity authorizations set limits on the expected uses. The surrogate can be measured and monitored by the amount of water taken and discharged daily at the hatchery (recorded by the hatchery operators) in comparison to the authorized limits in the hatchery's permits.

2.9.1.6 Summary of Expected Take of Natural-Origin Salmon and Steelhead

Using the best available information, NMFS has evaluated and estimated the take of salmon and steelhead associated with the proposed action (Table 32; Table 32; Table 35). These estimates are maximum levels and not likely to occur annually.

2.9.2 Effect of the Take

In the opinion, NMFS determined that the amount or extent of anticipated take, coupled with other effects of the proposed action, is not likely to result in jeopardy to the species or destruction or adverse modification of critical habitat.

2.9.3 Reasonable and Prudent Measures

"Reasonable and prudent measures" are nondiscretionary measures that are necessary or appropriate to minimize the impact of the amount or extent of incidental take (50 CFR 402.02).

NMFS concludes that the following reasonable and prudent measures are necessary and appropriate to minimize the effects of incidental and direct take. The specific details of these measures are included in the Terms and Conditions section below. This opinion requires the U.S. Army Corps of Engineers (Corps) and the Oregon Department of Fish and Wildlife (ODFW) to:

1. Fund and implement the hatchery programs according to the spring Chinook salmon HGMPs NMFS approved under limit 5 of the 4(d) Rule and the summer steelhead and rainbow trout HGMPs consulted upon in this opinion.

2. Minimize the effects of the hatchery programs on ESA-listed natural-origin salmon and steelhead in the North Santiam, South Santiam, McKenzie, and Middle Fork Willamette rivers.

3. Evaluate the outplanting of hatchery salmon above federal dams in establishing self-sustaining natural-origin runs in these historically accessible habitats.

4. Provide periodic progress reports on the implementation of the HGMPs.

2.9.4 Terms and Conditions

The terms and conditions described below are non-discretionary, and the Action Agencies (or any other agencies associated with the proposed actions, i.e. the ODFW) must comply with them in order to implement the Reasonable and Prudent Measures specified above (50 CFR 402.14).[20] NMFS, ODFW and the Corps have a continuing duty to monitor the impacts of incidental and direct take and must report the progress of the action and its impact on the species as specified in this Opinion and Take Statement (50 CFR 402.14). If the entity to whom a term and condition is directed does not comply with

[20] This Opinion and Incidental Take Statement are written with the understanding that action agency obligations to fund measures in the proposed action and the terms and conditions are subject to relevant appropriation proceedings.

the following terms and conditions, protective coverage for the proposed action would likely lapse. This Opinion requires the Corps and the ODFW implement the following terms and conditions:

1a. Production of hatchery spring Chinook salmon - In accordance with the proposed action, the Corps and ODFW shall ensure funding and production of hatchery spring Chinook salmon smolts for release annually in the following rivers: 704,000 in the North Santiam, 1,021,000 in the South Santiam River, 605,000 in the McKenzie River, and 1,672,000 in the Middle Fork Willamette River. Additional spring Chinook salmon production may occur according to the appropriate HGMP in order to meet federal mitigation responsibilities for fisheries (e.g. 267,000 in the Coast Fork Willamette River). If changes to production levels in the future are proposed, these changes must be consistent with the adaptive management approaches specified in the appropriate HGMP and NMFS SFD (contact below) must issue written concurrence with the change before being adopted. The levels of spring Chinook production specified above are necessary to ensure the objectives are met for hatchery broodstock, outplanting needs above federal dams, and Tribal treaty-trust responsibilities. These production levels are authorized by the Incidental Take Statement in section 2.9 above.

1b. Biometrics of hatchery salmon – The Corps and ODFW shall fund and collect information from salmon returning to collection facilities to determine sex ratio, length, and age of hatchery and natural-origin salmon. This data is essential to monitor trends in hatchery domestication and selection. The funding of this action between the Corps and ODFW should be allocated according to the cost sharing for each hatchery salmon program, or as otherwise mutually agreeable between these agencies.

2a. Use of natural-origin salmon for broodstock - The ODFW, in collaboration with the Corps, shall develop and send to NMFS SFD a written proposal for the use of natural-origin spring Chinook salmon for broodstock prior to June 1st each year. The document will include how the HGMP criteria are met for natural-origin broodstock use and estimated impact to the natural population. NMFS SFD shall concur with the proposal prior to implementation. In-season adjustments can be made as real-time information on the returns of adult salmon occurs at the various fish collection facilities throughout the UWR. NMFS SFD must concur with any in-season modifications before being implemented.

2b. Count salmon at Bennett Dams - In accordance with the proposed action, the Corps and ODFW shall fund and operate the fish counting stations throughout the entire spring Chinook salmon migration in the fish ladders at upper and lower Bennett dams on the North Santiam River. The existing fish ladders on these dams allow for the enumeration of returning salmon to this river. The Corps and ODFW shall seek to obtain permission from the City of Salem and Santiam Water Control District (owners of these dams) to continue to count fish at these dams; as no other options are available in the lower North Santiam River. The purpose of this information is to estimate the number of natural-origin salmon returning to this population and allowable numbers of natural-origin salmon that can be collected and integrated into the North Santiam hatchery salmon broodstock. Without run size information, impacts from hatchery broodstock integration cannot be determined. These counts will also provide estimates of pHOS. The funding of this action between the Corps and ODFW will be allocated according to the cost sharing for this entire program (operations at Minto Fish Collection Facility and Marion Forks Hatchery), or as otherwise mutually agreeable between these agencies.

2c. Count salmon at Lebanon Dam - The Corps and ODFW shall fund and operate a fish counting station throughout the entire spring Chinook salmon migration in the fish ladders at Lebanon Dam on the South Santiam River. The existing fish ladder on this dam allow for the enumeration of returning salmon to this river. The Corps and ODFW shall seek to obtain permission from the city of Albany (owner of the dam) to continue to count fish here; as no other options are available in the lower South Santiam River. The purpose of this information is to estimate the number of natural-origin salmon returning to this population and allowable numbers of natural-origin salmon that can be collected and integrated into the South Santiam hatchery salmon broodstock. Without run size information, impacts from hatchery broodstock integration cannot be determined. These counts will also provide estimates of pHOS. The funding of this action between the Corps and ODFW will be allocated according to the cost sharing for this entire program (operations at Foster Fish Collection Facility and South Santiam Hatchery), or as otherwise mutually agreeable between these agencies.

2d. Count salmon at Leaburg Dam - The Corps and ODFW shall fund and operate a fish counting station throughout the entire spring Chinook salmon migration in the fish ladders at Leaburg Dam on the McKenzie River. The existing fish ladders on this dam allow for the enumeration of returning salmon to this river. The Corps and ODFW shall seek to obtain permission from the Eugene Water and Electric Board (owner of the dam) to continue to count fish here; as no other options are available in the lower McKenzie River. The purpose of this information is to estimate the number of natural-origin salmon returning to this population and allowable numbers of natural-origin salmon that can be collected and integrated into the McKenzie hatchery salmon broodstock. Without run size information, effects from hatchery broodstock integration cannot be determined. These counts will also provide estimates of pHOS. The funding of this action between the Corps and ODFW will be allocated according to the cost sharing for this entire program (operations at McKenzie hatchery), or as otherwise mutually agreeable between these agencies.

2e. Reduce pHOS in the McKenzie River – In accordance with the proposed action, the Corps and ODFW shall implement and evaluate actions intended to reduce pHOS in the McKenzie River according to the HGMP. These actions include: smolt production reductions to 604,750 annual release, improvements to the entrance of the fish ladder at McKenzie hatchery, improvements to the water supply at McKenzie River, and removing hatchery salmon at Leaburg Dam. The Corps and ODFW shall explore possibilities to remove hatchery salmon from the existing fish ladders at Leaburg Dam in the most cost-effective manner while minimizing impacts to natural-origin salmon. The funding of these actions and evaluation should be allocated according to the cost sharing for this entire program, or as otherwise mutually agreeable between these agencies. Any plans for actions in the future must be sent to NMFS SFD (contact below) at least 60 days prior to adoption for review and concurrence.

2f. Improve broodstock holding at Willamette Hatchery – The Corps shall fund the design and construction of an improved broodstock holding facility at Willamette Hatchery in order to reduce the prespawning mortality of hatchery broodstock (including natural-origin salmon authorized by NMFS under limit 5 of the 4(d) Rule). The HGMP identified this fix as a critical need. The Corps is the owner of Willamette Hatchery and funds the spring Chinook salmon program in the Middle Fork Willamette River. The design will follow criteria and standards approved by NMFS at other facilities recently improved in the UWR for adult salmon holding, survival, and spawning (e.g. Minto, Foster FCFs). Once funding is obtained, design and specifications of the improved broodstock facility shall be provided to NMFS SFD (contact below) by the end of fiscal year (FY) following the Corps receiving funding. Construction of the new facility shall be completed by the end of FY after the design and specifications have been provided and concurred with by NMFS SFD (contact below).

2g. Analyze steelhead genetics – The ODFW shall fund and implement genetic sampling of *O. mykiss* in the North Santiam basin and South Santiam basin below the federal dams to determine the effectiveness of hatchery summer steelhead reforms. Study design will focus on determining current gene flow (introgression) from non-native steelhead into natural populations. Sampling should occur by the end of fiscal year 2021 (after production reductions in the South Santiam) and every five years after that. ODFW shall get written concurrence from NMFS SFD on the most appropriate sampling, genetic markers, and analytical approaches to answer management objectives. Results shall be sent to the NMFS SFD (contact below) within 90 days of all samples being processed.

2h. Assess future effects of hatchery summer steelhead in the North and South Santiam Rivers– The ODFW shall implement the reform actions included in the summer steelhead HGMP (2018). These actions are expected to further reduce the effects of this hatchery program and equate to less than 2% gene flow in any winter steelhead population in the DPS (HGMP Indicator 3.4.1). If these actions do not limit gene flow from summer steelhead to ESA-listed winter steelhead populations to less than 2% (as described in the HGMP and the Incidental Take Statement, section 2.9 above), further reductions in the release of hatchery summer steelhead in these rivers shall be implemented. If these actions do result in the intended level of benefits to ESA-listed winter steelhead, or if new science demonstrates a lowered level of risk to native winter steelhead in the North and South Santiam (where hatchery steelhead are released), increasing the stocking levels for the summer steelhead program may be reconsidered. NMFS SFD (contact below) must issue written concurrence of any changes to the summer steelhead hatchery program before being implemented by ODFW.

3a. Assess genetic pedigree of Chinook salmon – In accordance with the proposed action, the Corps shall fund the collection of tissue samples throughout the entire run annually for genetic pedigree determination from all spring Chinook salmon outplanted above the Corps' Detroit, Foster, and Cougar dams from now until a long-term juvenile fish passage solution is completed. The Corps shall fund pedigree analysis of tissue samples for previous year's samples collected since 2010 and including up to adult Chinook returns in 2019 with results being available by the end of fiscal year 2020, except where already analyzed. Additional pedigree analysis will occur from each area every five years (beginning in 2024; or more often if determined necessary by NMFS SFD in coordination with WATER technical committees) to inform specific actions to achieve HGMP outplanting program goals. Each five year analysis will include the previous five years of samples (e.g. 2020-2024) with results being available by the end of the following fiscal year (e.g. 2025). This data is essential to guide management decisions for natural-origin salmon collected at the federal dams according to the HGMP replacement criteria, evaluate the genetic effects of hatchery salmon in reintroduction efforts above federal dams, and to determine natural production by hatchery- and natural-origin salmon above federal dams. Sampling salmon in reaches below the Corps dams should also be analyzed periodically (e.g. every 5 years) to determine the extent salmon produced above the dam(s) are spawning below the dam(s). All results from pedigree analyses shall be sent to NMFS SFD (contact below) by the end of the appropriate fiscal year.

3b. Assess salmon spawning above federal dams – The Corps shall fund surveys for spring Chinook salmon above Detroit and Cougar dams to determine prespawning mortality and the distribution and abundance of hatchery- and natural-origin spawners. In the event marked hatchery salmon are outplanted above Foster Dam in the future, spawning surveys will need to be conducted there as well (presently no hatchery supplementation occurs above Foster Dam). This information is essential to evaluate the success of the outplanting program for reintroducing salmon above federal dams, collection and transport protocols, and the genetic pedigree analyses in 3a. Due to high prespawning mortality of salmon, these data are essential for determining actual spawning escapement and distribution that cannot be attained otherwise. Annual surveys will continue until <20% of the Chinook salmon outplanted above a given dam are hatchery fish (adipose finclipped), or until the NMFS SFD, in coordination with WATER, determines information is adequate to meet HGMP goals for the outplanting program. The surveys shall follow established protocols currently used by the Corps and ODFW and include the collection and analyses of coded wire tags, fin clips, scales, and otoliths as appropriate. Spawning ground surveys for salmon below federal dams are lower priority and should be implemented to monitor trends in pHOS and prespawning mortality, unless counts at Bennett, Lebanon and Leaburg dams are determined to be adequate by the NMFS SFD (contact below), in coordination with WATER, to evaluate pHOS and abundance trends.

3c. Adaptively manage hatchery salmon outplanting above federal dams – Formal reintroduction plans are to be completed by ODFW and NMFS prior to the completion of the long-term juvenile fish passage solutions at federal dams. These plans will incorporate the best available science to ensure the goals and objectives for establishing sustainable populations of Chinook salmon above federal dams are achieved according to the Recovery Plan (ODFW and NMFS 2011), while minimizing the effects of hatchery fish on natural populations. The outplanting protocols and guidelines currently specified in the HGMPs may need to be adapted in the future according to these Reintroduction Plans. Updates could include modifications to the number of hatchery Chinook salmon outplanted, criteria for when a reduction in hatchery supplementation occurs, and criteria for outplanting of natural-origin salmon above federal dams. Prior to any changes, the ODFW, in collaboration with the Corps, shall submit proposed plans to the NMFS SFD for review and obtain concurrence from NMFS prior to modification of the HGMP(s) and implementation.

4a. ODFW's Willamette Chinook Salmon Database – the Corps, ODFW, and any associated contractors shall use ODFW's existing databases for inputting research, monitoring, and evaluation associated with these Terms and Conditions in the future to maintain appropriate protocols and data sets. Information included in this database shall be made available to NMFS and the Corps as needed. Note: the Coded Wire Tag (CWT) database is not an ODFW database and not considered part of this specific action.

4b. The ODFW, in collaboration with the Corps, shall provide a report to NMFS SFD every three years on the implementation of the spring Chinook salmon HGMPs, specifically describing:

a. The number of natural-origin salmon collected and used for broodstock
b. The impact of broodstock integration on the respective natural-origin population, with reference to the HGMP criteria for maximum impact levels.
c. The proportion of hatchery- and natural-origin salmon spawning in their respective population areas (pHOS).

d. The total number of hatchery salmon released by brood year for the programs operating in the UWR.
e. Any proposed changes to the HGMPs and/or future hatchery production.
f. These reports in written form shall be sent to:

NMFS – Sustainable Fisheries Division (SFD)
Anadromous Production and Inland Fisheries Program
1201 N.E. Lloyd Boulevard, Suite 1100
Portland, Oregon 97232

Technical Contact:
Lance Kruzic , lance.kruzic@noaa.gov
(541) 957-3381

2.10 Conservation Recommendations

Section 7(a)(1) of the ESA directs Federal agencies to use their authorities to further the purposes of the ESA by carrying out conservation programs for the benefit of the threatened and endangered species. Specifically, conservation recommendations are suggestions regarding discretionary measures to minimize or avoid adverse effects of a proposed action on listed species or critical habitat or regarding the development of information (50 CFR 402.02).

NMFS has identified the following conservation recommendation appropriate to the proposed action:

1. The Corps and ODFW shall implement the hatchery reform actions as stated in section 1.1.6 of the HGMPs to the extent possible in order to further reduce any adverse effects of the programs on natural salmon and steelhead populations and their environment.

2. ODFW and NMFS should develop a reintroduction plan for the potential use of hatchery salmon to jumpstart the recovery of spring Chinook salmon in the Calapooia River taking into account the key limiting factors/threats identified in the UWR Recovery Plan.

3. The ODFW should fund a genetic pedigree analysis of spring Chinook salmon in the Molalla River to quantify the relative reproductive success of hatchery- and natural-origin salmon. Presently, most of the spawning salmon are of hatchery-origin. However, no information is available on the proportion of offspring being produced by hatchery- or natural-origin salmon.

2.11 Reinitiation of Consultation

This concludes formal consultation for NMFS' evaluation of HGMPs for spring Chinook salmon, summer steelhead, and rainbow trout programs in the UWR.

As 50 CFR 402.16 states, reinitiation of formal consultation is required where discretionary Federal agency involvement or control over the action has been retained or is authorized by law and if:(1) The amount or extent of incidental taking specified in the ITS is exceeded, (2) new information reveals effects of the agency action that may affect listed species or critical habitat in a manner or to an extent not considered in this opinion, (3) the agency action is subsequently modified in a manner that causes an effect on the listed species or critical habitat that was not considered in this opinion, or (4) a new species is listed or critical habitat designated that may be affected by the action.

2.12 "Not Likely to Adversely Affect" Determinations

There are ESA-listed species in this consultation where NMFS determined the proposed action "may affect, but not likely to adversely affect" these species. For these determinations, the effects of the proposed action are expected to be discountable, insignificant, or completely beneficial. Discountable effects are those effects that are extremely unlikely to occur. Insignificant effects relate to the magnitude of the impact where the action should never reach the scale where "take" occurs. Beneficial effects are contemporaneous positive effects without any adverse effects to the species. Refer to the biological opinion for a description of the proposed action and action area. The following species in Table 36 are included as may affect, but not likely to adversely affect determinations for this consultation.

For all of these species, they may potentially be in the lower Columbia River and estuary when UWR hatchery fish are also present. A further assessment of these determinations is included below.

Table 36. Listing status and critical habitat designations for species considered in this opinion. (Listing status: 'T' means listed as threatened under the ESA; 'E' means listed as endangered.)

SPECIES	LISTING STATUS	CRITICAL HABITAT
Chinook salmon (*Oncorhynchus tshawytscha*)		
Upper Columbia River spring-run	E: 6/28/05 (NMFS 2005c)	09/02/05 (NMFS 2005d)
Snake River fall-run	T: 6/28/05 (NMFS 2005c)	12/28/93 (NMFS 1993)
Sockeye salmon (*O. nerka*)		
Snake River	E: 6/28/05 (NMFS 2005c)	12/28/93 (NMFS 1993)
Steelhead *(O. mykiss)*		
Middle Columbia River	T: 1/5/06 (NMFS 2006b)	09/02/05 (NMFS 2005d)
Upper Columbia River	T: 8/24/09	09/02/05 (NMFS 2005d)
Snake River Basin	T: 1/5/06 (NMFS 2006b)	09/02/05 (NMFS 2005d)
Green Sturgeon *(Acipenser medirostris)*		
Southern DPS of Green Sturgeon	E: 4/7/06 (NMFS 2006c)	10/09/09
Killer Whales *(Orcinus orca)*		
Southern Resident DPS Killer Whales	E: 11/18/05 (NMFS 2005e)	11/29/06 (NMFS 2006d)
Eulachon *(Thaleichthys pacificus)*		
Southern DPS	T: 3/18/10	10/20/11

Other ESA-listed Salmon and Steelhead

ESA-listed salmon and steelhead produced in the Middle Columbia, Upper Columbia, and Snake Basin may be present in the lower Columbia River (below the mouth of the Willamette River) when UWR hatchery fish are also present. However, the co-occurrence of these species and UWR hatchery fish is extremely unlikely. ESA-listed fish from the Lower Columbia ESUs and DPS and chum salmon are evaluated in the opinion above.

For ESA-listed salmon and steelhead included in Table 36, the potential effect is entirely related to ecological interactions of juvenile and adult salmon and steelhead potentially coinciding together in the lower Columbia River. Based upon the best available information related to run timing of adult fish and emigration timing of juvenile fish, the potential for co-occurrence is unlikely. Our evaluation of ecological interactions of juvenile fish using PCDRisk showed no expected adverse effects. Juvenile interactions between UWR hatchery fish and natural-origin salmon and steelhead from these ESUs and DPSs are negligible due to 1) the relatively low number of hatchery fish releases from the UWR (4% of total) compared to all other hatchery fish coinciding in the lower Columbia River (Figure 29), and 2) their differences in emigration timing; where there is only some overlap in space and time (Table 32).

For the adult life stage, adult hatchery fish from the UWR may be present with adults migrating back to other production areas in the Columbia River. Due to the limited overlap in space and time (February through June), these ecological interactions are not expected to be adverse and entirely negligible. There is no information suggesting hatchery fish migrating upriver with natural-origin fish in the Lower Columbia would cause an adverse effect on listed salmon and steelhead.

Green sturgeon

The southern green sturgeon DPS includes all natural populations of green sturgeon that spawn south of the Eel River in Humboldt County, California. Critical habitat is designated for the lower Columbia River up to Rkm 74. The proposed action would increase the prey base of salmonids potentially available to green sturgeon from the release of hatchery fish (both juvenile and adult hatchery fish). Negative ecological impacts from the proposed action are not likely due to the size of green sturgeon (sub-adult and adult), differential habitat use, and life histories. Water quality and quantity effects from the operation of the hatchery facilities on green sturgeon critical habitat in estuarine waters is discountable due to the short-lived effect of hatchery effluent in upstream streams and rivers. We conclude green sturgeon may be affected, but are not adversely affected by the proposed action.

Eulachon

Eulachon are present in the Lower Columbia River and some of the larger tributaries. Critical habitat is designated for eulachon in the lower Columbia River and UWR hatchery fish are present only in this area. The overlap between eulachon and UWR hatchery fish is from February through June in the lower Columbia River. Eulachon would be migrating up the lower Columbia River to spawn and UWR hatchery fish would emigrating to the ocean as juveniles and upstream as adults. Potential adverse effects are unlikely due to differences in habitat use and behavior between eulachon and hatchery fish. Hatchery fish are readily emigrating to the ocean and not rearing in the river. The operation of the hatchery facilities will not affect eulachon because the fish are not present in the UWR. Given the potential for interaction between UWR hatchery fish and eulachon is entirely ecological in the action area, eulachon may be affected, but not likely to be adversely affected.

Southern Resident Killer Whales

Southern resident killer whales reside predominantly in the Strait of Juan de Fuca and Puget Sound regions during late spring through summer. During this period, these killer whales feed predominantly on returning Chinook salmon to the region, with selective preference given to consuming the older and largest Chinook salmon (Hanson et al. 2010). During the fall and winter periods, southern resident killer whales have been observed outside the Puget Sound Region, ranging from central California to northern Vancouver Island, Canada (Hilborn et al. 2012). While Chinook salmon still continues to be the preferred prey species of these killer whales, other marine species such as lingcod, greenling, sole, sablefish, and squid have also been observed in their diet (NMFS 2014[21]). The limited data available suggest the highest likelihood of southern resident killer whales being found potentially off the mouth of the Columbia River is from late fall through early spring. The occurrence of killer whales along the Oregon-Washington coasts likely varies from year to year, but known southern resident killer whales have been observed off these coasts several times over the last decade. During the period when killer whales are most likely to be present along the Oregon-Washington coasts (late fall through early spring), a mixture of Chinook salmon stocks originating from California to southeast Alaska have been found (Weitkamp 2010). Therefore, Chinook salmon potentially consumed by killer whales would not be solely from the UWR hatchery programs, and only a small percentage of the total abundance of Chinook salmon would be from the proposed hatchery programs described herein, based on the abundance of hatchery-origin Chinook salmon relative to total Chinook salmon. In addition to Chinook salmon, a variety of other salmonids and marine species are also available for consumption by killer whales along the Oregon-Washington coasts.

The proposed action includes the release of hatchery Chinook salmon which are a preferred prey source for these killer whales. Therefore, NMFS has determined the proposed action may affect killer whales, but the effects are not likely to be adverse. The proposed action will affect the natural production of salmon (the effects of hatcheries on natural-origin salmon), as evaluated above, and the proposed action increases the prey base of Chinook salmon for killer whales. Based on this, NMFS believes in total, the proposed action will not adversely affect Southern Resident killer whales.

[21] Information available from:
http://www.westcoast.fisheries.noaa.gov/protected_species/marine_mammals/killer_whale/index.html. Accessed February 13, 2014.

3 MAGNUSON-STEVENS FISHERY CONSERVATION AND MANAGEMENT ACT ESSENTIAL FISH HABITAT CONSULTATION

Section 305(b) of the MSA directs Federal agencies to consult with NMFS on all actions or proposed actions that may adversely affect EFH. The MSA (section 3) defines EFH as “those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity.” Adverse effect means any impact that reduces quality or quantity of EFH, and may include direct or indirect physical, chemical, or biological alteration of the waters or substrate and loss of (or injury to) benthic organisms, prey species and their habitat, and other ecosystem components, if such modifications reduce the quality or quantity of EFH. Adverse effects on EFH may result from actions occurring within EFH or outside of it and may include site-specific or EFH-wide impacts, including individual, cumulative, or synergistic consequences of actions (50 CFR 600.810). Section 305(b) also requires NMFS to recommend measures that can be taken by the action agency to conserve EFH.

This analysis is based, in part, on the EFH assessment provided by the NMFS and descriptions of EFH for the Pacific Coast groundfish (Pacific Fishery Management Council [PFMC] 2005), coastal pelagic species (CPS) (PFMC 1998), Pacific Coast salmon (PFMC 2014); and highly migratory species (HMS) (PFMC (2007)**]** contained in the fishery management plans developed by the PFMC and approved by the Secretary of Commerce.

3.1 Essential Fish Habitat Affected by the Project

The PFMC described and identified EFH for groundfish, coastal pelagic species, and Pacific coast salmon. The proposed action and action area for this consultation are described in the Introduction and Section 2.3 of this document. The action area includes areas designated as EFH for various life-history stages of groundfish, coastal pelagic species, and Pacific Coast salmon.

3.2 Adverse Effects on Essential Fish Habitat

See Section 2.4 of the biological opinion for a description of the adverse effects on anadromous species habitat for Pacific salmon (e.g. Chinook salmon). The effects of the action, as proposed, on Pacific Coast Salmon are similar to those described above in the ESA portion of this document. The estuarine and marine habitats potentially occupied by marine groundfish, and coastal pelagic species are not affected because no hatchery facilities occur in these areas.

NMFS concludes that the proposed action will have no adverse effects on EFH designated for Pacific Coast salmon in freshwater habitats where the operation of hatchery facilities and associated ancillary sites and activities occur. Pacific salmon, groundfish, and coastal pelagic species will not be adversely affected in estuaries.

3.3 Essential Fish Habitat Conservation Recommendations

NMFS does not have any EFH conservation recommendations for the operation and maintenance of the hatchery facilities assessed in this opinion.

3.4 Statutory Response Requirement

As required by section 305(b)(4)(B) of the MSA, the Federal agency must provide a detailed response in writing to NMFS within 30 days after receiving an EFH Conservation Recommendation from NMFS. Such a response must be provided at least 10 days prior to final approval of the action if the response is inconsistent with any of NMFS' EFH Conservation Recommendations, unless NMFS and the Federal agency have agreed to use alternative time frames for the Federal agency response. The response must include a description of measures proposed by the agency for avoiding, mitigating, or offsetting the impact of the activity on EFH. In the case of a response that is inconsistent with NMFS Conservation Recommendations, the Federal agency must explain its reasons for not following the recommendations, including the scientific justification for any disagreements with NMFS over the anticipated effects of the action and the measures needed to avoid, minimize, mitigate, or offset such effects [50 CFR 600.920(k)(1)].

In response to increased oversight of overall EFH program effectiveness by the Office of Management and Budget, NMFS established a quarterly reporting requirement to determine how many conservation recommendations are provided as part of each EFH consultation and how many are adopted by the action agency. Therefore, we ask that, in your statutory reply to the EFH portion of this consultation, you clearly identify the number of conservation recommendations accepted.

3.5 Supplemental Consultation

The co-managers must reinitiate EFH consultation with NMFS if the proposed action is substantially revised in a way that may adversely affect EFH, or if new information becomes available that affects the basis for NMFS' EFH conservation recommendations [50 CFR 600.920(l)].

4 DATA QUALITY ACT DOCUMENTATIONAND PRE-DISSEMINATION REVIEW

Section 515 of the Treasury and General Government Appropriations Act of 2001 (Public Law 106-554) ("Data Quality Act") specifies three components contributing to the quality of a document. They are utility, integrity, and objectivity. This section of the opinion addresses these DQA components, document compliance with the Data Quality Act, and certifies that this opinion has undergone pre-dissemination review.

4.1 Utility

Utility principally refers to ensuring that the information contained in this consultation is helpful, serviceable, and beneficial to the intended users. NMFS has determined, through this ESA section 7 consultation that operation of the UWR hatchery programs as proposed will not jeopardize ESA-listed species and will not destroy or adversely modify designated critical habitat. Therefore, NMFS can issue an ITS. The intended users of this opinion are ODFW (operator), Corps (funding agency), and NMFS (regulatory agency). The scientific community, resource managers, and stakeholders benefit from the consultation through adult returns of program-origin salmon to the rivers and streams in the UWR, and through the collection of data indicating the potential effects of the hatchery programs on the viability of natural coho populations of UWR spring Chinook salmon ESU and winter steelhead DPS. This information will improve scientific understanding of hatchery-origin steelhead effects on natural populations that may be applied broadly within the Pacific Northwest area for managing benefits and risks associated with hatchery operations. This opinion will be posted on the NMFS West Coast Region web site (http://www.wcr.noaa.gov). The format and naming adheres to conventional standards for style.

4.2 Integrity

This consultation was completed on a computer system managed by NMFS in accordance with relevant information technology security policies and standards set out in Appendix III, "Security of Automated Information Resources," Office of Management and Budget Circular A-130; the Computer Security Act; and the Government Information Security Reform Act.

4.3 Objectivity

Information Product Category: Natural Resource Plan

Standards: This consultation and supporting documents are clear, concise, complete, and unbiased, and were developed using commonly accepted scientific research methods. They adhere to published standards including the NMFS ESA Consultation Handbook, ESA Regulations, 50 CFR 402.01 *et seq*., and the MSA implementing regulations regarding EFH, 50 CFR 600.920(j).

Best Available Information: This consultation and supporting documents use the best available information, as described in the references section. The analyses in this biological opinion/EFH consultation contain more background on information sources and quality.

Referencing: All supporting materials, information, data, and analyses are properly referenced, consistent with standard scientific referencing style.

Review Process: This consultation was drafted by NMFS staff with training in ESA and MSA implementation, and reviewed in accordance with West Coast Region ESA quality control and assurance processes.

5 REFERENCES

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6 APPENDIX

Table 1. Species of fishes with designated EFH occurring in the Northeast Pacific Ocean.

Groundfish Species	redstriperockfish *S. proriger*	Dover sole *Microstomus pacificus*
spiny dogfish *Squalus acanthias*	rosethorn rockfish *S. helvomaculatus*	English sole *Parophrys vetulus*
big skate *Raja binoculata*	rosy rockfish *S. rosaceus*	flathead sole *Hippoglossoides elassodon*
California skate *Raja inornata*	rougheye rockfish *S. aleutianus*	petrale sole *Eopsetta jordani*
longnose skate *Raja rhina*	sharpchin rockfish *S. zacentrus*	rex sole *Glyptocephalus zachirus*
ratfish *Hydrolagus colliei*	splitnose rockfish *S. diploproa*	rock sole *Lepidopsetta bilineata*
Pacific cod *Gadus macrocephalus*	striptail rockfish *S. saxicola*	sand sole *Psettichthysmelanostictus*
Pacific whiting (hake) *Merluccius productus*	tiger rockfish *S. nigrocinctus*	starry flounder *Platichthysstellatus*
black rockfish *Sebastes melanops*	vermilion rockfish *S. miniatus*	arrowtooth flounder *Atheresthesstomias*
bocaccio *S. paucispinis*	yelloweyerockfish *S. ruberrimus*	
brown rockfish *S. auriculatus*	yellowtail rockfish *S. flavidus*	**Coastal Pelagic Species**
canary rockfish *S. pinniger*	shortspine thornyhead *Sebastolobus alascanus*	anchovy *Engraulis mordax*
China rockfish *S. nebulosus*	cabezon *Scorpaenichthys marmoratus*	Pacific sardine *Sardinops sagax*
copper rockfish *S. caurinus*	lingcod *Ophiodon elongatus*	Pacific mackerel *Scomber japonicus*
darkblotch rockfish *S. crameri*	kelp greenling *Hexagrammos decagrammus*	market squid *Loligo opalescens*
greenstripedrockfish *S. elongatus*	sablefish *Anoplopoma fimbria*	**Pacific Salmon Species**
Pacific ocean perch *S. alutus*	Pacific sanddab *Citharichthys sordidus*	Chinook salmon *Oncorhynchus tshawytscha*
quillback rockfish *S. maliger*	butter sole *Isopsetta isolepis* curlfin sole *Pleuronichthys decurrens*	coho salmon *O. kisutch*
redbanded rockfish *S. babcocki*		Puget Sound pink salmon *O. gorbuscha*